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IN THIS ISSUE

СПЕЦИАЛЬНЫЙ ВЫПУСК, ПОСВЯЩЕННЫЙ АЛЬТЕРНАТИВНОЙ ЭНЕРГЕТИКЕ ФРАНЦИИ И ФРАНКОГОВОРЯЩИХ СТРАН

СОДЕРЖАНИЕ

Основные проблемы энергетики и альтернативной энергетики

Энергетика и экология

Информация

На 1-й стр. обложки: солнечная печь CNRS в Одейлло (юг Франции). Большой параболический отражатель, состоящий из 9500 зеркал.

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THIS SPECIAL ISSUE IS DEVOTED TO ALTERNATIVE ENERGY OF FRANCE AND FRENCH SPEAKING COUNTRIES

CONTENTS

Basic problems of energy and renewable energy

Energy and ecology

Information

1st page of cover: the solar furnace of CNRS in Odeillo (South of France). A large parabolic reflector constitured of 9500 mirrors.

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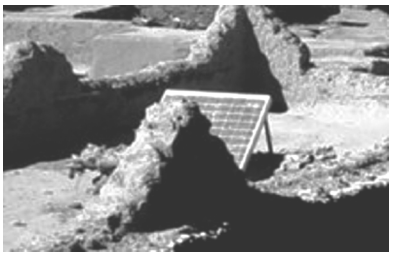
FOREWORDS OF THE DEPUTY EDITOR-IN-CHIEF FOR FRANCE AND SOUTHERN FRENCH SPEAKING COUNTRIES, GUEST-EDITOR OF THIS SPECIAL ISSUE

Professor **Pierre Saint-Gregoire**



It is a great pleasure for me to write the forewords for this special issue of the International Scientific Journal for Alternative Energy and Ecology, devoted to France and french speaking (or partially french speaking) countries of the south.

This volume is the result of a call for papers launched in june 2007 with the aim to give an overview on the research in the field of alternative energy and ecology in the mentioned geographical zone. To stimulate the international contacts and collaborations we proposed to publish also a short description of laboratories, groups, and institutes participating in this activity.

Obviously, our goal has only partially been reached, even if we received about one hundred propositions of papers: because of the "information screening" caused by the explosive development and competition in the field of renewable energies and related topics, several important french institutes are not yet represented in this special issue. In contrast, we have a vast representation of african french speaking countries that, albeit being potentially the main consumers of the renewable energy technologies, are frequently with an insufficient access to international journals. It is indeed important to keep in mind that the most important solar resources are located on the african continent, and that only few percents of the area of the Sahara region being covered by solar powerplants could satisfy the contemporary needs in the electrical energy!

The regain of interest in the field of renewable energies is clearly caused both by the explosive increase of prices of the non-renewable energy sources and by the global tendency of climate warming that is the origin of the present collective awareness. In this respect, we are certainly still only at the beginning of activities in this field: first because the pressure of civil societies on the scientific community will increase in future, with the confirmation of the emergency to find new solutions, then because a maturity of scientific groups working in this field will occur, and finally because the corresponding market will likely appear to be a motor of world economy in future.

This situation should reasonably result in the enhancement of north-south collaboration in this field and in number of related fields, and we hope that the information published in this issue about southern institutions will encourage further north-south collaboration contacts.

In France, activities on solar energy have started early, with the construction of the solar furnace of Mont-Louis in 1947, and of the big solar furnace in Odeillo around 1970 by CNRS, close to the former. Then, in 1983, an experimental solar powerplant was built in Targasonne, also in the south of France, but was stopped prematurely. It is significant that this experimental powerplant, which has inspired several models of so called "tower powerplants" over the world, is now rehabilitated, and gives the opportunity to experience new processes in near future.

For now, several french organisms, institutions, and associations, are working entirely or partially in the development and the use of renewable energies, and for the improvement of sustainable development approaches. We can mention ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie – Agency of Environment and Mastering of Energy), CNRS (National Centre for Scientific Research), ANR (Agence Nationale de la Recherche – National Agency for Research), EDF and particularly EDF-EN (Electricité de France; Energies Nouvelles – Electricity of France; renewable energies), ministries of research, for sustainable develop-ment, etc.

In southern countries, the same tendency is appearing, in particular with the appearance of structures for developping specifically the renewable energies. It is highly desirable in future to follow a global approach, in particular for optimizing the use of desert zones for energy production and for organizing research and industrialization in the frame of the sustainable development.

For all these reasons, this special issue is certainly a pale reflect of the forthcoming volumes in next years! If, nevertheless, this volume of ISJAEE may modestly help in structuring collaborations between southern and northern countries, it will play a significant role in the right direction.

Opening of the international meeting "Energaia" on renewable energies, organized by the "Conseil Régional Languedoc-Roussillon" Montpellier (France) 6-8 december 2007

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OVERVIEW ON FIELDS RELATED TO RENEWABLE ENERGIES RELEVANT FOR NORTH-SOUTH COLLABORATIONS

New perspectives of co-development

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In the perspective of a considerable expansion of research and use of renewable energies in near future, we present here an overview on fields and subjects that should be important in the frame of north-south collaborations, having particularly in mind the euro-african zone. This paper aims at favouring the creation of research networks in related topics and attracting attention on promising possibilities to develop southern countries and to setup a sustainable development.

Keywords: solar powerplants; energy of biomass; economical analysis in renewable energy; ecology of air atmosphere and space; philosophy problems

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Introduction

The fields related to renewable energies that are relevant for north-south (and south-north) collaborations are numerous, and it is out of the scope of this paper to give details in all of them. I shall nevertheless give a non-exhaustive overview on what seems to me the most important ones. I would like to mention also that this paper is written in an unusual way concerning references: instead of giving in bibliography the references of original papers that would not be accessible to most of southern scientists, I have preferred to list also internet addresses and references of papers in open access journals. This is for a practical reason, namely to provide in direction of the south, informations that may be used actually. I apologize with respect to authors who should be citated and are not because their paper is published in expensive journals, out of the means of universities of southern countries. Another objective of this paper is to attract attention on topics that seems to me important for the development of southern countries, and for the sustainable development of north; it is why this paper contains also a call for the constitution of research networks in the different topics.

Among different topics, I shall not neglect those based on very simple technology, even if they are not fashionable, because they may be important for the scientific activities in the south, and because they are in favour of an environmental reequilibrium of the corresponding regions. As an example, we can mention solar cookers, and, at a higher level, small or medium solar furnaces. The production of electricity using photovoltaic effect will also be discussed, together with the thermal powerplants and biodiesels.

Universities of the southern countries cannot compete with those of the most developed countries, but they have an important role to play in the development of renewable energies, in particular in fields that are not considered by northern research groups. One of the objectives of this paper is to attract attention on actions that may be pursued only by universities of southern countries, and on fields that may be developed in close contact and collaborations between institutes on both sites of Mediterranean Sea.

The present situation

A trivial constat is that in the euro-african zone, the solar resources are in the southern countries (Fig. 1), and the strongest needs and technology are in northern ones. However, in such poorly illuminated countries as Germany, there are at present time more solar powerplants than in the south (even if this will certainly change in future, with the development of powerplants in Spain, Portugal, Italy, etc), and the use of photovoltaic devices and solar thermal devices is the most developed. Such a situation is more due to a political decision than to a market mechanism: in Germany, the price of photovoltaic solar electricity is fixed at 0.50 € for 1 kW·h, which allows to planify the construction of photovoltaic solar powerplants at relatively high latitude. From financial point of view, the installation cost of PV powerplants is nevertheless still too high to attract massively investors, with a payback around 10 years and an environmental payback around half that time. The main challenge is therefore to decrease the cost of the "solar kW·h" in order to allow the spontaneous expansion of this production mode.

There is now a quasi consensus to attribute the cause of climate global change to the greenhouse gases emissions [1], mainly from industrial countries, and this led the EU to drastic decisions, namely to decrease the greenhouse gases emissions by 80 % before 2050, and to increase the part of renewable energies to 20 % by 2020 [2, 3]. In future, such political decisions could even be stronger if, as predicted, the global warming is more pronounced and climate changes are more evident. Environmental problems are now already considered by all political parties and play an important role in the public opinion, as observed recently in France with "*Grenelle de l'Environnement*" [4], an open meeting organized by the french government on environmental problems.

In the south, under-industrialized, environmental questions are not yet a priority, and the use of renewable energies, in spite of its obvious interest due to the strong solar radiation, remains marginal. In most african countries, the main source of electricity production is still based on fossil fuel. Poverty, finance problems, and external constraints hinder generally the southern countries to invest in the sector of energy. In many countries, extreme poverty is such that more than 95 % of the population do not have access at all to electricity, and the unique accessible energy source is the wood, thus leading to deforestation and to a considerable environment degradation. This has also as consequence, that mainly among the young generation, a lot have a strong will to emigrate, first within the country to big towns, and secondly to the north.

In a paradoxical way, the south may be a considerable source of energy for the future, obtained from solar powerplants, and from the potential exploitation of biofuels, both having positive impacts for at least two reasons: (i) they would tend to reequilibriate the planet with an energy harvesting without greenhouse gases and any environmental induced problem, (ii) they would considerably improve the economies and standard of life in southern countries.

In order to establish a new, more equitable, and sustainable order at a global level, the exploitation of solar resources and the exportation of energy from Africa, should reasonably be organized in future.

In the following, we mention the pharaonic projects that should be implemented in next years/decades, as a result of heavy financial investments, but we pay also attention to the projects that may be developed at a more modest scale, involving universities, non governmental organizations, researchers, and that may nevertheless have a strong environmental and economical impact. The next paragraph lists the different fields to be considered.

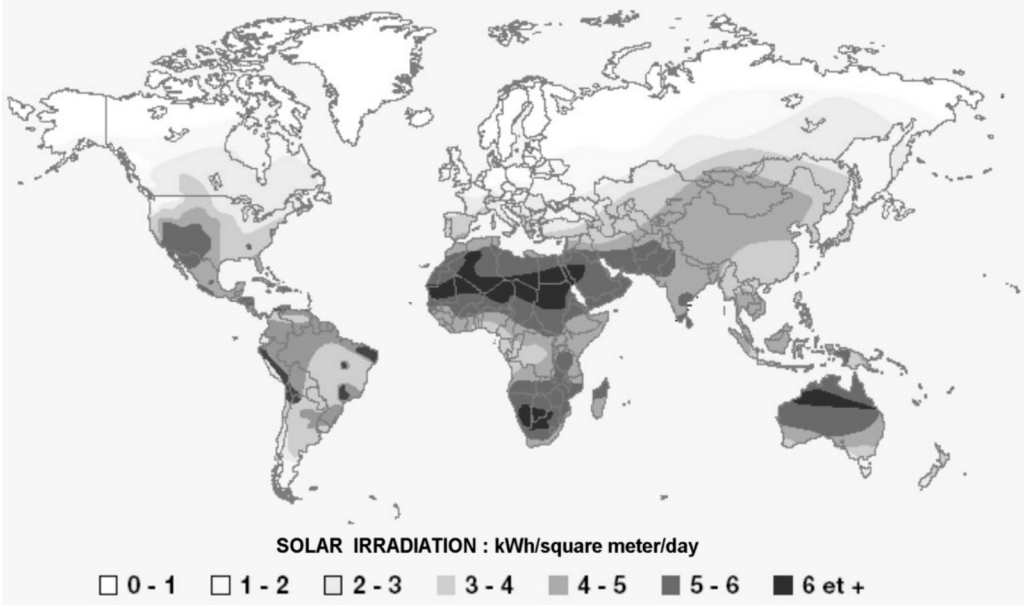


Fig. 1. *World map of solar resources*

Solar energy

Solar thermal devices

Solar concentration

Solar concentration is performed through an optical device, for collecting thermal energy at the level of a receiver. The concentration of the system is defined as the ratio between the area of the projected (collecting) surface of the optical device (in principle a lens, a mirror, or sets of lenses or mirrors) and the area of the receiver. In most cases, the optical device is nowadays constituted of mirrors. The thermal efficiency (the ratio between harvested thermal energy and incoming energy) is rather high in such systems, around 70 %. Losses are conductive, convective and radiative, and depend on the different geometries that are used, mainly for the receiver.

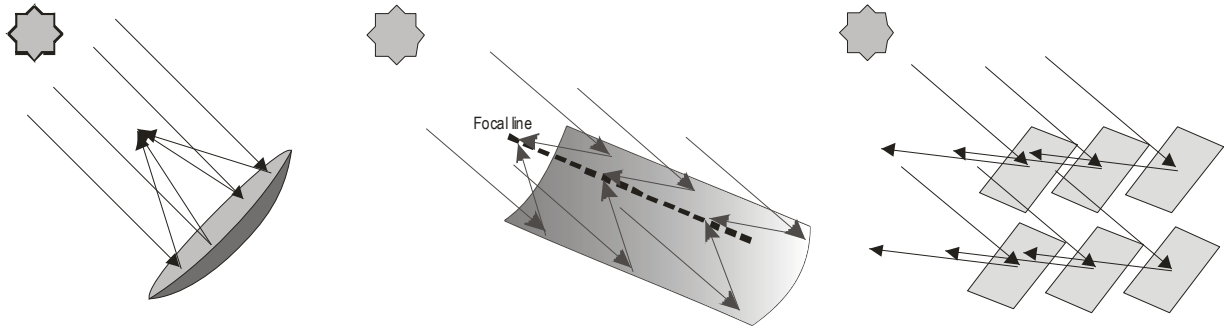
Different systems may be used in solar concentration [5]: the "parabolic-dish" reflectors (Fig. 2, *a*), the "parabolic-trough" (Fig. 2, *b*) and the sets of heliostats (Fig. 2, *c*).

The "parabolic dish" is based on a revolution paraboloid, which is well known for giving a perfect image of a point object situated at infinity on the axis. This system that needs a device for tracking the sun, achieves a high concentration, of several thousands, that may in principle be higher that 10^4. In practice, taking account the imperfections of the reflecting surface, the concentration ranges between 3000 and 5000.

In the parabolic-trough, a section of the mirror is parabolic, and in the perpendicular direction, it is linear: the focus of this device is therefore linear, which reduces the concentration to a value in practice close to one hundred. The system may be oriented in two manners: either north-south, with a continuous tracking of the sun during the day, or east-west with only a slight regular readjustment of the orientation.

Finally, in other technical solutions for achieving solar concentration, several mirrors (heliostats) can be used to focus continuously the light of the sun on a central point. Each mirror must track the sun in such a way that the image remains in a given direction. A compromise has to be found for the size of mirrors, since large mirrors need expensive bases and tracking devices, whereas smaller mirrors need simpler and hence cheaper devices, but should be more numerous.

Heliostats can be oriented either towards a receiver or towards a mirror, generally vertical and of paraboloid shape.



a *b* *c*

Fig. 2. *Different systems used for solar concentration: a – parabolic-dish, b – parabolic-trough, c – set of heliostats*

Thermal powerplants

Thermal powerplants designed for the production of electricity are based on one of the three concentrating systems presented above for collecting thermal energy, and on its transformation into mechanical energy and then to electricity.

Fig. 3. *The parabolic dish reflector in Odeillo (CNRS laboratory, South of France), equipped with a Stirling engine at the focus*

The idea to obtain mechanical energy from the sun was first made real by Auguste Mouchot who placed a steam engine at the focus of a parabolic mirror. He presented his invention at the Universal Exposition in Paris in 1878. In 1907, the trough parabolic collector was shown to be able to produce steam (a patent of Maier and Remshalden), and five years later, a plant was built in Meadi in Egypt.

Thereafter, it is only around 1970s that solar thermal projects began to be undertaken again, using the different concentration geometries.

Up to now, the best overall efficiency is obtained with parabolic-dish concentration, with a Stirling engine at the focus (see for instance Fig. 3). Efficiencies between 20 and 30 % were reported [6], but the weakness of this system lies in the Stirling engine that has still nowadays a limited operation time. Moreover, for obvious reasons, the size of the system is limited and devices are generally of few square meters; collecting more energy is then achieved by putting together several parabolic-

dish devices. This technical solution may be interesting in future for producing small to large quantities of electricity, but it will remain as a project as far as Stirling engines will not be more reliable. Another weakness of that system, is that it does not allow any storage of thermal energy, so that it is able to work only during directly illuminated day time. This may nevertheless be interesting in warm countries where the peak of electricity consumption is due to air conditioning and occurs precisely at about the same moments.

The concentration using heliostats has led to an architecture of solar powerplants where energy is focused onto a receiver located at the top of a tower. This was the case of the early powerplants CRS and CESA in Spain, Sunshine in Japan, Aurelios in Italy, Solar One, MSEE in USA, Themis in France, and C3C in Soviet Union (nowadays in Ukraina). All these powerplants were built between 1981 and 1985. The concentration for these powerplants are of several hundreds, from approximately 250 (Solar One, circular field of heliostats) to 700 for Themis (field of heliostats in the north of the tower).

Different materials were thus tested for the heat transfer and heat storage: water-steam, sodium, and molten salts. Each technology has its interests and difficulties. Molten salts, in solid state at ambient temperature, need to be heated well above 100 °C (140 for Themis, 220 for Solar Two) in the whole circuit, which may appear as a delicate task. This needs external energy, and also energy is consumed to insure the motion of the salts in the circuits. At the opposite, molten salts are well suited for the thermal storage at high temperature (between 550 and 1000 °C). The thermal efficiency of this type of system is around 73 %, and the maximal global efficiency (conversion solar energy into electricity) is about 23 %. Activities of research and development continue for this technology, see for instance the paper by Ferrière in this volume.

Finally, the most modest, with respect to expected efficiencies and technology, but also the most robust models, commercially available, are based on parabolic-trough reflectors. Solar powerplants of this type are exploited in USA in the desert of Mojave, till the mid 80s and have an overall power of 354 MW_e, divided in blocks between 30 to 80 MW_e. Nowadays, this technology is the cheapest one. It was first produced in series in the mid 1980s by the company Luz International which installed the mentioned powerplants in USA. Thereafter, this company disappeared, and more recently, the activity was pursued by Solar Millenium [7] and few others.

In this type of powerplant, the receiver lies in a glass tube in which vacuum is achieved in order to make the thermal losses at minimum. The thermal transfer fluid is here heated between 300 and 550 °C, it may be a synthetic oil, molten salts, or water. Such systems can still work in absence of radiation, due to thermal storage devices allowing autonomy and possibility to continue delivering electricity during periods depending on the storage capacity.

The mirrows for the plants come from Flabeg, manufacturer of technical glass. The concave mirrors are made from silver-coated white glass which is about 4 to 5 mm thick. The elementary mirrors are 2 to 2.8 square meters in size. Over 98 % of the solar radiation that arrives at the mirrors is reflected onto the absorber pipe along the focal line of the collectors. For further information see www.flabeg.com

The cost of this technology, expressed with respect to the electric power, depends naturally on the location of the power plant and the integration of thermal storages. Taking as an example one of the Andasol powerplants (South of Spain) which are currently being built, the capital expenditure is of about 300 millions €, and the electricity output will be of about 180 GW·h per year (Fig. 4).

Courtesy of Gollmer/Solar Millennium

Fig. 4. *Andasol powerplant in the south of Spain: mounting collectors*

Solar Millennium projects a decrease of prices in future, due to economies of scale. Moreover, investments in research and development, made by Solar Millennium (Fig. 5), are intended to reduce the costs of solar thermal power generation considerably during the next years. This can be achieved by the optimization of parabolic trough collectors by the use of direct steam generation. Water is to be directly vaporized in the absorber pipes located in the focal line of the collectors. Up to now a synthetic, liquid heat transfer medium is conducted through the absorber pipes and this medium emits its heat via heat exchangers to a steam cycle. If direct steam generation proves to be a reasonable alternative, the cycle with the heat transfer medium liquid and the heat

exchangers will no longer be needed. This will increase the yield of parabolic trough powerplants.
Another way to increase efficiency of solar thermal power plants is to improve the collector design as a whole. Therefore, Solar Millenium has developed a new generation of parabolic trough collectors. A series of innovations means that the investment costs for solar collectors will be reduced by 15 to 20 percent in the future (for details, see the press release [8]).
In future, the concentrated solar power (CSP) should therefore occupy a bigger place in the production of electricity.

Courtesy of Solar Millennium AG

Fig. 5. *Parabolic-trough collectors in working orientation*

In various countries, interest for such an electricity production is renewed in reason of the recent oil price increase and perspectives of further increase in future. In France, a small company, SOLAR EUROMED, has started building a prototype of solar powerplant with parabolic trough concentrators in a moderately illuminated region (the south of France), on the basis of experience elaborated at Themis.
The building of such powerplants in southern countries has started. First, of course, with Andasol in Spain, but also on the african continent. Solar Millennium will build in Kuraymat, approximately 95 kilometers south of Cairo (Egypt), a hybrid powerplant using both natural gas and solar power to produce a total output of 150 MW, with solar field of parabolic troughs with a total mirror surface area of approximately 130,000 square meters. Other countries of Maghreb, Algeria and Morocco in particular, will also build such powerplants.
The overall efficiency of such powerplants is now significantly above 20 %, with a net annual efficiency around 14 %.
Taking into account the high direct radiation received in some african regions, around 2900 kW·h/m^2 per year, it may be extrapolated that the production costs will be in the medium term around 0.6-0.7 €/kW·h and that at the same time the desertic regions of Africa should reasonably be used for electricity production, since it is now possible, using High Voltage Direct Current lines (HVDC) to carry energy over large distances without big losses. This production may then be purely solar, and not hybrid as in less favourable regions.
Energy may also be exported as hydrogen produced from solar energy. The water electrolysis using electricity produced from the sun will compete with the production via water decomposition at high temperature (in solar furnace) using different thermochemical cycles [9]. This still needs research. The interest of such projects will depend particularly on the progresses of fuel cells technology in future.
The quantity of electricity produced in this way will be determined not by natural constraints since Sahara could allow the production of much more than the present world consumption of electricity, but by political decisions and by financial volumes that may be dedicated to such projects. A relatively small ratio of the Saharian area, if covered with thermal powerplants, would produce the total energy consumption of Europe including Russia.
We only stress that such a production of electricity would avoid the emission of huge quantities of greenhouse gases, and that installation of powerplants in Africa would reduce the big gap of standards of life between northern and southern countries, that may be in future at the origin of big political instabilities in wide zones, and of uncontrolled migrations.
Till now, the construction of powerplants is due to decisions of particular countries, and projections in future on this basis led Greenpeace to predict that CSP could allow to furnish 5 % of the world production of electricity by 2040 (see the whole document of Greenpeace on the Concentrated Solar Thermal [10]); however, in future it would be highly desirable that countries associate efforts and cooperate around such a clean production of electricity and hydrogen, in order to achieve the largest possible production. Electricity production at zero emission of greenhouse gases is indeed possible with CSP, and at the same time may be a considerable factor of global economical growth since in african countries the (economic) marginal propensity is very high.
Besides such pharaonic projects, universities of southern countries should pay attention to research and development on CSP for rural production of electricity. This supposes in particular to design and test smaller size systems, and to look for solutions with minimal costs, even if efficiency is consequently reduced.

Solar furnaces

The first model of solar furnace for scientific purposes was built in Mont-Louis in the south of France in 1949 by Prof. Louis Trombe. This furnace, of more than 50 kW_{th} is still active and is used for scientific culture and applications [11]. Later on, between 1963 and 1969, a larger furnace was built close to this one, in Odeillo (Fig. 6), under the responsibility of CNRS [12]. The former is composed of a vertical parabolic mirror and one heliostat, whereas the latter, much larger, is composed of a large parabolic reflector composed itself of 9500 mirrors fixed to the frontage of a building facing a field of 63 heliostats of 45 square meters each. The power of this furnace reaches 1 GW_{th} and the working temperature at the focus may be above 3500 °C.

Both furnaces have widely demonstrated the possibility to use solar energy in material science and for applied purposes. Mention in particular applications in the synthesis of nanomaterials, in metallurgy, in burning, high temperature tests of materials, etc.

It is out of present possibilities of southern countries to build such a large furnace as that of Odeillo. However, furnaces of approximately the size of Mont-Louis furnace, with more modest costs may be planned. We would like to mention a very interesting project that follows convincing tests performed at Mont-Louis, namely the construction of a furnace in Morocco for burning traditional ceramics. Tests of burning ceramics using solar energy appeared positive, with practically no loss of items, and with very good esthetic qualities of the burned ceramics (see in [11]).

Universities of southern countries should perform research on the construction of solar furnaces for local purposes (metallurgy, burning ceramics, bricks, etc) following two directions: (i) design geometries eventually more proper to intertropical situations, (ii) reduce the costs, for instance by using local materials and cheap materials for mirrors – aluminum foils, plastic mirrors, etc.

The widespread use of such furnaces could indeed considerably reduce the environmental pressure, as will be seen in **Environmental impacts**.

Solar cookers and solar dryers

Solar cookers are examples of very simple devices [13] that could have a very strong impact on environment. Several models exist, either using the solar concentration on cooking recipients using a reflector, or using greenhouse effect in a box closed with glass and internally covered with a reflector (the cooking recipient absorbs light in both cases). Research in southern universities could be performed with the aims to increase the performances of these devices, to reduce the costs (for instance by using local materials in the conception), and to study carefully the appropriation by population and the preservation of woods that follows the use of these devices. In such studies, it is important to approach the situation with different points of view, and in particular from those of physics, anthropology, biology, economy.

Fig. 6. *The solar furnace of CNRS in Odeillo (South of France).*
A large parabolic reflector constituted of 9500 mirrors is facing a field of heliostats on the right, seen from the back

Photovoltaic cells, and photovoltageïc powerplants

If more and more photovoltaic powerplants and houses are built in Europe in reason of state helps, this type of project has not yet been reached Africa where its future will depend on the cost of such devices, at present much too high to be widespread. Mainly foreigners or international organizations do install such devices, for the electrical supply of isolated sites or for avoiding problems of supply interruptions. The Rwanda government has nevertheless shown interest for such installations, by taking the decision of building solar photovoltaic powerplants,

starting in the neighbourhood of the capital Kigali, at 2500 m high. This country, where 99.3 % of the population do not have access to electricity, is the first for developing such an approach, in the frame of the Germany-Rwanda cooperation (more precisely with Pallatinat) [14].
The challenge with photovoltaic cells is nowadays to attain a steep decrease of costs.

Locks with silicon cells

The technology of silicon cells is robust and reliable, with durability of cells around 25 to 30 years, and efficiencies that do not decrease too strongly all along the life of cells. The costs are nevertheless too high to be widespread and to answer to the needs in the south, or to market mechanisms in the north. It is well known that about 70 % of the cost of a silicon solar cell is the material itself, so that these cells are strongly dependent on the price of Si, the remaining part being related to the production process. To overcome these inconvenients, other photovoltaic devices have been designed, and exploration of new technologies has begun [15].

Second and third generation cells

In the second generation cells the problem of cost of basic materials has been overcome since these devices are based on thin films. Nowadays, there are several technologies and materials used in the production of these cells: mainly amorphous and microcrystalline silicon, CdTe, CIS ($CuInSe_2$ and related compounds) [16, 17].
The third generation cells [18, 19] are based on research in two opposite directions: (i) reducing price of cells with respect to the nominal power by increasing the efficiency at nearly constant cost, (ii) reducing considerably the costs even if efficiency is lowered.
Increasing the efficiency above the Schockley-Queisser limit (~ 30 %) can be realized with high technology devices: quantum wells (quantum dots, quantum ropes, etc) devices and tandem cells (multilayers), both based on the absorption of light in a wide spectrum [20]. In the tandem cell for instance, a photon that is not absorbed in a first layer is absorbed in the following or in one of the next ones (multispectrum cells). Reported efficiencies of existing devices are now above 40 %, a value that lets hope that the compatibility of these cells with solar concentration will be soon possible. These cells will certainly remain expensive in future.
In the opposite direction, the costs are strongly lowered because the technologies are no more based on classical semiconductor processes, but are very simple. This is achieved with polymer solar cells, nanocrystal solar cells, Dye-sensitized solar cells ("DSSC") [21], and photoelectrochemical cells [22]. Efficiencies around 10 % begin to be reached for such cells, with expected costs much lower than for the silicon technologies.

Interesting perspectives

African, and even many european universities cannot compete in the field of high technology third generation cells that may be designed and realized only in few centers. However, some perspectives seem interesting in the frame of cooperations.
A simple research direction is to increase the actual efficiency by tracking the sun [22, 23]: the solar pannels are then always oriented in an optimal direction, which may increase by 20 to 30 % the global efficiency of the device. Another simple idea is to conjugate the device with a concentration of the incoming light on the photovoltaic pannel, and thus harvest more electrical power. However, in "low efficiency cells", the energy that is not converted into electricity is transformed into heat, and the cells will rapidly reach too high temperatures, in particular in Africa where the ambient temperature is often above 30 °C during the day. Such devices should thus include displays to dissipate the heat that is necessarily generated, which could be performed by a simultaneous water heating. Universities of southern countries should perform such studies that are not so pertinent in other places and that would be fruitful for lowering the costs of PV pannels in Africa.
Another important direction, concerns the DSSC: these cells can be realized without major technological investment, and should be studied in laboratories of southern countries in the frame of international collaborations. Even at low efficiencies (for instance around 8 %), these cells of very low cost, that could be produced in southern countries, could very advantageously be used in Africa where the solar irradiation is strong and where space is generally available.
Research studies on the conception of such cells in the local conditions, and of their durability in real conditions should be performed. This may also be an interesting research direction in the frame of international cooperation between southern and northern countries.

Possible biodiesel production

Biofuels are the object of controversial papers, because their environmental bilan is not clearly positive. In northern countries where agriculture is highly productive because it consumes a lot of energy, it is relevant to keep in mind the cost in term of CO_2 emission, for evaluating the interest of producing biofuels. In southern countries, classical biofuels as those derived from sugars have clear negative consequences on environment: destruction of vast quantities of forests to replace the removed trees by cultures, and rarefaction of food in reason of the deviation towards energy production. Prices of such basic products as sugar, and various cereals, are strongly sensitive on the politics of energy, and it may be dangerous to develop such biofuels as those mentioned without an extreme caution.
However, all biofuels do not seem to be dangerous for the environment and for the economical equilibrium of the society. In particular, a very interesting plant can grow in tropical and subtropical regions, is robust, and its seeds may produce an oil that can be used as biodiesel. This plant, named "*jatropha curcas*", belongs to the family of euphorbiaceae [25], and though being

originary from Caribbean, it has been spred in nearly all tropical and subtropical regions: in Asia, Africa, America. It is currently advantageously used in hedges, and for stabilizing soils against erosion.
The oil, present in the seeds to an amount till 40 %, has proven to be successfully used in diesel engines without major problem. More and more tropical and subtropical countries have designed projects to grow this plant for the oil production (see for instance [26]).
Jatropha curcas grows rapidly, it may begin to produce seeds after about three years, adapts to different soils and climates (from North Africa – it grows in Egypt for instance, to subtropical and wet regions as Central Africa) and does not need a lot of water. Its productivity is nevertheless variable because it is generally found in a semi wild state and just begins to be domesticated. It ranges between 400 to 800 liters per hectare.
Environmentalists have promoted a project called "*green belt*", where jatropha curcas is apparently absent till now (see [27]). Though the environmental impact of this plant has not been the object of studies in long term, the observation of fields where jatropha curcas is present since many years, does not exhibit environmental problems and at the opposite, shows that it is very useful to protect the vegetation in semi arid places. In Africa, it has also been integrated with other plants, and is currently used as medicament, or for domestic purposes (soap production, oil for lamps...).
Jatropha curcas could change the rural situation in so called Third World by increasing steeply the standard of life at a moment when the price of such products as coffee, cacao, and coton are very low, provided its production be free. In Central America, India, and Mali, for instance, its culture has led to a considerable improvement of the life by giving access for the population, to electricity produced from generators working with biofuels and by giving supplements of incomes, especially as the extraction of oil does not need sophisticated technical means, and is accessible to modest categories of population.
The large scale culture of this plant all around Sahara to stabilize the desert (such a country as Senegal, for instance, looses 50 000 ha of land per year to the profit of desert) should be accompanied by scientific studies to precise the environmental, economical, and human (ethnological and anthropological) impacts. It would at the same time increase the income of the concerned regions: the expected production could amount to 50 billions liters of oil, which corresponds, taking into account the average sale price in internal markets (~ 1 €/l) to 50 billions €. Such a "jatropha green belt" around Sahara to stabilize the desert could concern Mauritania, Senegal, Mali, Burkina Faso, Niger, Chad, Suddan, Ethiopia, Egypt. Without taking into account the human factors, its extension to other countries or other regions more distant from the desert, is sustainable and could allow to reach a production representing a non negligible part of the present world consumption of diesel oil. Since nearly all african countries have soils able to grow jatropha curcas , and most of other intertropical countries also, this favourable situation could in a first period result in a decrease of the international tensions around energy, but at long term lead to a wild competition among producers, with price instabilities. This, especially as diesel production by algae, which is also a realistic perspective, has not been taken into consieration here.
In all cases, the development of such biofuel production, would involve several hundreds of thousands of jobs. This is of course very important for economy in countries where the rate of unemployment is high, and the number of workers in a state of poverty among the young generation has increased in last ten years to 87 %. It should result in a steep global economic growth. Again, as for solar thermal powerplants, the feasability of such a project depends on political decisions and an international project could be initiated in that sense.

Environmental impacts

In many places in Africa, an environmental degradation is reported in the last decades. Causes are of different origins, in some cases phenomena are related to global climate changes, in others they are clearly due to an environmental degradation related to a direct human intervention. Around capitals and big towns, for instance, a deforestation is generally observed, due to the use of wood, even in town, as main fuel for cooking. Bangui, the capital of Central African Republic, was completely surrounded by dense forests at the beginning of colonialism, whereas forests are nowadays divided and distant of the town by several tens of km.
In this respect, it is important to consider the preservation of vegetation that the use of solar energy can induce. It depends naturally on the density of vegetation.
Consider first solar cookers. Equiping a village of 1000 inhabitants with solar cookers leads each year to the preservation of vegetation over an area of more than 100 ha – (1 million square meters), for an initial cost smaller than 10 000 €, in regions between forest and savana with an intermediate density of trees. In such fragile environments as sahelian regions, this area may be much larger and be around 1000 ha.
In the example of burning ceramics using a solar furnace of 50 kW_{th}, it is estimated that approximately 600 cubic meters of ceramics can be burned in one year, which corresponds to the preservation of 2000 T of wood. Generalizing the use of such devices for metallurgy, bricks or ceramics burning, and cooking, would therefore lead to a considerable environment preservation, in regions often initially very fragil.
Concerning powerplants, it is important to have in mind their payoff. The financial payoff determines the spontaneous feasability by investors, and we shall rather consider here the "environmental payoff". For a silicon powerplant, the financial payoff is nowadays somewhat less than 10 years, whereas the environmental payoff is

about twice shorter. Producing Si indeed induces direct emission of CO_2 (carboreduction of SiO_2) and needs energy for processing the cells. It is estimated that the cell will compensate these environmental costs after operating approximately 5 years. In the case of thermal powerplants, the environmental payoff is considerably reduced since it is estimated to be around 5 months, and after that period, the gain is quasi total during the whole operating time, estimated around 20-30 years. Moreover, in comparison to a modern coal fired power plant, a 50 MW Andasol-type parabolic trough power plant saves 149,000 tons of CO_2 per year.

As far as integration of powerplants in their environment is concerned, mention the problem in saharian zones, where dust will deposit on mirrors and strong winds carrying sands will damage the optics. Solutions for protecting mirrors has to be found, otherwise powerplants should be more advantageously located in regions (sahelian) where the agressivity would be reduced whereas the irradiation is of the same order.

Thermal powerplants should therefore advantageously be developed in Africa. Moreover, in arid regions where plants do not survive easily in reason of a too strong solar irradiation, the shadow of reflectors would play a protection role and permit their growth and culture, especially as solar powerplants can be used also for the simultaneous desalination of water. Such possibilities are naturally important in such countries as South of Morocco, Mauritania, and Senegal or in those at the east side of Africa at the same latitude.

Finally, in the case of the considered possibility of biodiesel production from the jatropha curcas plants, mention that the environmental gain is also important in reason of the stabilization of soils that would follow from the culture of this species, and because these plants were already observed to have a protection role on other plants. Besides, carbon is naturally fixed in the leaves, the branches, and the roots of the plants, so that the carbon bilan of such a culture is favourable since the very beginning of the process. Moreover, biodiesel obtained from this plant is known to be much less aggressive and is exempt of some pollutants contained in petroleum derived diesels.

Risks, erroneous “good ideas”, needs for a respectous approach with different points of view

In the past, several “good ideas” or projects recommended by experts have appeared as disastrous in Africa, the reason being generally due to partial analyses of the situations and disregards of local opinions. Neglecting aspects related to education led also to failures.

As an example, mention what happened in some places with the solar pumping of water; after installation, population and herds have concentrated around equipped wells, which led to the degradation of vegetation all around, and to the abandonment of traditional wells working manually. When the pumping equipments did not work anymore, the vegetal degradation appeared irreversible, and the traditional wells were unable to work anymore.

Concerning any introduced device, a very cautious attitude should be adopted. A strategy that may appear good, though not sufficient by itself, is to involve students in the development of their own original human environment: they know the situation, and as such, can explain the interests of introduced devices. They also may give pertinent opinions. The distribution of solar cookers, for instance, in regions where people use to cook only inside the houses (this has happened actually, and cookers were of course not used) leads to a failure that may be predicted by persons knowing the habits.

Finally, the problem of maintenance is very important in geographical zones where the distances are large. It is crucial to analyse all the possible causes of failures in order to prepare missing items, to form local personal for simple maintenance, and to set up a hierarchy of maintenance personals as a function of the degree of complexity of the reparation to be performed on the site: simple reparations may thus be performed rapidly by local interveners, and more complex failures will need equipments and interveners from more distant places.

Conclusion

In future, the situation of Africa with respect to energy should be at the center of a sustainable development approach both for Africa and for Europe: in the south, the generalisation of such simple and cheap solar devices as solar cookers would strongly reduce the pressure on environment, of populations that otherwise use wood, and the use of solar furnaces (in particular concerning the burning of ceramics, bricks, etc) would also avoid the degradation of vegetation over large zones.

Both the implantation of solar powerplants and of fields of jatropha curcas would considerably increase the incomes of the african continent, and at the same time lead to a huge progress in diminishing the emission of greenhouse gases since Africa is able to furnish enough energy for Europe and for itself. This would be made possible by raising large quantities of capital at this purpose, but not doing it as soon as possible would certainly cost much more to the humanity. Moreover, at a moment when in the north the question of emigration is considered by some as a problem, creating a fund for setting up such projects would favour the economical development of southern countries, and lead to the reduction of the emigration pressure.

Such a scheme, where the production of solar electricity is performed in arid zones and where biodiesel plants are grown, can be developped in nearly all continents, and seems to be the unique possibility for avoiding the disaster of the global warming in future, precisely at the moment where the permafrost and antartic ices melting is confirmed and may accelerate the phenomena [27, 28]. International organizations, governments, and various partners should understand that the question of energy is

crucial in the development of the african continent and for the world equilibrium from several viewpoints. Universities in Africa should be encouraged to perform research studies on the topics of energy in relation with the possible perspectives in their country, and should be encouraged also to form engineers able to work in the construction of the powerplants in future.

Concerning south-north cooperation in euro-african zone, it seems pertinent to constitute networks around the following topics: solar concentration, photovoltaics, and biofuels. Interested scientists wishing to take part to such networks are invited to manifest themselves at pstgregoire@gmail.com.

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ESTIMATION OF HYDROGEN PRODUCTION FROM WIND POWER IN THE SOUTH OF ALGERIA

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The current work gives an estimation of hydrogen production from wind power. Two aspects of the system are considered. Estimation of the wind power produced by three types of wind turbines generators and the energy required for the electrolysis process.
Wind data at seven sites of the south of Algeria were used. The hydrogen production at various sites has been found to vary according to the wind speed and the wind speed frequency distribution. However, for the same speed at different sites we obtained different values. For an average speed of 7.5 m/s at 30 m height, we obtained 3900 Nm^3 for the 10 kW wind turbine, 25350 Nm^3 for 50 kW and 99150 Nm^3 for 250 kW.

Keywords and codes: hydrogen production, electrolysis, wind power, wind turbine

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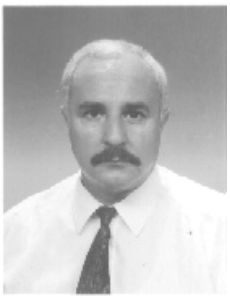

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Introduction

Nowadays, wind energy is one of the most economical energy sources with a well-known technology. Nevertheless, the instability caused by the wind turbines to the grid and the intermittence of the wind source, make necessary to develop efficient energy storage system [1].
Hydrogen as an energy vector, together with electrolyser and fuel cell technologies can provide a technical solution to this challenge. Such a system has been developed throughout the world [2-6].
Additionally, the use of hydrogen for a clean transportation fuel will increase the need of renewable hydrogen generating [7, 8]. Furthermore, the energy available for hydrogen production is strongly dependent on the wind energy resource [7]. In this context, the proposed study is interested to the hybrid system wind turbine-electrolyser. It assumes that the produced wind energy is delivered directly to the electrolyser for hydrogen production.
Several studies have been done on the wind power potential resources in Algeria [9-12]. As showed in the Fig. 1 [13], the south is the most promising region for wind power applications with mean wind speed range from 4 m/s to 10 m/s. The speed reaches 8 m/s in the region of Adrar.
Therefore, we focused our study on the south of Algeria which is characterized by a big desert, scattered populations and remote communities.
Wind speed data of seven sites situated in the big south of Algeria were used to provide an estimate of annual wind energy available for hydrogen production.
The characteristics of alkaline electrolysers [14] were used to estimate the rate of electrolytic hydrogen annually produced. The energy efficiency has been also considered.

Theoretical analysis

A promising option for hydrogen production from renewable resources is electrolysis [7].
Hydrogen is produced via electrolysis by passing electricity through two electrodes in water. The water molecule is split and produces oxygen at the anode and hydrogen at the cathode.
Electrolysis uses direct current (DC) electricity to split water into its basic elements of hydrogen and oxygen. Since this process uses only water as a source, it can produce up to 99.9995 % pure hydrogen and oxygen [15].
Three types of industrial electrolysis units are being produced today [14]. Two involve an aqueous solution of potassium hydroxide (KOH), which is used because of its high conductivity, and are referred to as alkaline electrolysers. These units can be either unipolar or bipolar.
The third type of electrolysis unit is a Solid Polymer Electrolyte (SPE) electrolyser. These systems are also referred to as PEM or Proton Exchange Membrane electrolysers. In this unit the electrolyte is a solid ion conducting membrane as opposed to the aqueous solution in the alkaline electrolysers.

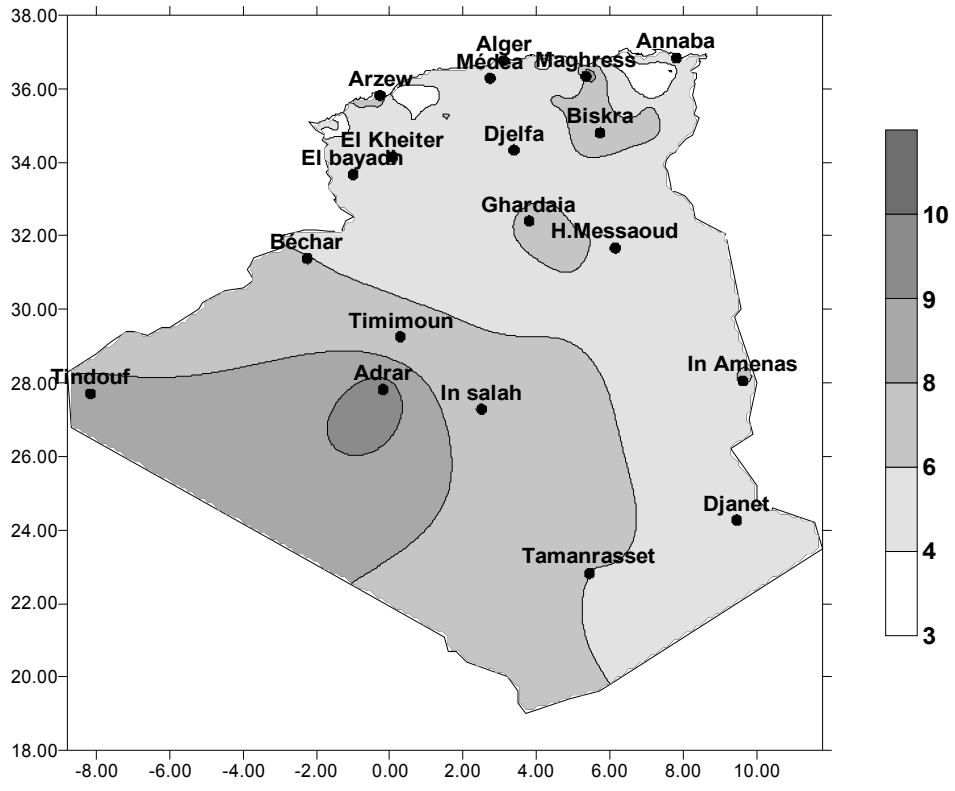

Fig. 1. *Wind speed contours at a height of 30 m above ground (m/s) [13]*

Regardless of the technology, the overall electrolysis reaction is the same: $H_2O \rightarrow ½\ O_2 + H_2$.
However, reaction at each electrode differs between PEM and alkaline systems.
The electrolysers usually tested for wind electrolyses are the alkaline ones [5, 8, 16], the PEM ones are in the state of development.
Therefore, we selected the alkaline electrolysers. Their electrical consumption is about 5 $kW/Nm^3 \cdot h^{-1}$ of hydrogen produced [5, 8, 16], with an energy efficiency minimal of 75 % [15].
Where, the energy efficiency is defined as the higher heating value (HHV) of hydrogen divided by the energy consumed by the electrolysis system per kilogram of hydrogen produced [15].
A schematic of the complete hybrid renewable energy system developed at the Hydrogen Research Institute (HRI) is presented in Fig. 2. It consists of a wind turbine (WT), coupled with an electrolyser powered by the excess electrical energy produced from the wind energy source. The electrolyser converts the electrical energy into hydrogen, which is stored in the form of compressed hydrogen. When the energy produced from the WT source is not enough, the stored hydrogen is converted back to electricity via a fuel cell generator [2].
In our study, we considered that the whole of the electrical energy produced from the wind turbine is fed to the electrolyser to produce hydrogen. The hybrid system is then reduced to the wind turbine and the electrolyser.

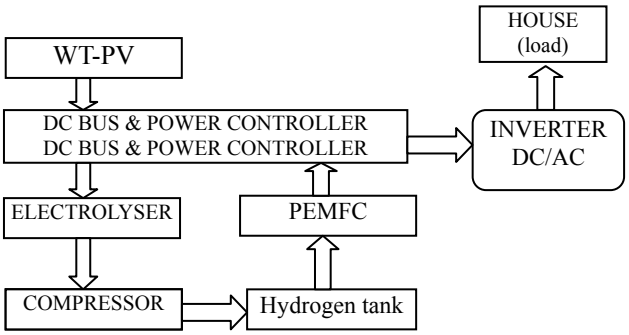

Fig. 2. *Hybrid wind-hydrogen system diagram [2]*

Three types of wind turbine (WT) sizes were selected: small (10 kW), medium (50 kW) and large (250 kW). Their power curves are represented on the Fig. 3-5.
The WT is characterised by a cut-in speed, a rated speed and a cut-out speed. The power increase from the cut-in speed to the nominal speed at which it is nominal and it cuts at the cut-out speed.
The hub height of tower is 30 m above the ground.
The wind ressources are requiered to estimate the wind power available for the electrical production.

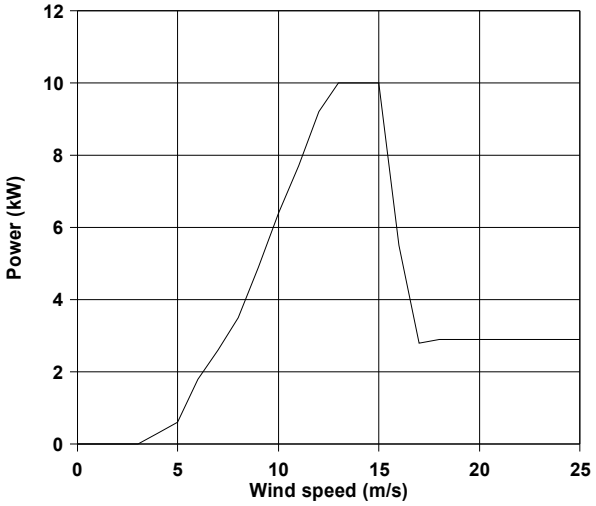

Fig. 3. *Power curve of Bergey BWC Exe*

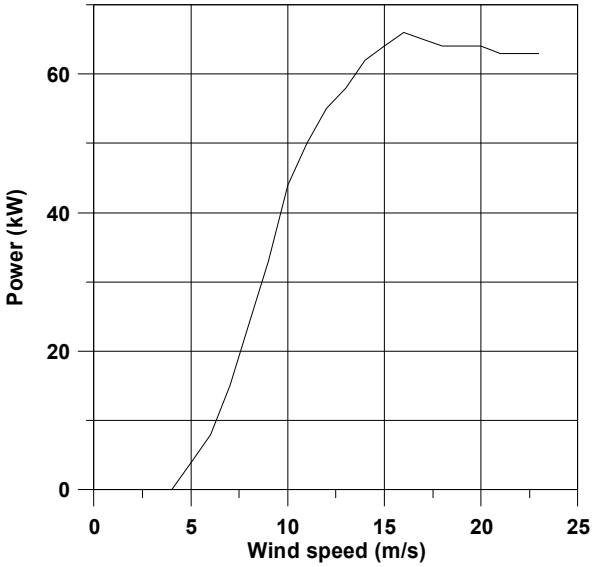

Fig. 4. *Power curve of Entegrity Wind System AOC 15/50*

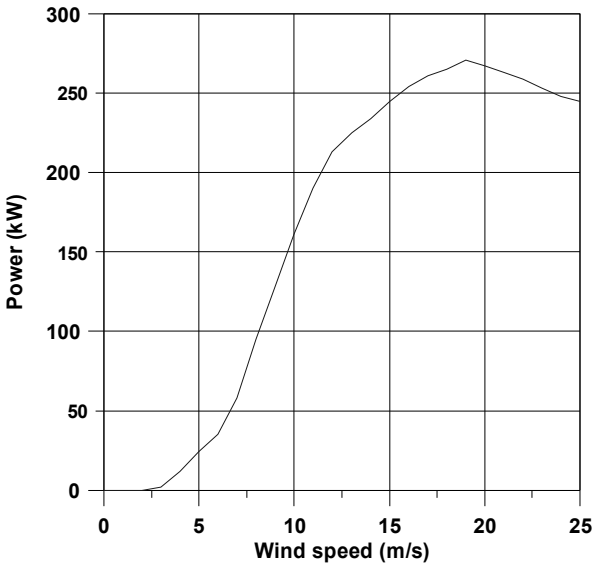

Fig. 5. *Power curve of Nordex N 29*

Indeed, the wind power density is given at standard conditions of 15 °C and 101.3 kPa by the equation [17]

$$\overline{P} = \sum P(V_i) f_i \,, \tag{1}$$

where $P(V_i)$ is the wind turbine power produced at the wind speed V_i, f_i is the wind speed frequency at the wind speed V_i given by the Weibull distribution.

The Weibull function is a two parameter function used to estimate wind speed frequency distribution. It is expressed as [17]

$$f(V) = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} \exp\left(\left(\frac{-V}{c}\right)^{k}\right), \tag{2}$$

where c is called the scale factor (m/s) and k is the shape factor (dimensionless).

The wind speed and the Weibull shape factor are adjusted vertically according to the power law model [18]

$$\frac{V_2}{V_1} = \left(\frac{Z_2}{Z_1}\right)^{\alpha} \tag{3}$$

$$a = a + b \ln V_1 \tag{4}$$

where V_1 is the observed wind speed at height Z_1 and V_2 is the calculated wind speed at height Z_2, α is the power law coefficient, it depends on the wind speed measurement.

$$\frac{k_2}{k_1} = \frac{1 - 0.088 \ln \frac{Z_1}{10}}{1 - 0.088 \ln \frac{Z_2}{10}}, \tag{5}$$

where k_1 is the Weibull shape factor at height Z_1 and k_2 is the Weibull shape factor at height Z_2.

Results and discussion

In order to estimate the wind power delivered to the electrolyser, the retscreen model for wind energy project [20] was used. The model calculates the annual wind energy delivered according the equation (1). The model considers the temperature and pressure adjustment coefficients and losses coefficient.

The wind speed and the weibull wind distribution estimated at 10 m [19] were adjusted according the equations (3), (4) and (5) at 30 m height for seven sites of the south of Algeria. The values obtained are given on the Table 1.

The power curves of the three wind turbines presented in Fig. 3, 4 and 5 and the annual mean wind speed and the weibull shape factor given in the Table 1 were used to simulate the wind power produced annually. The hydrogen production rate is 1 $Nm^3 \cdot h^{-1}$ at 5 kW input with an energy efficiency of 75 %.

The results obtained are plotted in the Fig. 6, 7 and 8 for the three WTs. It appears clearly that the hydrogen production depends on the wind speed and the size of the WT. A look at the Fig. 6, 7, 8 reveals that the highest production is observed for the highest windy site Adrar. The lowest value of 1800 Nm^3 is observed for Hassi-Messaoud. In Salah and Béchar for the 10 kW WT. While, the Figs 7, 8 shows that the lowest production is observed only for Hassi-Messaoud.

Table 1

Mean wind speed and shape factor at 30 m above the ground

Site	V(m/s)	k (m/s)
Adrar	7,5	2,4
Béchar	4,9	1,5
Hassi-Messaoud	4,9	1,7
In Amenas	5,6	2,1
In Salah	5	1,8
Timimoun	6,6	2,1
Tindouf	5,6	2,2

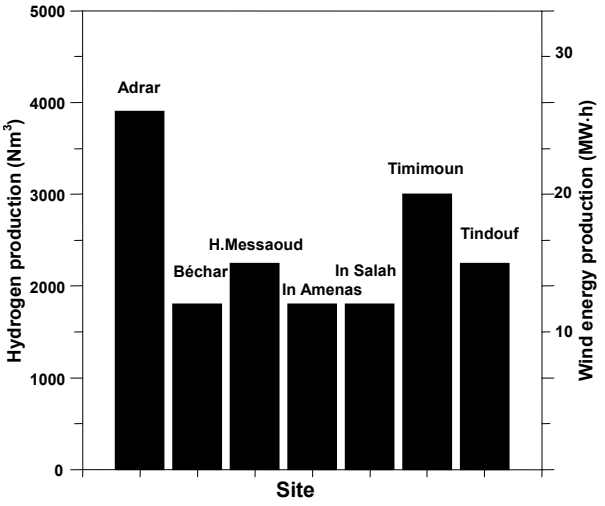

Fig. 6. Hydrogen and wind power production by the 10 kW WT

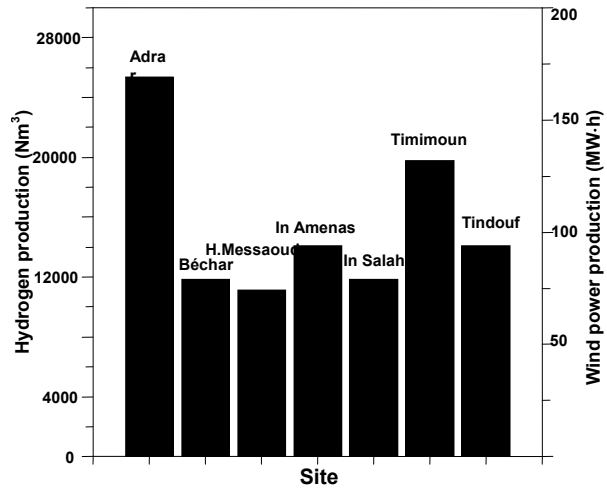

Fig. 7. Hydrogen and wind power production by the 50 kW WT

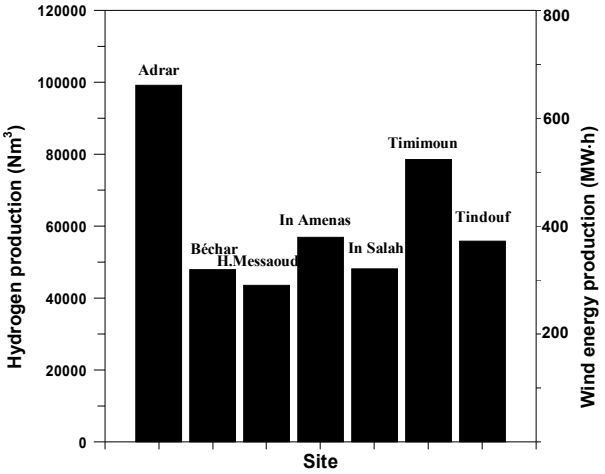

Fig.8. *Hydrogen and wind power production by the 250 kW WT*

These results indicate that for the same wind speed we obtain different values of hydrogen rate when we increase the WT size. Obviously, this means that the Weibull wind speed distribution can make the difference. On another hand, we noticed that the increase rate of hydrogen production for the three sizes of WT is approximately equal to the increase of the WT nominal power.

Conclusion

To evaluate the potential viability of electrolytic hydrogen wind production systems, it is important to make an accurate wind energy resource assessment.

This study gives a simplified methodology to evaluate the hydrogen production from the wind profile available and the wind power curve of a wind turbine.

The results indicate that the hydrogen production strongly depends on the wind speed and its frequency distribution.

Furthermore, in order to increase the efficiency of the hybrid wind-electrolyser system, it is primordial to choose the right wind turbine size for the best windy site.

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STRUCTURAL AND VIBRATIONAL PROPERTIES OF SPRAY PYROLYSED MOLYBDENUM OXIDE THIN FILMS

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MoO_3 thin films were prepared by spray pyrolysis technique by using 0.1 M of molybdenum chloride ($MoCl_5$) dissolved in deionized water on glass substrates heated at different temperatures. Influence of substrate temperature T_s on structural and vibrational properties is discussed; X-ray diffraction characterization revealed that the films are monoclinic for 200 °C and become orthorhombic above 225 °C. Raman spectra of the films were reported and explained the transformation phase.

Keys words: structural properties, vibrational properties, molybdenum trioxide.

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- 1 publication in Microelectronic Engineering.
- 1 publication in Molecular Physics Reports.

Introduction

Transition metal oxide films have a great technical interest for their optical and electronic properties. Indeed, these materials can be switched between two different optical states prompted by photochromic, thermochromic or electrochromic effect [1]. Moreover, a number of these oxides such as MoO_3, V_2O_5, and V_6O_{13} are promising cathode materials for rechargeable lithium batteries [2-4].

MoO_3 thin films were prepared by various techniques, such as reactive sputtering [5], chemical vapor deposition [6], pulsed laser deposition [7], oxygen plasma assisted molecular beam epitaxy [8] and flash evaporation [9]. We have used spray pyrolysis technique to fabricate molybdenum oxide thin films. The detailed study of structural and optical properties of MoO_3 thin films prepared by spray pyrolysis technique has been reported in a previous work [10] and shows that structural and optical properties of these films depend on substrate temperature.

The temperature dependence of the phonon spectrum has been investigated previously by Julien et al [11], the same authors have studied the substrate temperature dependence of flash evaporated MoO_3 thin films properties [9], but as far we know the effect of substrate temperature on vibrational properties of MoO_3 thin films prepared with spray pyrolysis technique has not been studied. So, in this paper, our objective is a comparative study of the spray pyrolysed MoO_3 vibrational and structural properties according to the substrate temperature.

Experimental details

Thin films were deposited by spray pyrolysis technique on glass substrates at different temperatures varying from 200 °C to 300 °C. Spraying solution of Molybdenum chloride ($MoCl_5$) dissolved in deionized water, with 0.1 M concentration is used. The description of spray pyrolysis technique has been reported previously [12].

Structural characterization was been carried out at room temperature in the θ –2θ scan mode using a Rigaku Miniflex diffractometer ($CuK_{\alpha 1}$ radiation, λ = 1.5406 Å). Raman spectroscopy measurements were performed at room temperature in a backscattering microconfiguration using the 514.5 nm line from an Ar-ion laser focused on the surface as a spot of 1 μm in diameter and with a power density of ~ 3 MW/cm^2. The scattered light was analysed with a Jobin Yvon T64000 spectrometer, equipped with a liquid nitrogen cooled CCD detector. The spectrometer provided a wave number resolution better than 3 cm^{-1}.

Results and discussion

Structural properties

X-ray diffraction patterns of molybdenum films prepared at different substrate temperatures are given in Fig. 1.

At 200 °C, the pattern exhibits (011) and (200) peaks with low intensity. These peaks are indexed by comparing the experimental data (measured inter-reticular distances d_m) with the JCPDS card No. 47-1081, corresponding to the β-MoO_3 (monoclinic phase, *P*2/*c* space group (No. 13)). This phase has been obtained by thermal treatment of spray dried powders of aqueous molybdic acid solutions [13] and by pulsed laser deposition [7].

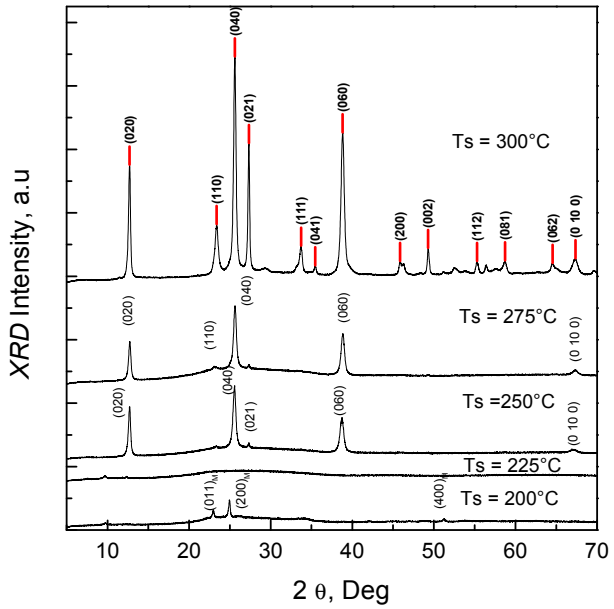


Fig. 1. *X-ray Diffraction spectra of spray pyrolysed samples prepared for different substrate temperatures with 0.1M of spray solution $MoCl_5$*

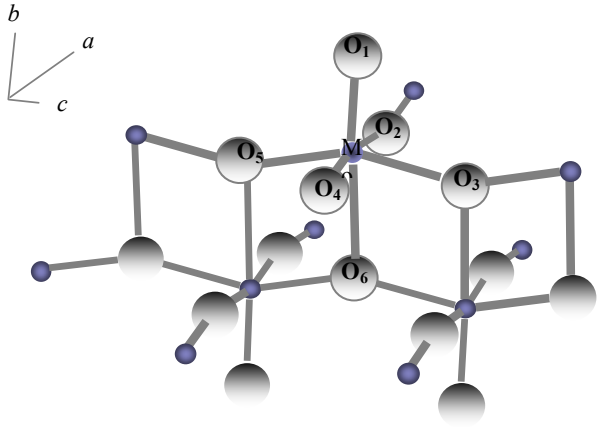
At 225 °C, the diffraction spectrum shows a large band suggesting a disorder in the structure due probably to the β-MoO_3 and α-MoO_3 mixture.

At 250 °C and 275 °C, the (0k0) peaks predominate indicating a preferential growth and suggesting layered structure of the films. The grains have the *b*-axis perpendicular to the substrate surface. Indeed, the *α*-MoO_3 can be described as a layered structure in which each layer is built up of MoO_6 octahedra at two levels connected in the direction to *c* axis by edge and corner sharing so as to form zig-zag rows, in the direction to the *a* axis the octahedron are connected by corners sharing [14] (see Fig. 2). Our result is similar to that obtained in literature for flash evaporated MoO_3 thin films [9].

At the higher temperature 300 °C, the pattern exhibits several peaks in different directions indicating the thin films polycrystalline nature. A good agreement is observed between the inter-reticular distances of thin films deposited in the range from 250 to 300 °C and those of JCPDS file (card N° 05-0508) corresponding to the orthorhombic phase (α-MoO_3).

The experimental lattice parameters are *a* = 3.973 Å, *b* = 13.902 Å and *c* = 3.692 Å [10], which are in good agreement with the literature data (*a* = 3.962 Å, *b* = = 13.858 Å and *c* = 3.697 Å) [15]. Moreover, the grain size increases with increasing substrate temperature, its values are about 21 nm for the range (250-275 °C) and 26 nm for 300 °C [10]. The α-MoO_3 spray pyrolysed films are light colored at low temperature and become deeply greyish when the substrate temperature increases, This fact suggests that the number of defects increases due to oxygen vacancies formation in the films and induces a decrease of the optical gap of MoO_3 [9, 16].

In order to confirm our hypothesis that the large band observed on the diffraction spectrum at 225 °C is attributed to the mixed phase during the transformation from β-MoO_3 to α-MoO_3 and to affine our obtained results, we present the study of spray pyrolysed MoO_3 vibrational properties according to the substrate temperature.



Mo-O_1: 1,67 Å; Mo-O_2: 2,25 Å; Mo-O_3: 1,95 Å; Mo-O_4: 1,73 Å; Mo-O_5: 1,95 Å; Mo-O_6: 2,33 Å

Fig. 2. *Structure of α-MoO_3 (zig-zag chains of octahedra [14])*

Raman micro-spectroscopy

The obtained Raman spectra in the range 80-1100 cm^{-1} for samples prepared by spray pyrolysis at substrate temperatures varying from 200 °C to 300 °C, are shown in Fig. 3 and 4.

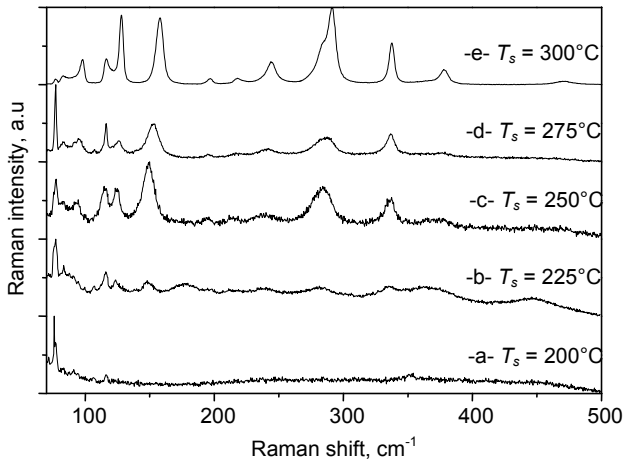


Fig. 3. *Raman spectra in the frequency range 80 to 550 cm^{-1} of MoO_3 films prepared at different substrate temperature*

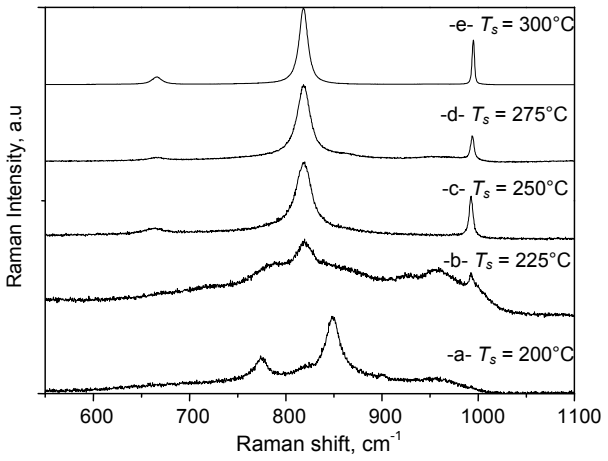


Fig. 4. *Raman spectra in the frequency range 550 to 1100 cm^{-1} of MoO_3 films prepared at different substrate temperature*

Vibrational study in 80-550 cm^{-1} spectral region

In the range 80-550 cm^{-1}, we can observe that the vibrational behaviors of the different samples are not the same. Thus, the spectra can be separated on three parts: the first concerns the vibrational behavior of the sample prepared at 200 °C, the second part amounts to T_s = 225 °C and the thin films prepared at T_s = 250 to 300 °C correspond to the last part. All the observed bands in Fig. 3 and 4, are summarized and compared with previous literature data in Table 1.

For the sample prepared at T_s = 200 °C, in the spectral range 80-550 cm^{-1}, we can only observe some very weak peaks below 200 cm^{-1}, above this frequency value we notice weak peak at 355 cm^{-1}. This band has been observed for β-MoO_3 phase [7, 17] and can be assigned by deformation bending mode δOMo_3. Moreover, in Fig. 5, we present the Raman spectrum of this sample in the range 72 to 80 cm^{-1}. A resolved doublet at the bands 76 and 77 cm^{-1}, is observed. The peak at 76 cm^{-1} has a width at half maximum smaller than the second peak. However, we know the existence of a plasma ray in this spectral range. So, it is reasonable to assign the band at 76 cm^{-1} to this ray plasma and the band at 77 cm^{-1} to our material. In the literature [7], the band at 77 cm^{-1} corresponds to a vibrational mode of β-MoO_3. This result must be confirmed by the spectral study on the range 550-1100 cm^{-1}.

Table 1

Experimental frequencies (cm^{-1}) and assignment of the Raman active modes of orthorhombic MoO_3

This work (cm^{-1})	E. Haro-Poniatowski et al [7]	Eda [18]	Assignement [19]
995, s	995, s	995	A_g, B_{1g} *v* O═Mo
818, vs	819, vs	819	A_g, B_{1g}, *v* OMo_2
666, w	667, w	666	B_{2g}, B_{3g}, *v* OMo_3
471, w	471, w	471	A_g, B_{1g}, *v* OMo_3
378, m	379, m	378	B_{1g},δ O═Mo
364*, vw	365, w	366	A_g, δ O═Mo
337, m	337, m	338	A_g, B_{1g}, δ OMo_3
291, s	291, s	291	B_{3g}, δ O═Mo
284*, m	283, m	283	B_{2g}, δ O═Mo
244, m	245, m	246	B_{3g}, δ OMo_2
218, w	217, w	217	A_g, δ OMo_2
197, w	198, w	197	B_{2g}, δ OMo_2
158, s	158, m	159	*Other deformation modes*
128, s	129, w	129	
116, m	115, m	117	
98, m	98, m	100	
83, w	82, s	84	

*w = weak, m = medium, s = strong, vs = very strong, * fitted frequency value*

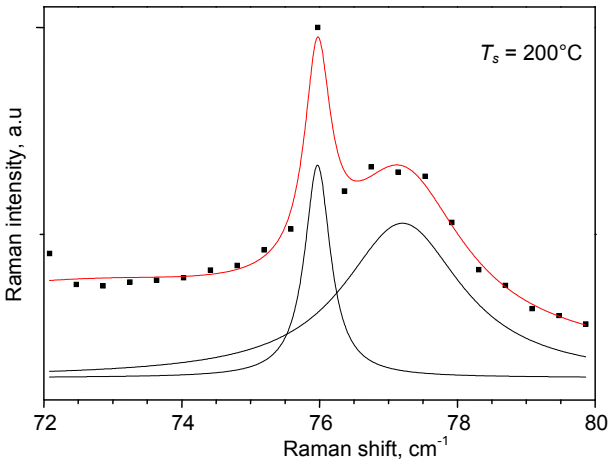


Fig. 5. *Raman spectra in the frequency range 72 to 80 cm^{-1} of β-MoO_3 films prepared at 200 °C*

When the substrate temperature reaches 225 °C, some weak broad peaks are observed at 158, 238, 281, 336, 372 and 447 cm^{-1}, a well resolved doublet appears at 116 and 124 cm^{-1} and medium peak is observed at 148 cm^{-1}. The bands at 238, 281, 336, 372 cm^{-1} are near to the ones observed in literature for α-MoO_3 [17, 18, 19] (Table 1). In comparison with the previously Raman studies on β-MoO_3 or α-MoO_3, it seems that the weak broad peak at 447 cm^{-1} has not indexed. However, it can explain the disorder in the structure.

For the third part (T_s = 250 to 300 °C), we always observe in the Fig. 3 a medium peak, nearby to 337 cm^{-1}. A strong peak with shoulder appear near 290 cm^{-1} in the case of the sample prepared at 300 °C, whereas we notice a broad peaks at same frequency value for 250 and 275 °C, all theses bands are due to the Raman-active bending modes [19]. In order to analyse the peak shape, lorentzian fitting is used in 270 to 300 cm^{-1} spectral region (Fig. 6), the curve fittings confirm the existence of shoulder bands (fitted frequencies values labeled * in Table 1), it is clearly that the δMo═O vibrations corresponding to frequencies of 284 and 291 cm^{-1} are closely dependant to substrate temperature and the intensity ratio (I_{291}/I_{284}) increases as function of T_s.

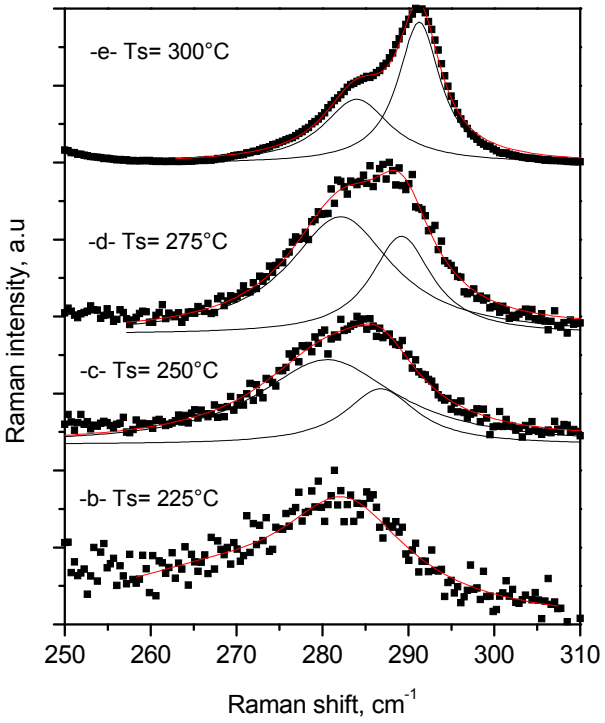


Fig. 6. *Analysis of the peaks 284 and 291 cm^{-1} as a function of substrate temperature*

The line shifted from 149 cm^{-1} to 153 cm^{-1} (Fig. 3, *c, d*) is assigned to B_{1g} mode (translational rigid MoO_4 chain mode, T_b), when substrate temperature reaches 300 °C, a strong band at 158 cm^{-1} is observed and assigned to A_g mode (translational rigid MoO_4 chain mode, T_b).

The resolved doublet at 116 and 124 cm^{-1} is always observed with a shift of 5 cm^{-1} for 124 cm^{-1} band at 300 °C, theses bands are assigned respectively to B_{2g}, B_{3g} modes (translational rigid MoO_4 chain mode, T_c).

We can notice that the different modes for MoO_3 thin film prepared at 300 °C are more resolved than films prepared at 250 or 275 °C.

Vibrational study in 550-1100 cm^{-1} spectral region

In Fig. 4, *a*, the more intense peaks at 849 cm^{-1} and 774 cm^{-1} can be assigned to the stretching vibrations of Mo–O bonds in the expected corner-sharing octahedral Mo–O–Mo and the weak peak observed at 901 cm^{-1} indicates a stronger distortion of the MoO_6 octahedra. The monoclinic MoO_3 contains two crystallographically independent octahedra, shown the disorder at the Mo and O sites; its ReO_3 structure is analogous to WO_3. Indeed the Raman spectrum of MoO_3 thin film prepared at 200 °C (Fig. 3, *a* and Fig. 4, *a*) is similar to WO_3 as described in the literature [7, 13]. This spectrum exhibits other very weak bands at 818 and 957 cm^{-1} that are determined by lorentzian fit of the experimental spectrum. The very weak band at 818 cm^{-1} corresponds to stretching vibration of Mo–O–Mo suggesting the slight presence of α-MoO_3 in thin film deposited at 200 °C.

For T_s = 200 °C, the band at 957 cm^{-1} was observed at 951 cm^{-1} by S.H. Lee et al [5] for sputtered amorphous MoO_3. The authors assigned to Mo═O stretching mode of terminal oxygen atoms possibly on the surfaces of the cluster, these terminal oxygen bonds are created by breaking of Mo–O–Mo bonds at the corner-shared oxygen, which are common to two octahedron [13], T.Ono et al [20] have observed this band at 955 cm^{-1} for MoO_3 catalyst exchanged with O^{18} that assigned to vibration of Mo–O^{18} bond.

When the substrate temperature reaches 225 °C, the peaks being particularly broad, indicate the poor crystallization of film, confirming the X-ray diffraction measurements. The 848 cm^{-1} and 774 cm^{-1} characteristic peaks of β-MoO_3 becomes very weak and the band at 957 cm^{-1} becomes more intense due to disorder increase in film. According to T_s = 200 °C, additional peaks at 819 cm^{-1} and 992 cm^{-1} appear, these modes characterizing the α-MoO_3 are assigned respectively to Mo–$O_{(2)}$–Mo and Mo═$O_{(1)}$ stretching vibrations. That's why it is reasonable to think that at T_s = 225 °C, we have a mixture of α-MoO_3 and β-MoO_3. The weak band observed at 924 cm^{-1} is not mentioned by other experimental works and it can be explained by film disorder. Above 225 °C, further the stretching vibrations modes at 819 and 994 cm^{-1}, a weak band is observed at 666 cm^{-1}, that assigned to OMo_3 bridging stretching vibrations. With the increasing substrate temperature, a shift toward the mode frequencies characteristic of orthorhombic phase (α-MoO_3) is observed and the bands become well resolved. The band at 994 cm^{-1} is more intense which confirm the layered structure of the film. The bands corresponding to orthorhombic phase are assigned according to α-MoO_3 single crystal studied by

Py and Maschke [19] and summarized in Table 2, our results are in good agreement with those reported in literature [7, 9, 17-19].

Table 2

Experimental frequencies of Raman active modes of MoO_3 spray pyrolysed thin films deposited at different substrate temperatures

β-MoO_3 [7]	This work, °C					α-MoO_3 [19]
	200	225	250	275	300	
76 (s)	76					
		83	83	83	85	83
91	91					
		90*	93	94	98	99
	116	116	115	116	116	116
130 (w)		124	124	126	128	129
		148	149	153		154
		158			158	158
176						
194						
		195*	195	195	197	198
		214*	214	217	218	217
237 (w)		238	239	241	244	246
283 (w)		281	279*	280*	284*	283
			287*	288*	291	291
310 (w)						
		336	337	336	337	338
349 (m)	355					
						365
		372	373	374	378	379
391 (w)						
414 (w)						
		447				
					471	473
			662	666	666	666
774 (s)	774	784*				
	819*	819	818	818	818	819
849 (vs)	849	855*				
904 (m)	901					
		924				
	957	960				
		992	992	994	995	995

*w = weak, m = medium, s = strong, vs = very strong, * fitted frequency value*

Conclusion

MoO_3 thin films were prepared by spray pyrolysis technique on glass substrate with a temperature variation from 200 to 300 °C. The films exhibit respectively a monoclinic structure at low temperature and an orthorhombic structure at high temperature. The structural results reveal that the films structure changes with substrate temperature.

The samples were characterized also by Raman spectroscopy; the results confirm the temperature dependence of the nature of the film. At 200 °C the Raman frequencies correspond to β-MoO_3. A mixture of monoclinic and orthorhombic structure is observed at 225 °C, the spectrum is particularly broad for this temperature, which explains the poor film crystallization and the absence of peaks in XRD diagram. Above 250 °C, all frequencies Raman corresponding to α-MoO_3 are observed and confirm the XRD results.

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OPTIMIZATION OF AN ANTISCALE TREATMENT TO PREVENT SCALING OF A SOLAR DESALINATION UNIT USING EVAPORATION-CONDENSATION PRINCIPLE

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The main purpose of this investigation was to optimise an antiscale treatment to prevent scaling of a solar desalination plant using brackish water. Scales were identified by XRD as $CaSO_4 \cdot 2H_2O$. To prevent its formation, laboratory study was performed. Three antiscalants (STP, Flocon and RPI 2000) were tested at different conditions to stop or delay gypsum crystallisation in supersaturated solutions prepared by mixing $CaCl_2$ and Na_2SO_4 solutions. Kinetics, XRD and SEM data showed that the RPI 2000 was the most efficient.

Keywords: solar energy, alternative energy and ecology

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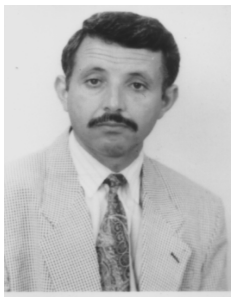

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Introduction

Tunisia (North Africa) is currently confronted to the crucial problem of the public, agricultural and industrial feed water supply, in particular in the center and south areas. Production of fresh water by seawater and brackish water desalination has proved to be an alternative for these regions. Water desalination stations that use conventional methods such as reverse osmosis (RO), multi-stage flash (MSF) and multiple effect (ME) distillation are large and non- autonomous. In addition, they consume high energy and have a heavy structure. The use of solar-powered water desalination plants seems to offer an attractive alternative, given the availability of this free energy source in the arid regions, the low cost infrastructure, and the low maintenance [1-2]. However, all the desalination processes are based on the concentration principle of waters already presented higher salinity. So, scale problem can occurs by the accumulation of minerals such as $CaCO_3$ and $CaSO_4$. These salts form hard and strongly adhering deposits on the surfaces and their formation is favoured by the decrease of their solubility with increasing temperature [3]. Calcium carbonate scale can be prevented by several methods e.g. antiscalants and acid treatments. On the other hand, calcium sulphate crystallisation cannot be controlled easily. The only method that is always applied to control its formation is the use of scaling inhibitors at very low concentration (mg/L). Studies have shown that these inhibitors performance strongly depend on their structure such as the functional groups, the chemical composition and the molecular weight [4-5]. Therefore, the choice and the optimization of the antiscalant are important to reduce the cost of product water. The effectiveness of a number of additives such as aminophosphate polymers, organic phosphate, mineral phosphates, and polyacrylate in preventing or reducing the crystallization of calcium sulphate from supersaturated solution has been the subject of numerous investigations [6–10]. El Dahan and Hegazy [7] studied the effect of organic phosphate ester on gypsum precipitation at temperature ranging from 40-90 °C and showed that the dose required for inhibition increases with temperature. Linnikov and Podbereznyi [6] showed that, for the same aminophosphate antiscalnt dose (20 mg/L), the growth rate of gypsum scale in seawater is 6 times more important at 82 °C than 70 °C. Jasbir [8] has examined the influence of a polyamine Phosphonate. It was found that this inhibitor was very effective for controlling all salts that can be precipitated in sea water desalination.

The main objective of this study was to optimise an antiscalant treatment to elude scaling problem in a solar desalination unit hosted in the south of Tunisia and using the solar multiple condensation evaporation cycle principle (SMCEC). For this purpose, a characterisation of the scale and feed water was performed. The effect of three antiscalants on scale crystallisation, from thermodynamics, kinetics and crystallographic point of view, were developed at laboratory scale.

Problematic and unit characterisation

The unit has three major components: solar collectors, evaporation tower and condensation tower. Fig. 1 shows a representative schema of this unit. The structure of the evaporation and condensation towers is completely made of polypropylene tubes. The principle of this installation consists of heating brackish water by solar collectors via a heat plate-exchanger. The temperature varies between 50 and 90 °C with season. Then the hot water is injected to the top of the evaporation tower (via the polypropylene tubes). The latter is equipped with a packed bed (a polypropylene vertical tissue) which has as role to increase the surface of contact water/air and therefore to improve the humidification rate. The saturated humid air migrates towards the condensation tower by natural or forced convection. This vapour is finally condensed in contact with the cold condensation plates. The distilled water is collected in a basin at the bottom of the condensation tower. The basin is made of polypropylene material. Pumps are installed to facilitate water circulation in different parts of the desalination unit. Water which may not be evaporated is collected in a basin at the bottom of the evaporation tower and then recycled. This concentrated water is thereafter discarded generally after 24 hours. After some weeks, scale deposits were observed on the heat exchanger surfaces, on the polypropylene tubes and on the packed bed tissue which require frequent stoppage of the unit. Fig. 2 shows a photo of a polypropylene conducts completely encrusted.

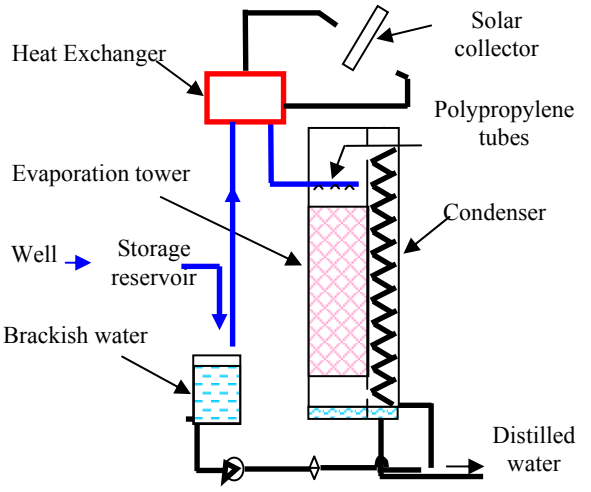

Fig. 1. *A representative schema of the desalination unit [1]*

Fig. 2. *Scale formation on the polypropylene conducts*

Water analyses (Table 1) show that the feed water is brackish water (salinity < 10 g/L). It is rich in calcium (520 mg/L) and sulphate ions (2430 mg/L) for only 51 mg/L of bicarbonate ions. The calcium sulphate precipitation is thus more probable than calcium carbonate one. In addition, it should be noted that the scaling tendency of the desalination unit increases with work time by increasing ions concentration responsible to form scale: Ca^{2+}, SO_4^{2-} and HCO_3^- (Fig. 4) [11].

XRD analyses (Fig. 3) show that the formed scales were only gypsum.

Table 1

Physicochemical analyses of well water

Water characteristics	
pH	8.1
Conductivity, μS/cm	6510
Dry residual, g/L	5.6
Calcium, mg/L	520
Magnesium, mg/L	146
Sodium, mg/L	1310
Bicarbonates, mg/L	51.24
Sulphates, mg/L	2430.5
Chlorides, mg/L	803.4
Potassium, mg/L	9
$\Omega_{CaSO_4 \cdot 2H_2O}$ (supersaturation) at 30 °C	1.35
$\Omega_{CaSO_4 \cdot 2H_2O}$ (supersaturation) at 90 °C	2.6
Ω_{CaCO_3} (supersaturation / calcite)	3.15

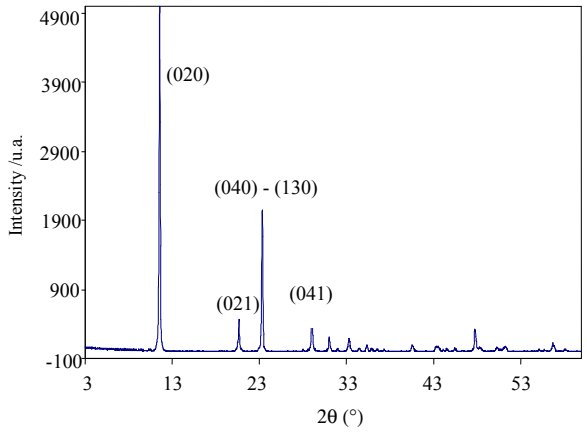

Fig. 3. *X-ray diffraction patterns of deposit scale*

This threat of scaling is more serious when the temperature increases; indeed, these two salts, $CaCO_3$ and $CaSO_4$, present the particularity to have an inverse solubility phenomenon.

The precipitation of each salt can not occurs only if the ion activities product exceeds the solubility constant. Knowing the water characteristics, the supersaturation ratios, Ω, of gypsum and calcite were calculated considering the liquid – solid equilibrium between Ca^{2+} and SO_4^{2-} and solid $CaSO_4 \cdot 2H_2O$ for gypsum (1) and Ca^{2+} and CO_3^{2-} and solid $CaCO_3$ for calcite (2):

$$\Omega_{gypsum} = \frac{a_{Ca^{2+}} a_{SO_4^{2-}}}{Ks_{CaSO_4 \cdot 2H_2O}}, \quad (1)$$

$$\Omega_{calcite} = \frac{a_{Ca^{2+}} a_{CO_3^{2-}}}{Ks_{CaCO_3\,(calcite)}}, \quad (2)$$

where a – the ion activity and Ks – the solubility constant of gypsum ($Ks = 3.3 \cdot 10^{-5}$ at 30 °C and $Ks = 3.5 \cdot 10^{-5}$ at 90 °C) [12–13] or calcite ($Ks = 3.09 \cdot 10^{-9}$ at 30 °C) most stable varieties of calcium sulphate and calcium carbonate, respectively.

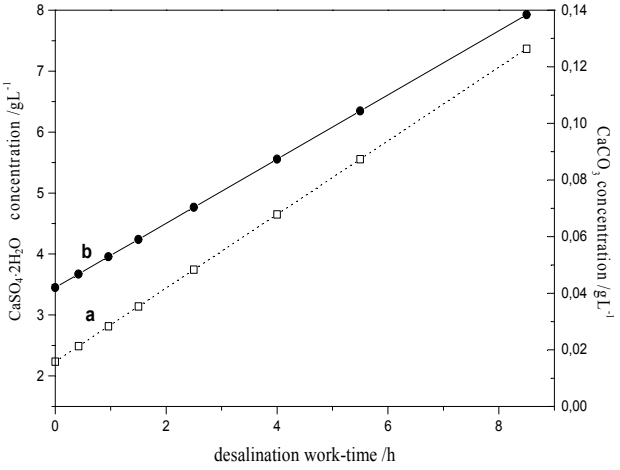

Fig. 4. *Effect of water evaporation on (a) $CaSO_4 \cdot 2H_2O$ and (b) $CaCO_3$ concentrations [11]*

It can be concluded that well water is initially supersaturated on both calcium sulphate and calcium carbonate: $\Omega_{gypsum} = 1.35$ and $\Omega_{calcite} = 3.15$; and therefore susceptible to form scale. When the temperature and the working time of the unit increase, the evaporation rate increases and therefore the supersaturation coefficient of gypsum and the one of calcite increase also. This explains, theoretically, the fastest scale formation in this unit. In these conditions, considering that gypsum and calcium carbonate precipitate together, calcium carbonate constitutes about 1.7 wt % of the mixture [11]. Gypsum is thus the only scale deposits. This confirms the XRD analyses.

In the following, the effect of three antiscalant inhibitors, with different chemical composition, were tested at laboratory scale.

Experimental methods

All crystallization tests were carried out in a 0.350 dm^3 double-walled Pyrex vessel thermostated by water circulation through a constant-temperature bath at the

desired temperature. To avoid the effect of evaporation, especially for high temperatures, the system was fitted with a water-cooled condenser. The total volume of the working solution was 0.200 dm^3 and the stable supersaturated solutions employed were prepared by mixing equal volume of equimolar $CaCl_2$ and Na_2SO_4 solutions previously kept at the work temperature. Chemicals were of analytical grade. The solutions-stirring was performed at constant speed using a magnetic stirrer. The onset of gypsum precipitation was accompanied by the drop of free Ca^{2+} ions, measured by EDTA complexometry titration of small water samples. The experiment was stopped after the concentration of free calcium ion had no more significant change.

Fig. 5 shows the temporal evolution of free calcium ion concentration after mixture of Na_2SO_4 and $CaCl_2$ solutions in absence of any additives. Three parts can be distinguished on this curve. The first, within $t = 0$ and $t = t_N$ (nucleation time), corresponds to the nucleation step where the concentration of free Ca^{2+} remains constant. From t_N, the crystalline growth stage begins. The free calcium ions concentration decreases gradually until t_S, scaling time, (part II). From t_S, the precipitation rate becomes infinitely slow.

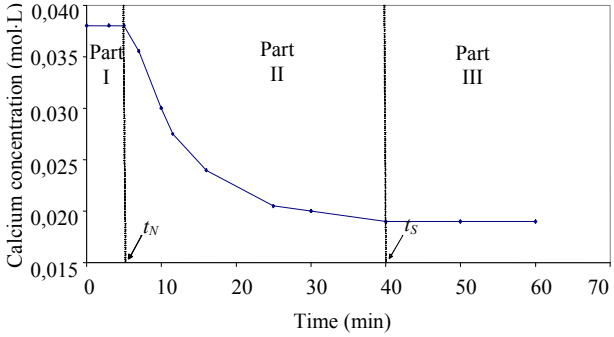

Fig. 5. *Evolution of calcium concentration vs time in absence of additives*

From this precipitation curve, the supersaturation coefficient Ω at $t = t_S$ and the crystalline growth rate V can be determined as:

$$\Omega_{gypsum} = \frac{a_{Ca^{2+}} a_{SO_4^{2-}}}{Ks_{CaSO_4 \cdot 2H_2O}} \quad (3)$$

$$V = \frac{d[Ca]}{dt} \quad (4)$$

Crystallisation tests were done in presence of three antiscalant inhibitors used in the Tunisian industry:

– The STP, Sodium TriPolyPhosphate, mineral with chemical formula $Na_5P_3O_{10}$, marketed as a powder. It represented 100 % of active matter.

– The Flocon 260, a mixture of polycarboxylate and phosphonate. The active phase represents 35 % of which 79 % of sodium CIS (poly-2-carboxyethyl) phosphinate.

– The RPI 2000, sodium polyacrylate, has an active phase representing 30 %.

Two addition modes of these inhibitors solutions to the system were studied. In the first mode, the inhibitor solution was added to the $CaCl_2$ solution before mixing. This addition mode is referred below to as mode A in the text for simplicity. The second mode (mode B) consists of adding the inhibitor in the Na_2SO_4 solution.

Throughout this study, the crystallisation temperature was fixed at 70 °C, which is the fluently reached temperature in the desalination plant. The supersaturation was fixed at 6. It corresponds to the one reached before a working time of 4 hours [11].

At the end of each experiment, precipitate was recovered by filtering the precipitating solution through a 0.45 µm filter. The samples were dried at room temperature before analysis by XRD and SEM (Philips Quanta 200). XRD was carried out at room temperature with a Philips X'PERT PRO diffractometer in step scanning mode using Co_Kα radiation. The XRD patterns were recorded in the scanning range 2θ = 10-55°. The d spacing and the normalized intensity of each peak were determined using "X'Pert HighScore Plus" software.

Results and discussion

In Table 2 are recapitulated the kinetic (t_N, t_S, V) and the thermodynamic (supersaturation coefficient Ω) parameters determined for each crystallisation test in absence and in presence of inhibitors.

It can be seen that either the addition mode (A or B), the presence of the inhibitors delay the nucleation time t_N and prolongs the scaling one t_S. The effect on nucleation time depends on the scale inhibitor types: t_N passes from 5 minutes in absence of inhibitors to 10, 14 and 35 minutes in presence of only 1 mg/L of STP, Flocon and RPI respectively. The same effect is observed for t_S. An increase in inhibitors concentrations increases the t_N and decreases the crystalline growth rate V. For example, the presence of 1 mg/L of Flocon slowed down the crystalline growth rate by a factor 4 compared to the base line (precipitation in absence of inhibitors). This factor becomes 21 and 583 when the Flocon concentration increases to 2 and 3 mg/L respectively.

It is interesting to note that the addition mode of the inhibitors has an important effect on the kinetics parameters. When it is added in the calcium solution, the inhibitors prolong the nucleation time and the scaling one and decrease the growth rate.

From Table 2, it is also remarkable that, either the antiscalant type, the nucleation time t_N and the scaling time t_S determined in mode B are less significant than those registered when the inhibitors are added following mode A. , in the presence of 1 mg/L of RPI t_N is about 20 minutes according to the mode B and it is 35 minutes according to the mode A. In the same way for t_S: it is about 130 and 145 minutes respectively according to whether the RPI 2000 is added in the solution of sulphate or calcium. Moreover, the crystalline growth rate V of gypsum was also affected. It was slowed down by a factor 4 in presence of 3 mg/L of RPI: it passes from

$2.1 \cdot 10^{-3}$ mmol·l^{-1}·min^{-1} to $8 \cdot 10^{-3}$ mmol·l^{-1}·min^{-1} if it was added according to mode B or A, respectively.

At the end of the precipitation, marked by a constant free Ca^{2+} concentration value *vs* time, the calculated supersaturation values Ω were about 2. Therefore, it can be concluded that, at the contrary to their effect on kinetics parameters, the presence of the inhibitors did not influence the thermodynamic condition of the solution at the end of precipitation. In spite of elevated operate temperatures, the Ω values remain sharply superior to 1 (thermodynamics equilibrium). This metastable state can be explained by the presence of foreign ions in the $CaSO_4$-H_2O system [11].

Table 2

Effect of the addition mode of the tested inhibitors on t_N, t_S, V and Ω

		Inhibitors added in calcium solution MODE A				Inhibitors added in sulphate solution MODE B			
	C, mg/L	t_N, min	t_S, min	Ω	V, mmol·l^{-1}·min^{-1}	t_N, min	t_S, min	Ω	V, mmol·l^{-1}·min^{-1}
STP	0	5	30	1. 88	3.5	5	30	1. 88	3.5
	1	10	42	1.96	2	5	35	2.04	2.5
	2	15	90	2.04	1.2	10	60	2.04	0.9
	3	20	120	2.04	0.3	15	106	2.04	0.2
Flocon	0	5	30	1.88	3.5	5	30	1. 88	3.5
	1	14	40	1.96	0.8	7	30	1.96	0.6
	2	38	300	2.04	0.2	30	230	2.04	0.2
	3	55	400	2.25	$6 \cdot 10^{-3}$	45	260	2.12	$3.6 \cdot 10^{-2}$
RPI	0	5	30	1.88	3.5	5	30	1. 88	3.5
	1	35	145	1.96	0.3	20	130	1.96	0.2
	2	45	395	2.04	$2.8 \cdot 10^{-2}$	40	385	2.04	$2.4 \cdot 10^{-2}$
	3	65	590	2.16	$8 \cdot 10^{-3}$	50	520	2.16	$2.1 \cdot 10^{-3}$

The fact that the tested inhibitors are more effective when they are added in the calcium solution can be interpreted by the affinity of the calcium ion to the functional groups ($-PO_3^{2-}$) of STP, (-COO-) of RPI and ($-PO_3^{2-}$, -COO-) of Flocon. Indeed, the calcium ion has the possibility to react with SO_4^{2-} or these functional groups. Because of its affinity to these groups, Ca^{2+} spends more time in their neighbour than of the sulphates ion [14]. According to the mode A, the possibility of forming a germ is thus more probable than in the case of mode B.

Fig. 6 and 7 show that, by comparing the kinetics parameters, the RPI 2000 antiscalant is the most efficient. It delays more the nucleation step and the crystalline growth one of gypsum crystallisation. It can be also concluded that the STP is the least effective inhibitor. Indeed, it should be noted that for temperature superior to 70 °C, the polyphosphate STP molecules are hydrolysed in shorter chains to lead finally to the orthophosphate form which does not inhibit any more [7].

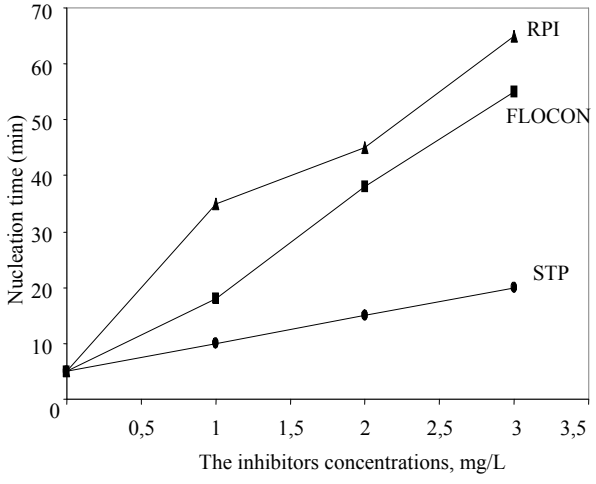

Fig. 6. *Effect of the tested inhibitors concentrations on the nucleation time t_N*

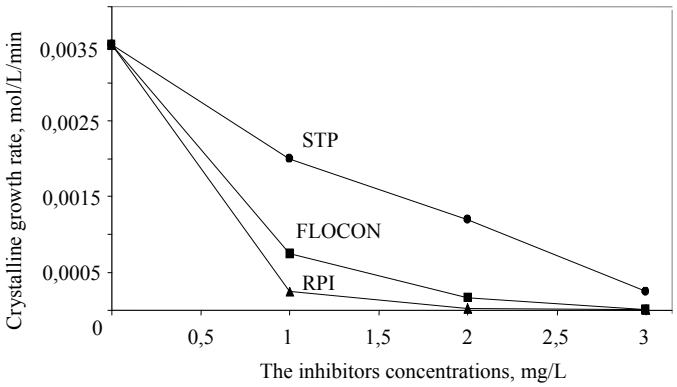

Fig. 7. *Effect of the tested inhibitors concentrations on the crystalline growth rate V*

In the goal to better understand the effect of the tested antiscalant on gypsum crystallisation, SEM analyses were done. Fig. 8 shows the photos of the recuperated precipitates, at the end of experiments, in presence of 3 mg/L of STP, Flocon, RPI and in absence of inhibitors. In absence of inhibitors, $CaSO_4 \cdot 2H_2O$ crystallized in a needle form (Fig. 8, *a*) with an average size of 100 μm. The presence of inhibitors did not affect the gypsum morphology in the same way. The addition of STP influences only the needles size (Fig. 8, *b*). The presence of Flocon alters the gypsum morphology (Fig. 8, *c*). This influence is even more remarkable when the added inhibitor is RPI 2000 (Fig. 8, *d*) where the laminated structure is completely destroyed by the adsorption of the additive molecules on the gypsum crystalline surface.

X-ray diffraction analysis shows that the addition of the tested inhibitors did not change the precipitates variety which remain $CaSO_4 \cdot 2H_2O$.

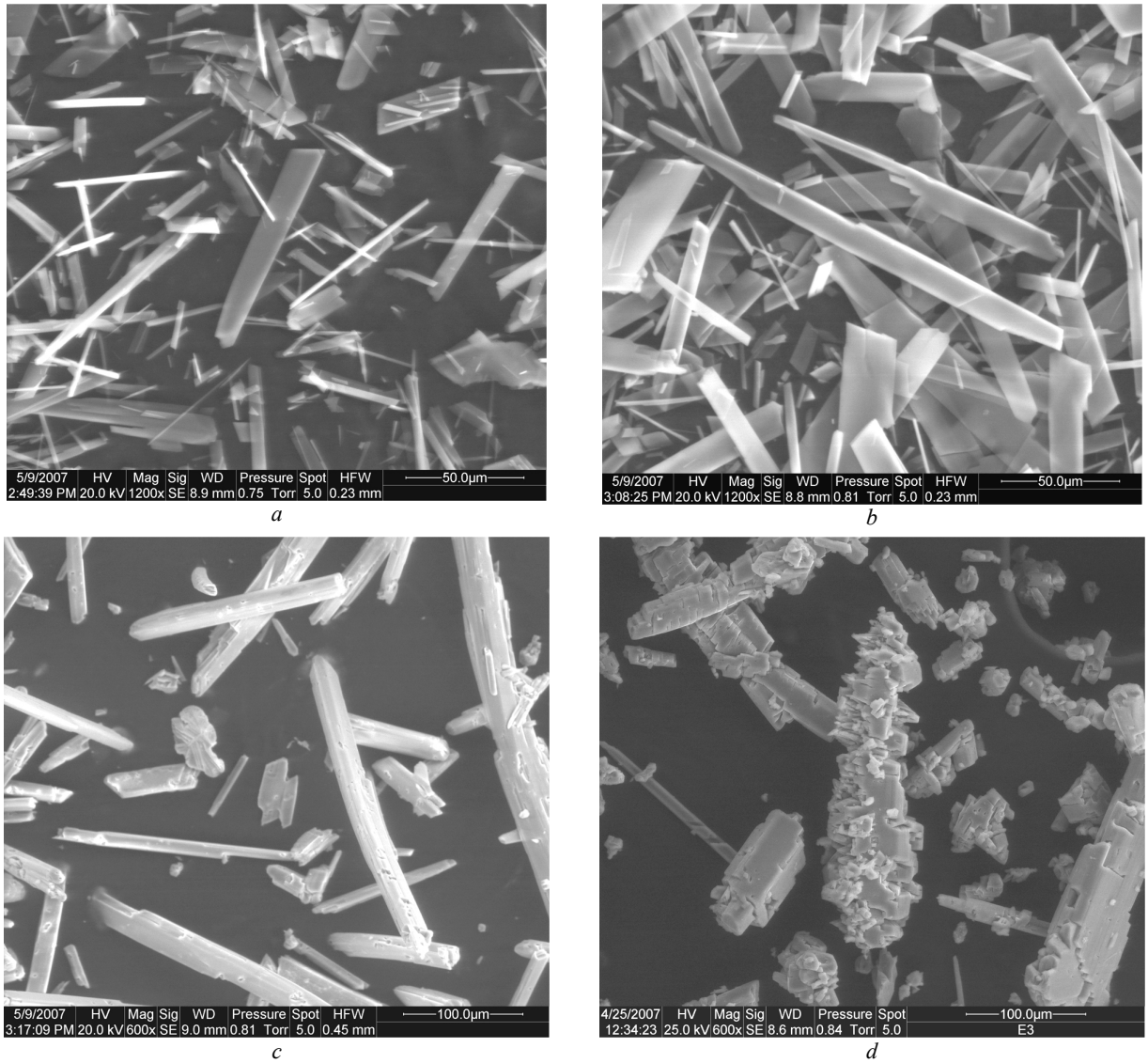

Fig. 8. *SEM photos of gypsum precipitated at 70 °C (a) in absence of inhibitors and in presence of 3 mg/L of (b) STP, (c) Flocon and (d) RPI 2000*

Conclusion

The scale deposit in the studied desalination unit was identified as gypsum. Three chemical antiscalants were tested at laboratory scale and in conditions reported those encountered in the desalination plant. It was shown that the tested inhibitors are more efficient when they are added in the calcium solution. From kinetics data analyses, it can be concluded that the RPI 2000 is the most effective inhibitor. SEM analysis shows that the RPI influences gypsum crystallisation by adsorption on crystal growth sites. The X-ray diffraction analysis showed that the addition of the inhibitors did not affect the deposits scale structure.

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NEW CONCEPT OF SOLAR AIR HEATER INTEGRATED IN THE BUILDING

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We present a new solar air collector totally integrated in a shutter. The air is moved by a fan provided in electricity by a PV module, this air pass a first time in the cover then between the cover and the absorber, and is injected in the house, this solar shutter is reversible and can run in all positions, The concept of this new solar air heater is described in this article and the experiment is presented.

Keywords: solar buildings

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Introduction

There's no doubt that the fossil energy resources of our Earth are being decreasing and that the strong economical development of the developing countries as China or India will increase the resources drop. In the other hand, it appears that the massive utilization of fossil fuels (and nuclear ones) endangers our Environment.

The part of the used energy for building is very important and hasn't stopped increasing; to limit or to reduce this building energy consumption, it is necessary to develop some actions concerning the rational energy management in parallel with the utilization of renewable energy sources. The decreasing of the energy consumption in abodes should not be realized to the detriment of the life quality of its occupiers and mainly of their health.

We present a new patented concept of solar air heater totally integrated in a shutter and able to produce with a total autonomy hot air from sun radiations and to introduce it inside the house. It allows conserving the integrity of the architecture of the house of the building.

Problems of the energy consumption in France

The residential and tertiary sector is the first energy consumer in France (Fig. 1) with 71 MTOE in 2006 [1] i.e. 43.83 % of the total final energy. The green house gases produced by this sector in 2000 are estimated at 119 MT of CO_2 (25 % of the total emission). The part of the residential and tertiary sector stays stable (around 42-43 %) but in absolute value, the energy consumed in this sector increase. The total energy consumption of the building sector increased of about 50 % during these twenty last years with a high penetration of electricity (+130 %) which covers 40 % of all the needs whose 50 % for captive use as lighting, domestic appliances, etc…).

The final consumption in the residential sector in 2002 corresponds to 452 TW·h and 100 TW·h for wood energy. The repartition of the consumption by type of use for a main home (i.e. 83 % of the total of the housings) is: 69 % for heating, 12 % for specific use of the electricity, 11 % for water heating and 7 % for cooking.

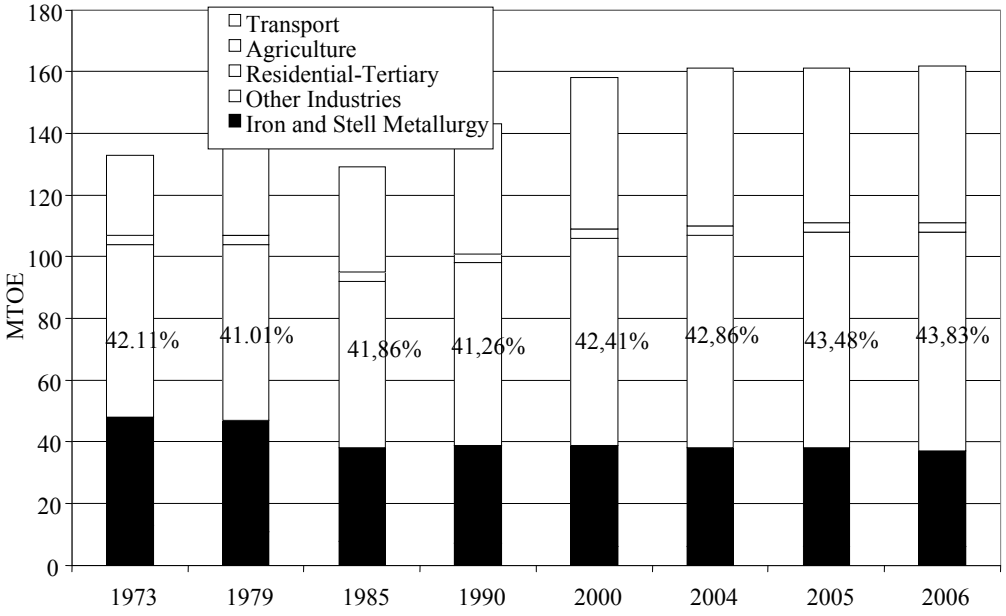

Fig. 1. *Final energy consumption by sector in France [1]*

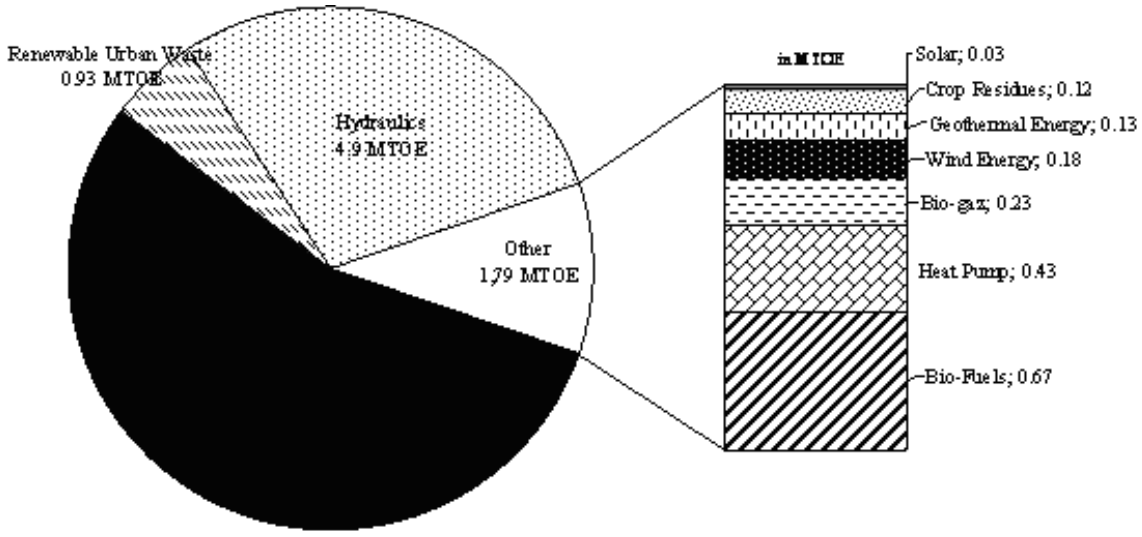

Fig. 2. *Renewable energy production by type in France (2006) [1]*

Moreover, for housings built before 1975 (65 % of the total of the housings), we can estimate that 50 % have been thermally rehabilitated but it stays some energy economies to realize in these housing which have an energy consumption higher than in new buildings.
The final energy in the tertiary sector, with 29.2 MTOE increases of more than 25 % in 15 years due to particularly the multiplication of specific uses of electricity as office automation and lighting. We note a high and increasing part of the energy in building of residential or tertiary type; the heating is the more energy consumer. Improving the energy efficiency in building is a research and development domain very important and has a very good future. The utilization of renewable energies to participate to the improvement of the energy efficiency in Building is very important. In France, the part of renewable sources in the energy production is still very low (Fig. 2).

The house of future

An Austrian study showed that the house of tomorrow must meet all following requirements [2-3]:
− the final or primary energy consumption must be low. Table 1 shows the objectives to reach for a low energy house and a passive house. These goals can be reach by:
− a decreasing of the heat losses by transmission (minimization of the exterior walls areas, improvement of the thermal insulation, ...);
− a reduction of heat losses by air conditioning (thermal envelop, re-heating of exterior air, …);
− an utilization of renewable energies;
− an utilization of high efficient appliances;
− the potable water consumption must be limited to 30 litres per day and per person. This objective can be reached by a used water recycling and the use of raining water;
− the polluting emissions in water, air and ground must be low;
− a high air quality must be reached by a total air replacement at least every three hours. The CO_2 concentration must stay under 1000 ppm.
− a high thermal quality can be obtained:
  − when the air and the inside surface temperatures are between 18 and 22 °C in winter and between 22 and 25 °C in Summer;
  − when the relative air humidity varies between 35 and 70 % and when the absolute air humidity is under 12 g/kg.
− a high visual quality is reached when there are a sufficient day light and a sufficient direct lighting by the sun;
− a high acoustic comfort must be reach with a acoustic level less than 20 dB in life rooms.
Engineers and builders recognize that building high energy efficient housings is a sensible, ethical, ecological idea and workable at medium and long-term. A lot of them think that innovation is an essential component of their job. However, if we observe the majority of recent or in process buildings, we note easily that the previous considerations are not taken into account at the moment to design or to build the house.
Often, we hear the ideas men say "we have a lot of good ideas, but we had not been able to realize them because it was not the good moment or because our clients did not want to apply them or because it is too expensive, too risky…"

Table 1

Values to reach for the energy consumption of a low energy house and a passive house compared to an existing house in kW·h/m² of inhabitable area (Climate corresponding to 3500° day per year)

Consumption	Existing house before 1980	Low energy house	Passive house
Heating	150-250	< 40	< 15
Final energy		< 70	< 42
Primary energy		< 160	< 120

To be an innovator it's to know how to put into practice or how to give concrete expression of its creativity. Introduce innovating and environmentally positive solutions is a difficult work. The obstacles are numerous and various: financial obstacles, technical obstacles, psychological obstacles, incompetent professionals or building standards too conservatives [4].

Thermal comfort, healthy inside atmosphere and energy savings

The ventilation is the process allowing to renew the inside air (polluted air) by an outside air (new and clean). Its function is to obtain, in an inside environment, good health, comfort and optimal productivity conditions for the human inhabitant:
1) in giving an air with a sufficient quality for respiration in diluting the polluting substances existing in the inside environment;
2) in controlling the humidity level;
3) in heating or cooling.
However using such a ventilation has a double negative impact: creation of thermal losses and if it is not perfect, it causes a discomfort due to a cold air-stream. From an energy point of view and taking into account the progressive increasing of the thermal insulation of building, the losses due to ventilation accounts for a larger and larger part of the heating needs (up to 30 %).
Primary, the various factors exposed before i.e.
− increasing part of the residential sector in the total energy consumption;
− dominating part of the heating in the residential energy consumption;
− heating losses by ventilation being able to reach 30 % of the thermal losses of the building explain the interest to find efficient methods to reduce these losses in increasing the comfort of the occupants. Secondly, the

objectives to reduce the utilization of fossil energies lead the architects to use more and more renewable energies in the building.
Thus these two observations conduce us to research new technical solutions, technological and/or architectural using renewable sources to reduce the thermal losses of houses by aeration and to add a complementary heat gain improving also the inside atmosphere for its occupants.

Brief analysis of existing solutions

The purpose of this paragraph is not to present precisely the various solutions to provide a hot and heatly air in the building but to give some general considerations about thses solutions which are:
− Passive solar systems and buildings: bio-climatic design of building envelopes allowing to regulate the thermal behaviour of buildings by using natural means, without supplementary energy contribution. These system are walls or windows with parietodynamical effect; The principle of these ventilated facades opaque (wall) or translucent (windows) is to preheat fresh air by making it circulate in one or two serial air gaps [5-8].
− Active systems: solar air collectors, the air is heated by a solar collector and injected in the house.
The advantages of a parietodynamic envelopes are to evacuate the heat during summer and to improve the comfort during winter limiting the heat losses. This solution induces adding costs and the installation must be realized perfectly. This solution can be only applied to new constructions and not to old ones, it is a problem because the old buildings have always the worst energy performances.
Concerning the classical air solar collectors, the most important disadvantage is that they are not integrated in the building and the visual impact is negative.
These solutions are efficient but the aesthetic problem and the no-applicability of passive solutions to existing buildings limit their utilization. Thus, we developped a new solar collector with a good efficiency and without negative visual impact (perfectly integrated). It is applicable to existing and new buildings.
Between all the surfaces available in the house, excepted the walls, the only part with large available area is the shutters and we gave to them an active function. Our new concept of solar air collector have the following advantages:
– a new active function is added to the shutter;
– they can produce heat in all positions between open and closed thanks to their symetrical conception;
– the vertical inclination allow to produce more energy during winter and less during summer;
– it can be sized and produced for all the windows because each part of the shutter can be made-to-measure;
– the installation of these solar shutters are very easy for old (existing) and new houses. The old shutter must be replaced easily by a new solar one;
– the air is directly introduced into the house by a rotative air collector without costly and big air distribution systems;
– the classical functions of the shutter are preserved: sound and thermal insulation and mechanical resistance;
– the solar air shutter is an autonomous heater because the fan is directly supplied by the PV modules integrated in the shutter and it can be used in remote areas.
However there are also two disadvantages: it is impractical to rolling shutters, the number of windows in the house implies the size of the heating system.

Presentation of the solar air shutter

The solar air shutter has the same aspect than a classical shutter (Fig. 3). The internal area is used as a heat converter and the frame can be built in various material (wood, aluminium, PVC). The heat converter is composed by a black aluminium absorber between two clear covers in extruded polycarbonate. This new solar air shutter is patented. This configuration allows not to use a thermal insulation area as in a classical solar collector.

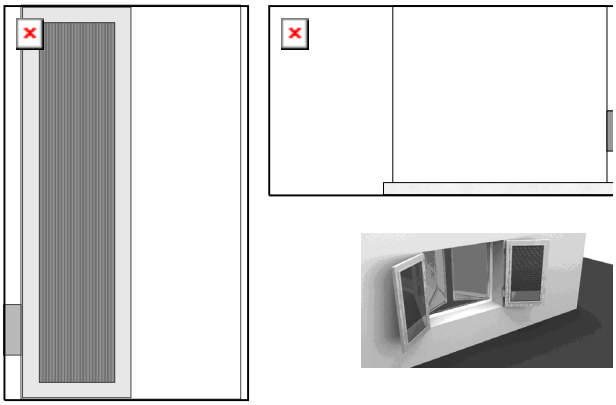

Fig. 3. *The new solar air collector: the solar shutter*

The air flow system is composed by a rotative part attached to the shutter, a fixed part including the fan embedded in the wall. A a-Si photovoltaic module is integrated in the low part of the shutter and allows to provide electricity to the fan via an electronic device specially conceived.
The air flows enter in the shutter by the lower part of the extruded polycarbonate cover as seen in Fig. 4 and they pass at first into the extruded polycarbonate cover then the air flows are mixed and pass between the cover and the absorber; the total air flow is collected in the lower part of the shutter and is evacuated into the room by the slice of the shutter.
This technic does not use a classical thermal insulation. More the air is heated more it penetrates into the solar collector and limits the conductive and convective losses towards the outside and the outside surfaces of the shutter are maintained the more cold possible limiting the heat losses with the ambient.

The advantage of the absence of a thermal insulation is a reduction of the thickness of the shutter and a low stagnation temperature reducing, during summer, the temperature of the shutter and the radiative exchanges between the shutter and the inside of the house. We can consider that it is a dynamical thermal insulation what it makes this solar collector unique and original. The air inputs are in the lower part of the shutter to avoid the rain to enter.

We chose a 1-3 mm cover in polycarbate because this material is well adapted [9], it is light, supple and solid and usable for temperatures up to 323 K, nowadays, it is treated againt UV and guaranted 10 years for the ageing. In the solar air shutter, we use a double air flow and the absorptance of polycarbonate in IR radiation is near 90 %, thus this cover participates strongly to the heat production.

The absorber is built in aluminium with a matt black coat of paint. It is not necessary to use a method to reduce the IR emmissivity of the absorber because the cover absorbs this type of radiation.

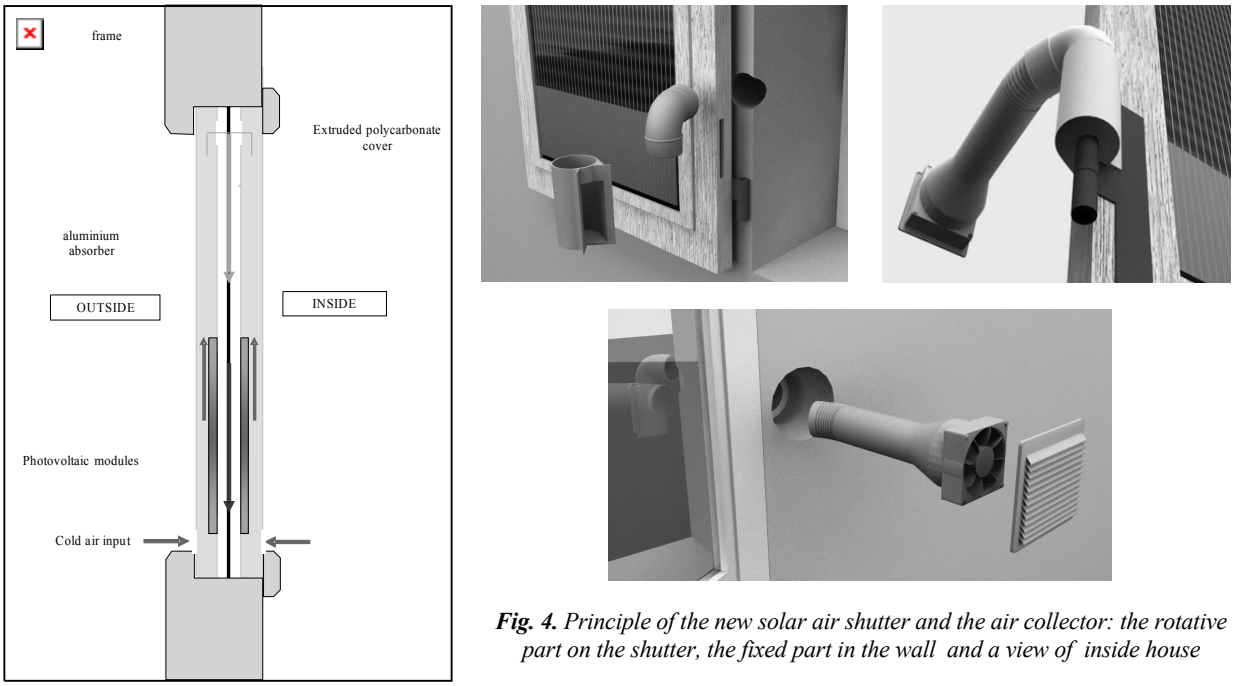

Fig. 4. *Principle of the new solar air shutter and the air collector: the rotative part on the shutter, the fixed part in the wall and a view of inside house*

For the PV modules, we had some constraints: a power and a voltage adapted to the fan, a correct size to be able to be integrated in the shutter, a good aestheticism. Thus, we chose ASI® OEM Outdoor solar modules from Schott available in various power and easily to integrate [10].

The experimentation

We set up an experimentation with three objectives:

– to test the thermal and electrical behaviour of the solar shutter, to collect experimental data for various meteorological conditions and to measure its energy performances;

– to validate a thermal model that will be developed in a furture work;

– to make adjustments necessary to improve the performances and the efficiency of the solar shutter.

We build an experimental wall with two window-openings able to receive two shutters for french windows and two shutters for classical windows (Fig. 5).

Fig. 5. *The experimental wall*

Fig. 6. *The experimentation: window shutter, french-window shutter, data acquisition system*

The shutters are with a wood or aluminium frame (Fig. 6). One shutter for french-window is implemented with numerous temperature sensors to study more precisely the thermal behaviour of the the solar collector, for the three other ones, only some measures are realized to calculate energy performances. The meteorological data measured on the experimental wall are:

− the global solar radiations in a horizontal and vertical planes;
− the diffuse radiation on horizontal plane;
− the ambient temperature;
− the air humidity;
− the wind speed and direction for each shutter are measured:
− the output air temperature;
− the output air humidity;
− the air flow;
− the voltage and current for each PV generator;
− the temperature of the absorber;
− the temperature of the extruded polycarbonate cover for the french-window shutter, a lot of temperature sensors have been integrated in the collector (absorber, PV modules, cover) in various positions to follow the temperature evolution in the different parts of the shutter.

Perspectives

After having calibrated the sensors and determined the characteristic curves of the fan, we will be able to realize some experiments:

− experimentation with a constant flow rate (the PV modules will be replaced by a stabilized current generator);
− research of the optimal flow rate for the best performance;
− determination of the thermal response time of the solar shutter;
− measure of the stagnation temperature;
− determination of the repartition of the air flow into the shutter (using an IR camera) and optimization of the repartition (adding some baffles in the air flow);
− estimation of the influence of the double- air flux (one in the sunny side and the other one in the shaded side).

The experimentation will be running in October 2007 and all the tests will be able to begin. In the same time, a thermal modelization of the solar shutter will be realized in view to analyse the behaviour of this new solar collector and to envisage the modifications to implement for a optimization of this solar shutter.

Conclusion

A new concept of solar air collector with a high integration level in the building was presented. The "solar shutter" called "Volet'air®" can be applied not only in new houses but also in old and existing buildings. The technical particularities of this solar shutter are that it works in all positions and it does not use thermal insulation. An experiment has been implemented and the first results concerning its thermal behaviour will be available in some weeks.

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TERRA COTTA BRICKS IN MATTER INSULATING AND LIGHT BY COAL ADDITION IN AN ARGILLACEOUS MASS

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The idea of the passage of a light concrete product to that of a terra cotta product is fixed on the launching of a manufacturing range of brick products satisfying some properties which will be adapted to contemporary construction and the modern architectural tendencies. This is carried out by using a mixture of two types of clays, grey clay and yellow, plus an additing of porogene agent "coal" which, under the effect of the heat of the furnaces of cooking, sublimates, thus creating pores. This adaptation enabled us to develop a "recipe" of manufacture and a judicious design, by considering a method of production more economic and obtaining a material of better quality. The nature of coal depends on its characteristics in volatile matters, calorific value, density etc. The use of coal in the field of ceramics is to be explored. The work concerns four mixtures (M_1; M_2; M_3; M_4) corresponding to the proportions: (50 – 55 – 60 % and 65 %) for the first type of clay. As for the second the values are 30 % and remain constant. The contents of coal corresponding to each mixture are respectively: (20 – 15 – 10 % and 5 %) with granulometry of (0,25 – 0,50 – 1,00 and 1,60 mm). The technical values of the variant M_2, with, a granulometry of 1,60 mm confers mechanical qualities more or less interesting, for example, a mechanical resistance (compression) of the order of 361.6 kgf/cm^2 corresponding to a bulk density of 1.88 g/cm^3. These structural components out of terra cotta light cumulate structural properties and insulating qualities. In addition, this type of materials, by their porosity, contributes to a good quality of the interior air, in particular by an effective hygrometrical regulation. Thus according to a study of the CSTB, a mono alveolar terra cotta wall absorbs a volume of steam 5 times more important than a wall in concrete blocks, without its initial qualities.

Key words: clays coal porous material, resistant insulating

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Introduction

The insulation of the envelope of the building is determining for the management of energy saving and the quality of life of the inhabitants. However certain carcinogenic allergens, pollutant gas emanations, support the development of the micro-organisms. Nowadays certificate ACERM makes it possible to guarantee the isolating capacity and the characteristics from certain traditional insulators (example: wool of sheep, glass, fibres of wood etc…) The answer to a good practice of insulation is to place the good product at the right place such is the research orientation which takes into account a powerful insulation, a sealing of the air controlled and a

well dimensioned ventilation [1]. A mixture of clay to the sawdust or other organic matter is necessary. These substances are consumed during cooking what accentuates the formation of pores. These pores contain confined and mobile air favourable to the insulation [2]. The manufacturers of bricks seek more and more to decrease the thermal conductibility of their products to obtain high thermal resistances and to increase the porosity of the shard [3]. To this list of product, another component could be added. This component with a high capacity of accumulation and restitution could be like heat insulator and acoustic of walls floors or roofs having good air tightness. As porosant element one is interested in an organic component which is coal. This last belongs to the type of sedimentary rock organo-detrital coming from very varied plants (vegetable various, ferns, mushrooms, algae) composed of various fabrics (sheets, stems, barks, resins, pollens, etc). It constitutes a heterogeneous rock containing sufficient carbon to be usable like fuel and others. These principal current uses are: production of electricity in the industrial sectors like the iron and steel industry and the production of vapor without to forget the residential sector what confers to this later to be in use in new light products [4]. The percentage of carbon increases with its age. The denser it is more it burns slowly and more it is more profitable [5]. This work is the complement object study aiming at the sector of ceramic industry or the addition was of vegetable type to knowing: sawdust resulting from the pine of Alep and the Eucalyptus, which provided definitely better characteristics. This reveals that for the same size of particle and a content twice less low, the value of bulk density is lower (produced lighter) and having a value of definitely high mechanical resistance.

Experimental methods

The analyses were carried out on raw materials local (grey clay and yellow clay) and like addition of coal. Initially we determined the natural moisture of each raw material starting from a drying oven of laboratory at the temperature 105 °C of the type: Memmert UL50 (maximum temperature 220 °C with ventilation).
The granulometric analysis was determined by wet process by using a series of sieve of various diameters (& # 1060; = 5; 2; 1; 0.63 and 0.20 mm) and per "pipette of Robinson" by considering the following fractions (1 to 0.063 mm), (0.063 to 0.01 mm), (0.01 to 0.005 mm), (0.005 with 0.001 mm) and those < 0.001 mm.
The chemical analysis was determined by the sequential spectrometer of X-ray of the type SRS 303 Siemens. Water supply: 3V min. Supply air: 2V min.; pressure water: 4 to 8 bars, Pressure air: 4.5 to 10 bars. The principal minerals combined with clays and natures of phases are determined by diffractometer X-ray of the Siemens type "500D" 20 my – 40 kV with X-ray Cu tube. The preparation of the mixtures is carried out starting from 04 types of compositions of masses made up of clays grey, yellow and of coal which are: (M_1 – M_2 – M_3 – M_4) with the respectively following proportions: (50 – 30 – 20 %), (55 – 30 – 15 %), (60 – 30 – 10 %), (65 – 30 – 5 %). The contents of coal are: (5 – 10 – 15 – 20 %) with a diameter of particles which varies: (0.25 – 0.50 – 1.00 and 1.60 mm). The shaping was carried out in a traditional draw bench. The drying of briquettes proceeded in two stages: with the free air during 24 hours then in a drier with room during 24 hours cooking was carried out in a tunnel kiln with the temperature 950 °C. The characterization of the mechanical and physical properties was related to the drying and firing shrinkage, absorption, porosity, the bulk density, the specific mass. The mechanical resistance is given in an apparatus of inflection Type 401 NEZSCH EN100.

Results and discussions

The results of moistures of careers of the matters considered are carried in Table 1.
According to these results, one notes that grey clay contains less moisture than yellow clay this is at the season of its extraction which is probably the summer. As for the second type of clay a drying is necessary before any use to especially avoid the problems of filling of the equipment during its treatment.

Table 1
Values of natural moistures of the raw materials

Types of matters	Grey clay	Yellow clay	Charcoal
Value moisture of career (%)	5.65	15.1	10.85

The results of chemical analysis are carried in Tables 2-3.

Table 2
Chemical analysis of two clays

Principal elements	Contents (%)	
	Grey clay	Yellow clay
SiO_2	48.02	51.28
Al_2O_3	10.63	12.34
Fe_2O_3	4.68	4.76
CaO	13.49	11.39
MgO	1.67	1.48
SO_3	1.23	0.95
K_2O	1.51	1.67
Na_2O	0.61	0.57
Loss in ignition PF	17.34	14.72

According to Table 2, one notes that the two types of clays are joint on the one hand: the rate of Al_2O_3 which in both cases is < 14 % what makes it possible to classify

them in the group of acid clays [6] and in addition the limestone rate lies between 6-20 making it possible to classify them in the group of marly clays and where the products cooks yellow [7].

Table 3 shows well that the chemical element which constitutes coal comes from the carbon which in its turn draws its origin of CO_2 which is released after decomposition from limestone or dolomite. The value in high loss on the ignition confirms the presence of the other volatile elements which are SO_3 and Cl.

Table 3

Chemical analysis of coal

Content of the principal elements combined with coal (%)													
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	MnO	NaO_2	K_2O	P_2O_5	SO_3	CuO	CI	PF	Total
1.44	0.32	0.17	3.70	0.34	0.014	< 0.05	0.29	0.035	0.05	0.0059	0.06	93.50	100

The elements playing the part of energy fluxes (K_2O, Na_2O) have a rate slightly more raised concerning yellow clay, which confers better properties of cooking to him. The principal elements which make distinguish these two clays are first of all the rate of SiO_2 which is higher in yellow clay this makes it possible to say than this type of clay is sandier and plays consequently the part of grease-remover. It is also noticed that the rate of CaO, SO_3 is higher in the case of grey clay what is in exact correlation with the rate raised in loss on the ignition.

According to the results of the mineralogical analysis (Table 4) the nimble yellow is of type illite/ montmorillonite and grey clay is of type Illite/Kaolinite /chlorite.

The grain size analysis of the two types of clays is illustrated in Tables 5 and 6. According to Table 5 one notes that grey clay contains much more argillaceous particles than yellow clay this is in correlation with the data of Table 1.

According to Table 6 one observes that the rate of refusal of yellow clay is weaker than that of grey clay. In addition yellow clay is made up much more small particles probably with the mineral montmorillonite which is associated clay and which is in correlation with the results of Table 4.

Table 4

Mineralogical analysis of clays

Principal minerals	Contents (%)	
	Grey clay	Yellow clay
Quartz	32	27.5
Calcite	21	18
Dolomite	3	2
Feldspar: potassic	1	1
Feldspar: sodic, calcic	2.5	2.5
Semi gypsum hydrate	2	2
Ferriguneux minerals	4.5	4.5
Illite	13.5	15
Kaolinite / chlorite	12	13.5
Montmorillonite	8.5	14

Table 5

Granulometric analysis of clays "Pipette of Robinson"

Type of clay contents (%)	Dimensions of the particles (mm)				
	1 to 0.063	0.063 to 0.01	0.01 to 0.005	0.005 to 0.001	< 0.001
Grey clay	14.65	30.99	13.20	11.00	30.16
Yellow clay	12.40	25.28	13.28	22.72	26.32

Table 6

Granulometric analysis of clays "Wet process"

Type of clay contents (%)	Mesh sizes of sieve (mm)				
	5.00	2.00	1.00	0.63	0.20
Grey clay	0.00	0.00	0.03	0.03	0.10
Yellow clay	0.00	0.00	0.00	0.1	0.03

While referring to the granulometric classification of the grounds one notes that grey clay known as consists of "fine sand" and yellow clay is of character "silt" [2]. Histogram below Fig. 1 shows the variation of the moisture of shaping of the various mixtures according to the addition of coal and its granulometry.

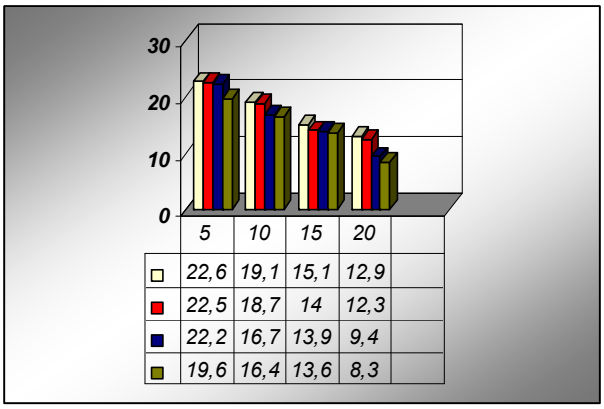

Fig. 1. *Variation of the moisture of shaping according to the addition of coal and its granulometry*

Coal tends to play the part of a grease-remover. For each addition one notes a reduction in the moisture of the argillaceous mixture according to the increase in the content and the size of this last. Starting from a content of 10% and a size of particles of 0.50 mm the capacity binding becomes weak. For this same size of particles and a content of coal of 20 %, the quantity of water for the shaping reaches the value of that used to moisten powders intended for pressing. This type of alternatives (proportions of mixtures) are allotted low mechanical resistances.

The drying shrinkage varies same manner as moisture of shaping. The corresponding values are definitely higher than the normal for the sizes of particles (0.25 – 0.50 – 1.00 mm) and a coal rate of 5 %. The recorded values are respectively: (9.00 – 8.70 and 8.50 %). This last reaches the values wished starting from the size of 1.60 mm for the coal rates higher than 5 % the recorded values enter the fork of the standards. The values higher than 8 % pose problems of production. It is conceived that the gradients of moisture during drying through the product will generate displacements during first phases of drying and thus of the constraints prejudicial to the quality of the products [3]. The variations of firing shrinkage are proportional to the size and the coal content. For a size of particles of 1.60 mm, the values corresponding to (5 – 10 – 15 and 20 %) are respectively 0.67 – 0.91 – 1.50 and 2.00 %. High values are due to the CO_2 outburst and the other volatile substances such as SO_3, Cl as indicates it Table 2 of the chemical analysis. These reactions are accompanied by a rearrangement by the particles and an orientation ordered in the crystal lattice which leads to a texture consolidated compared to the initial state followed by a contraction "shrinkage" [8-9].

The comparative results for the coal of contents 5 and 10 % for sizes of particles of 0.50 and 1.60 mm (Table 7), let us to suppose that the value of moisture 16.40 % will be regarded as the quantity of water necessary to provide a mass witch can be worked by holding account in parallel of the natural water contained in coal. Consequently it should be stressed that the element responsible for the great drying shrinkage (see Table 7) is with the quantity of high water of shaping which one associates the natural water of coal. This fact the threshold of plasticity is exceeded involving a rise of shrinkage.

Table 7

Comparative results of the physical and mechanical characteristics of the products obtained with content of coal 5 and 10% and sizes of particles of 0.50 and 1.60 %

Content of coal 5 %											
H_f, (%)	**Drying shrinkage (%)**	**Firing shrinkage (%)**	**Abs (%)**	**Apparent porosity (%)**	**Sealed porosity (%)**	**Total porosity (%)**	**M_v g/cm^3**	**M_s g/cm^3**	**R_{Flex} kf/cm^2**	**R_{Comp} kf/cm^2**	**Φ (mm)**
22.50	8.70	0.30	2.90	6.20	5.30	10.50	2.14	1.92	154.0	616.00	**0.50**
19.60	8.00	0.67	5.20	10.70	7.01	71.17	2.06	1.75	145.4	581.6	**1.60**
Content of coal 10 %											
H_f (%)	**Drying shrinkage (%)**	**Firing shrinkage (%)**	**Abs (%)**	**Apparent porosity (%)**	**Sealed porosity (%)**	**Total porosity (%)**	**M_v g/cm^3**	**M_s g/cm^3**	**R_{Flex} kf/cm^2**	**R_{Comp} kf/cm^2**	**Φ (mm)**
18.70	7.20	0.80	7.60	15.00	10.30	25.30	1.98	1.52	121.6	486.4	**0.50**
16.40	6.70	0.91	940	17.70	11.90	29.60	1.88	1.45	90.4	361.6	**1.60**

Legend: **H_f** – Moisture, **Abs** – Absorption, **M_s** – Specific mass, **R_{Flex}** – Bending strength, **Φ** – Diameter, **M_v** – Bulk density, **R_{Comp}** – Compressive strength.

Table 8

Variation of the characteristics of the various mixtures according to diameters of particles (1.60 mm) and the content (10 %) of coal optimized

Characteristics (%) Coal	Diameter of the coal particles (1.60 mm)										
	H_f (%)	Drying shrinkage (%)	Firing shrinkage (%)	Abs (%)	Apparent porosity (%)	Sealed porosity (%)	Total porosity (%)	M_v g/cm^3	M_s g/cm^3	R_{Flex} kf/cm^2	R_{Comp} kf/cm^2
5	19.60	8.00	0.67	5.20	10.70	7.01	17.71	2.06	1.75	145.4	581.6
10	**16.40**	**6.70**	**0.91**	**9.40**	**17.70**	**11.90**	**29.60**	**1.88**	**1.45**	**90.4**	**361.6**
15	13.90	5.70	1.50	12.4	22.00	13.80	35.80	1.78	1.31	64.7	258.8
20	8.30	4.20	2.00	19.8	30.50	17.00	48.60	1.59	1.07	39.4	157.6

In addition by always considering the values indicated in Table 7 and that of the histogram we observe that the bulk densities and the specific masses decrease according to the increase in the content of coal and the size of its particles. As for the values of porosities, these last are in correlation with those of absorption. To the values of porosities and high absorptions correspond of low resistances. The properties sought in this study are to have a product equipped with a low bulk density a high porosity and better a mechanical resistance. The optimized physical parameters (Table 8) making it possible to gather these three properties those are taken into account in the mixture M_2 with a size of coal particles of 1.60 mm.

Conclusion

For the moment the ceramic industries have an increasing look on insulating and light products.

A former study to this research was the subject of a project on the development of this type of material by incorporating different sawdust of two woods as porogene and insulating agent.

The products obtained showed desired characteristics.

Thus our objective is fixed on the use of another type of addition which is coal.

This later has always been used in the production of electricity, the residential sectors, iron and steel industrial sector, production of vapour.

Its adding with the sizes of particles which vary of 0.25 – 0.50 – 1.00 and 1.60 mm and of the contents of 5 – 10 – 15 and 20 % in four types of argillaceous mixtures give a range of products having different characteristics.

A low content of addition with low size of particle gives great drying shrinkage thus making drying delicate. Higher contents gave a rather weak capacity binding.

A comparative study and of optimization enters the various mixtures enabled us to deduce that the mixture answering the required criteria provided a bulk density of M_v = 1.88 g/cm^3 and correspondent with a value of bending strength of R_{flex} = 361.6 kf/cm^2.

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A MAXIMUM POWER POINT TRACKING FUZZY LOGIC CONTROLLER FOR PHOTOVOLTAIC PUMPING SYSTEM

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In this paper, the fuzzy controller is used to track the maximum power point (MPP) for a photovoltaic pumping system. For the best use, the photovoltaic (PV) panel must operate at its maximum power point (MPP). The PV panel efficiency, for given conditions, is maximal when its voltage equals a certain value that is optimal voltage which depends on irradiation, temperature and panel state. The pumping system considered in this paper consists of a photovoltaic generator (PVG) with a power electronic converter allowing maximum power point tracking (MPPT), the whole is feeding a DC motor coupling with a centrifugal pump. In the presence of the temperature and irradiation variations, the duty cycle of the converter, which is chosen as the controller law, is adjusted by using fuzzy logic controller (FLC) to track the MPP. The used FLC, incorporates expert knowledge, and doesn't depend on system mathematical model accurate. The effectiveness of the proposed approach is investigated by simulation at different operating conditions in Matlab/Simulink environment.

Keywords: photovoltaic pumping system, DC/DC converter, fuzzy logic controller, maximum power point tracking

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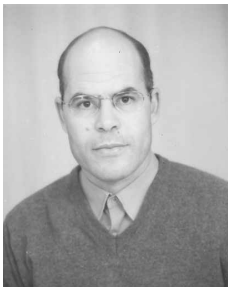

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Introduction

It is well established that energy production and use based on consumption of fossil fuels can have deleterious environmental and human health impacts, including the potential of global warming of the earth through changes in the atmosphere's concentration of carbon dioxide. The worldwide conventional energy sources are rapidly depleting. The increasing of the world energy demand, due to modern industrial society and population growth, is motivating a lot of investments in renewable energy source such as photovoltaic (PV) power, since it is clean, pollution-free and inexhaustible. One of the most popular applications of the photovoltaic

energy utilization is the water pumping system driven by electrical motors. A PV array is a non-linear power source. There is a unique point on the curve (Power-Voltage), called the maximum power point (MPP), at which the PV array produces maximum output power and its voltage equals a certain value that is the optimal voltage. As it is well known, the MPP of a PV power generation system depends on array temperature, solar irradiation, and PV cells ageing, so it is necessary to constantly track the MPP [1, 2, 3] of the solar array. A switch-mode power converter, called a maximum power point tracker, can be used to maintain the PV array's operating point at the MPP. The pumping system considered in this paper consists of a photovoltaic generator (PVG) with a power electronic converter allowing maximum power point tracking (MPPT), the whole is feeding a DC motor coupling with a centrifugal pump. Instead of maximizing the PV power, we will maximize the pump power, i.e. his rotation speed.

For years, research has focused on various MPP control algorithms to track the maximum power of the PV array. These techniques include methods using neural networks [4, 5], perturbation and observation (P&O) methods [6, 7], incremental conductance [8], slide control method [1, 9] and computational methods. One of the computational methods which have demonstrated fine performances under different environmental operating conditions is the fuzzy based MPPT technique [3, 10, 11]. In recent years, fuzzy logic control has been widely used for industrial processes owing to their heuristic nature associated with simplicity and effectiveness for booth linear and non-linear systems. However, in a number of cases, such as those, when parameter variations take place, or when disturbances are present, or when there is no simple mathematical model, fuzzy logic based control systems have shown superior performance to those obtained by conventional control algorithms. The main advantages of fuzzy logic controllers over the conventional controllers are: they do not need accurate mathematical model, they can work with imprecise inputs, they can handle nonlinearity and they are more robust than conventional nonlinear controllers. The aim of this paper is to present a fuzzy control of the duty cycle of the boost converter, that is considered as the control law of the system, to track the maximum rotation speed of the pump for different operating conditions. The paper is organized as follows: in section 2 mathematical model of the photovoltaic pumping system is given. In section 3, the structure configuration of the fuzzy logic controller applied of the system is presented. Section 4 presents the simulation results and a conclusion is given at the end of the paper.

Description of the photovoltaic pumping system

A photovoltaic water pumping system is mainly composed by a PV generator, a power electronic converter as a control organ, and an electrical motor usually coupled to a centrifugal pump. The schematic diagram of the proposed system is shown in Fig. 1. It consists of a photovoltaic generator (PVG), a DC/DC boost converter and DC motor with a constant magnetic flux driving a centrifugal pump.

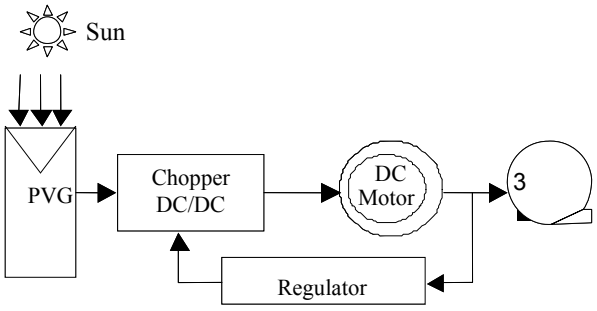

Fig. 1. *General diagram of the photovoltaic pumping system*

Photovoltaic generator model

The solar cell is a non-linear power source, the output current and voltage depend on the irradiation level and temperature. The equivalent circuit of a PV module is shown in Fig. 2. The solar cell modules can only provide maximum power at specific voltage and current levels. So, for the PV array, there is a unique point on its $P - V_p$ curve at which the power is maximum, and for optimum utilization, the equilibrium operating point of the PV array should coincide with this point.

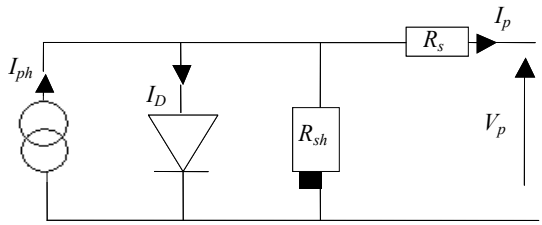

Fig. 2. *PV module equivalent circuit*

The characteristic equation $V_p - I_p$ of a PV module is given by the following equation:

$$I_p = I_{ph} - I_0\left(\exp\left[A\left(V_p + R_s I_p\right)\right] - 1\right) - \frac{V_p + R_s I_p}{R_{sh}} \quad (1)$$

$$\text{with } I_0 = I_{0r} - I_0\left(\frac{T}{T_r}\right)^3 \exp\left[\frac{qE_{GO}}{K\gamma}\left(\frac{1}{T_r} - \frac{1}{T}\right)\right],$$

$$I_{ph} = \left[I_{SCR} + K_I\left(T - T_r\right)\right]\frac{\lambda}{1000} \text{ and } A = \frac{q}{N\gamma KT},$$

where I_{ph} – photocurrent, I_0 – cell reverse saturation current, I_{0r} – cell saturation current at T_r, I_{SCR} – short circuit current at 298.15 K and 1 kW/m^2, K_I – short circuit current temperature coefficient at I_{SCR}, λ – solar irradiation in W/m^2, E_{GO} – band gap for silicon, γ – ideality factor, T_r – reference temperature, T – cell temperature, K – Boltzmann's constant and q – electron charge.

The PVG is composed of many strings of PV module in series, connected in parallel, in order to provide the desired values of input voltage and current of DC motor

system. This PVG exhibits a non-linear $I_g - V_g$ characteristic given, by the following equation.

$$I_g = I_{phg} - I_0\left(\exp\left[A\left(V_g + R_{sg}I_g\right)\right] - 1\right) - \frac{V_g + R_{sg}I_g}{R_{shg}}, \quad (2)$$

where V_g – the PVG output voltage, I_g – the PVG output current, $A_g = A/N_s$ – the PVG constant, $R_{sg} = (N_s/N_p)\ R_s$ – the PVG series resistance, $R_{shg} = (N_s/N_p)$, R_{sh} – the PVG parallel resistance, $I_{phg} = N_pI_{ph}$ – the photocurrent of the PVG, $I_{0g} = N_pI_0$ – the saturation current of the PVG, N_s – the number of PV connected in series and N_p – the number of parallel paths. Both N_s and N_p are designed carefully to have the amount of energy required by the motor pump.
The variation of the output $V_g - P_g$ characteristic of the PVG generator as function of irradiation and temperature is shown in Fig. 3 and Fig. 4 respectively, where $P_g = V_gI_g$ is the PVG power.

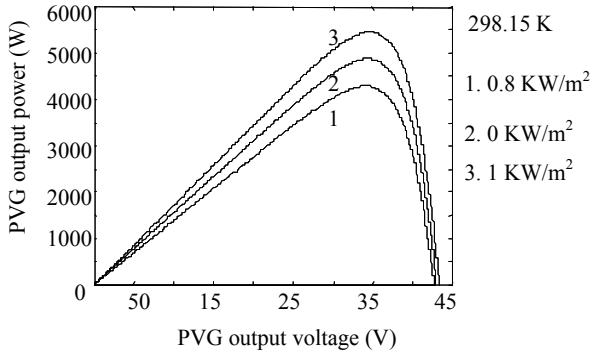

Fig. 3. *Characteristic of the PVG with constant temperature and varying irradiation*

From these figures, at any value of irradiation and temperature, there is only one point at which P_g is maximal. This point is called the MPP. Due to the relatively high cost of the PVGs, it recommended to operate at this MPP at all values of irradiation and temperature to increase the efficiency of the system.

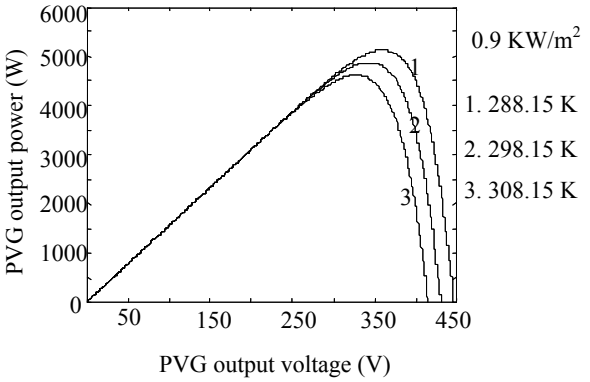

Fig. 4. *Characteristic of the PVG with constant irradiation and varying temperature*

Power electronic converter

In order to improve the performance of a photovoltaic pumping system, a controlled DC–DC converter known as a maximum power point tracker is used to match continuously the output characteristics of a PVG to the input characteristics of a DC motor. The power electronic converter is a boost chopper (Fig. 5) inserted between the PVG generator and the motor with a variable duty cycle α. The output voltage of the PVG is fed to the boost converter. It has to be adjusted to the optimum value by adjusting the duty ratio to the required value. The main function of the converter is to adjust the PVG output voltage to a value in which the PVG transfers maximum energy to the motor. The duty ratio of the boost converter is adjusted with the help of a fuzzy logic controller (FLC).

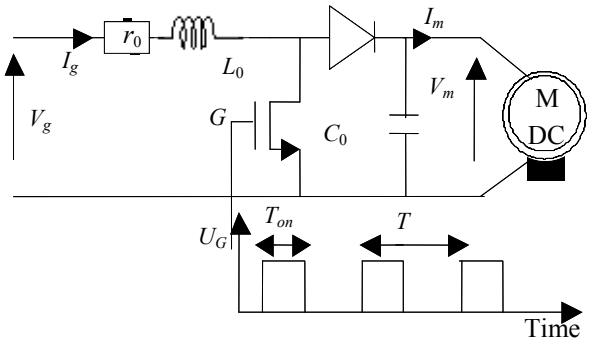

Fig. 5. *Boost chopper*

If the chopping frequency is sufficiently higher than the system characteristic frequencies, we can replace the converter with an equivalent continuous model. By considering the mean values of the electric quantities over a chopping period, the state equations of the converter are:

$$I_m = (1-\alpha)I_g - C_0\frac{dV_m}{dt}, \quad (3)$$

$$V_g = (1-\alpha)V_m + L_0\frac{dI_g}{dt} + r_0I_g + \alpha R_{DS}I_g, \quad (4)$$

where L_0 – the inductor of the converter, C_0 – the output capacitor of the converter, r_0 – the inductor equivalent resistance, and R_{DS} – the *MOSFET* resistance *ON*.
The inductor value, L_0, required such the converter operates in the continuous conduction mode is calculated such that the peak inductor current at maximum input power does not exceed the power switch current rating. So L_0 is calculated as: $L_0 \geq V_g\frac{\alpha_m}{f_s|\Delta I|}$. The output capacitor value calculated to give the desired peak-to-peak output voltage ripple is: $C_0 \geq \frac{I_m}{\Delta V_c}\frac{\alpha_m}{f_s}$, where f_s – the switching frequency, ΔI – the maximum input current ripple, ΔV_C – the maximum output voltage ripple and α_m – the duty cycle at maximum converter input power.

Electrical motor modeling

We consider a DC motor with a constant magnetic flux and we neglect the magnetic reaction and the commutation phenomena. The choice of a DC motor for

a PV powered system is economical because PV arrays supply DC power. Also, photovoltaic modules produce direct current, so using DC motors eliminates the need for AC/DC power converters. The mathematical relation that describes the dynamic model of a DC motor with constant magnetic flux can be expressed as follows:

$$V_m = RI_m + L\frac{dI_m}{dt} + E_c \qquad (5)$$

with $E_c = K_e\Omega$.
The motor torque is:

$$C_m = K_m I_m . \qquad (6)$$

The parameters of the DC motor are: K_e – the back emf constant, K_m – the torque constant, L – the armature inductance, R – the armature resistance and Ω – the rotation speed.

Centrifugal pump model

For PV water pumping systems, two types of pumps are widely used: the volumetric pump and the centrifugal pump. It is found in the case of the centrifugal pumps, the operation takes place for longer periods even for low irradiation levels, and the load characteristic is in closer proximity to the PVG maximum power locus [12]. The centrifugal pump opposes to the motor a resistant torque C_r that is given by the following equation [13]:

$$C_m - C_r = K_r\Omega^2 , \qquad (7)$$

where K_r – the proportionality coefficient.
The mechanical equation of the system is given by:

$$C_m - C_r = J\frac{d\Omega}{dt} , \qquad (8)$$

where J – the group inertia.

Fuzzy logic controller structure and design

The fuzzy logic permits to define control laws of any process starting from a linguistic description of the control strategy to be adopted. Fuzzy logic uses instead of numerical variables linguistic a variables whose values (fuzzy subsets) are labels or sentences in a natural or artificial language.

Fuzzy logic controller structure

In a typical basic configuration of a fuzzy logic controller (FLC) one can find:
– Fuzzification or linguistic coding of input variables, which transforms a given set of numerical inputs (measured or calculated) into a fuzzy linguistic variables set composed of fuzzy subset called also membership functions.
– Inference fuzzy rules which contains a set of fuzzy rules in linguistic form as well as the database which is a collection of expert control objectives. This control rules base can be set up using IF-THEN rules, based on expert experience and/or engineering knowledge, and learning rule-based system which has learning capabilities.
– Defuzzification of the inference engine, which evaluates the rules based on a set of control actions for a given fuzzy inputs set. This operation converts the inferred fuzzy control action into a numerical value at the output by forming the "union" of the outputs resulting from each rule. The deffuzification produces a non-fuzzy output control action that best represents the recommended control actions of the different rules.

Fuzzy logic control design

The typical power-voltage characteristic of photovoltaic generator is shown in Fig. 3 and Fig. 4. The MPP is reached when the PVG output voltage V_g for given conditions equals its optimal value V_{op}. One has also $P_u = K_r\Omega^3$ the centrifugal pump power that must be maximum. Then at the MPP the rotation speed is maximum. The boost converter with an adjusted duty cycle permits the maximization of the rotation speed by an online adaptation of the PVG output voltage to steer in finite time at its optimal value. The duty cycle α of the converter, which is chosen as controller law is adjusted by using fuzzy logic controller (FLC), is proposed to keep the rotation speed at its maximum according to the solar irradiation (λ) and the temperature (T) variations. Fig. 6 shows the block diagram of this fuzzy controller.

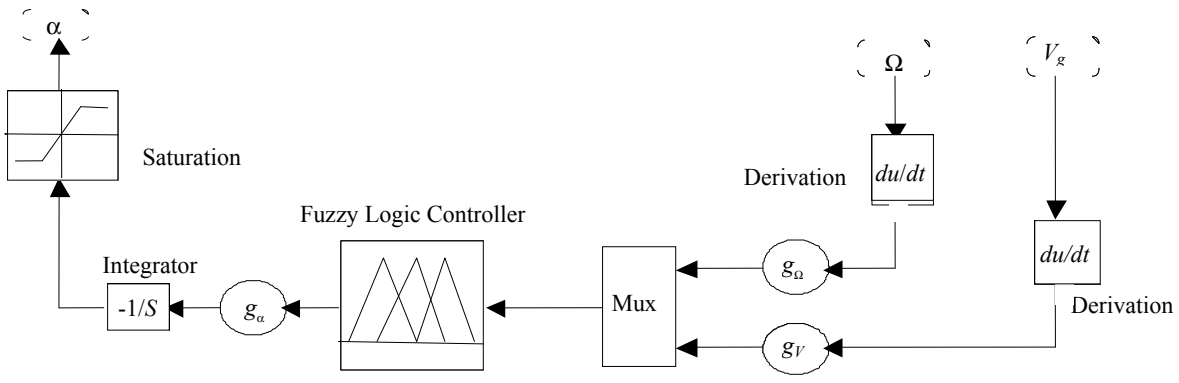

Fig. 6. *Synoptic scheme of the proposed fuzzy controller*

The two input control variables of this fuzzy controller are the rotation speed variation $d\Omega$ and the PVG output voltage variation dV_g; $d\Omega$ and dV_g are normalized using the two input scaling factors g_Ω and g_v. The output of the controller is the duty cycle variation $d\alpha$ that is normalized by scaling factor g_α.

In the fuzzification process the numerical variable is converted into a linguistic variable or subset. The following five fuzzy levels are chosen for the controlling inputs and output of the fuzzy controller ($d\Omega$, dV_g and $d\alpha$) in fuzzification {NB (Negative Big), NS (Negative Small), ZE (Zero), PS (Positive Small) and PB (Positive Big)}. Membership functions for both controller inputs and output variables are defined on the common normalized range of [-1, 1]. In this paper, asymmetric triangular membership functions are considered and their representation is shown in Fig. 7.

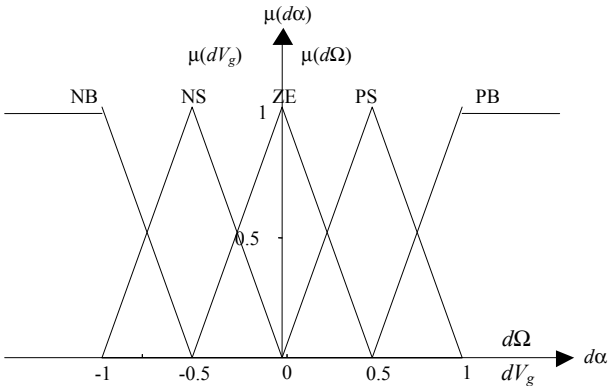

Fig. 7. *Membership functions of dV_g, $d\Omega$ and $d\alpha$*

The generated rules should be done properly and arranged in a fuzzy matrix table. Twenty five rules have been deduced from a qualitative analysis of the influence of the rotation speed variation $d\Omega$ and the PVG output voltage variation dV_g which are given in Table 1. This rule table can reflect experiences of the human experts basis of Fig. 8. The fuzzy rules are designed to incorporate the following considerations keeping in view overall tracking performance.

1 – If a negative variation of the rotation speed is accompanied with a negative variation of PVG output voltage and vice versa, then we would decrease the duty cycle.

2 – If the variation of the rotation speed is sufficiently close to zero which means that its maximum is reached, then we would not make any variation in the duty cycle.

3 – If a positive variation of the rotation speed is going with a negative variation of PVG output voltage and vice versa, then we would increase the duty cycle.

During the inference process, the product-sum inference mechanism is used to calculate the fuzzy output of the controller. This is achieved by forming the union of the fuzzy output resulting from each rule, which is the corresponding output membership function weighted by the rule strength. The gravity center deffuzification method is used to convert the fuzzy output of the fuzzy controller into a numerical value. In this case, the change of the controller output is computed by the following equation:

$$d\alpha = \frac{\sum \mu_i y_i S_i}{\sum \mu_i S_i}$$

with $(1 \le i \le 25)$,

where μ_i – represents the ith rule degree of the fulfillment at the kth sampling period, y_i – the gravity center abscissa of the output fuzzy membership function corresponding to the ith rule and S_i – its surface.

The final control signal sent to the system is: $\alpha(K) = \alpha(K\text{-}1) + g_\alpha\, d\alpha\, (K\text{-}1)$.

Table 1

Rule base of fuzzy logic controller

Change of PVG output voltage (dV_g)	Change of the rotation speed ($d\Omega$)				
	NB	**NS**	**EZ**	**PS**	**PB**
NB	NB	NB	EZ	PB	PB
NS	NB	NS	EZ	PS	PS
EZ	PS	PS	EZ	PS	PS
PS	PB	PS	EZ	NS	NB
PB	PB	PB	EZ	NB	NB

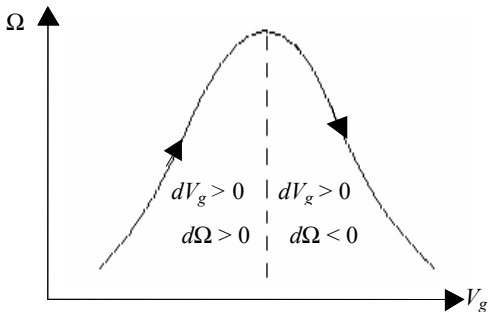

Fig. 8. *Fuzzy rules deduction from versus V_g function*

Simulation results

For the simulation we consider the parameters of the system:

– The photovoltaic panel SM55:

$R_s = 0.1124\ \Omega$, $R_{sh} = 6500\ \Omega$, $\gamma = 1.7404$, $I_{SCR} = 3.45$ A, $I_{0r} = 4.842\ \mu$A, $K_I = 4 \cdot 10^{-4}$ A/K, $N = 36$, $N_s = 20$, $N_p = 5$ and $T_r = 298.15$ K.

– *DC* motor: ABB DMI 180B: $V_{mn} = 400$ V, $I_{mn} = 12.2$ A, $\Omega_n = 104.7$ rad/s, $R = 9.84$ W, $L = 0.12$ H, $J = 0.06$ Kg m^2.

– Chopper parameters: $L_0 = 3.5$ mH, $C_0 = 4.7$ mF, $r_0 = 60\ \text{m}\Omega$, $R_{DS} = 85\ \text{m}\Omega$.

– Centrifugal pump parameter: $K_r = 28 \cdot 10^{-4}$ W (s/rad)^3, $\Omega n = 104.7$ rad/s.

– Fuzzy logic controller parameters: $g_\Omega = 10^{-4}$, $g_v = 7 \cdot 10^{-4}$, $g_\alpha = 1.2$.

Fig. 9, 10, Fig. 11, 12 and Fig. 13, 14 show respectively the good concordance between the rotation speed Ω, the PVG power P_g and the duty cycle control α with the theoretical results when the irradiation and the temperature increase (decrease) (Table 2).

It is noted that when the irradiation and temperature vary, the duty cycle control is judiciously adjusted to its optimal value. Consequently the rotation speed converge to their optimal values which is corresponding to maximum power.

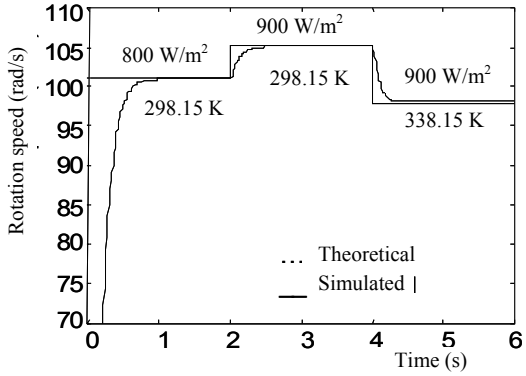

Fig. 9. *Rotation speed with increasing irradiation and temperature*

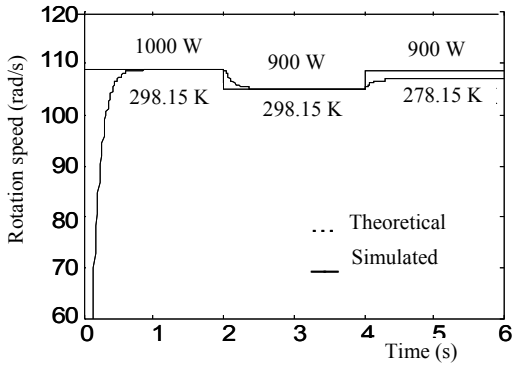

Fig. 10. *Rotation speed with decreasing irradiation and temperature*

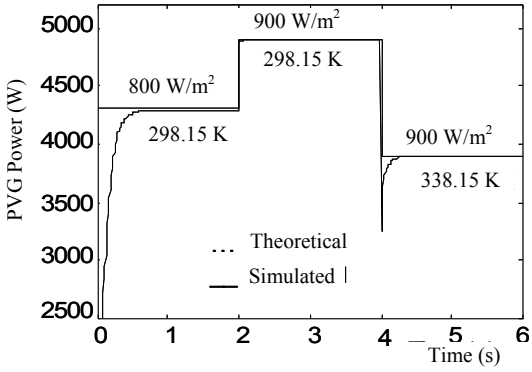

Fig. 11. *PVG power with increasing irradiation and temperature*

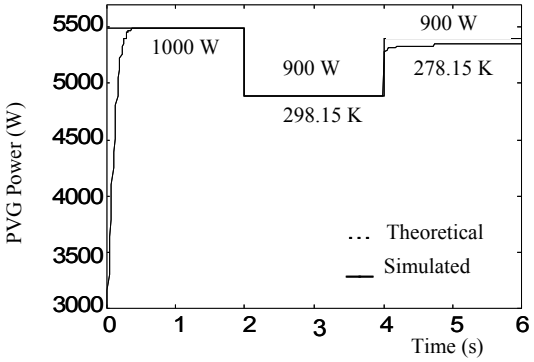

Fig. 12. *PVG power with decreasing irradiation and temperature*

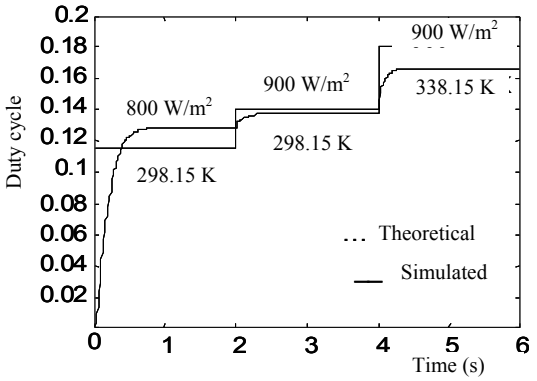

Fig. 13. *Duty cycle with increasing irradiation and temperature*

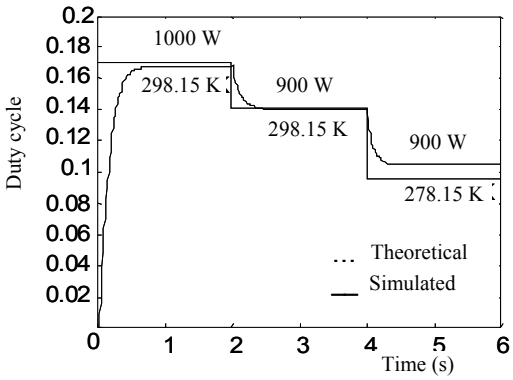

Fig. 14. *Duty cycle with decreasing irradiation and temperature*

Table 2

Theoretical results for given irradiation and temperature

Irradiation λ and temperature *T*	PVG Power Pg (W)	Rotation speed Ω (rad/s)	Duty cycle α
λ = 800 W/m^2 *T* = 298.15 K	4313	101.1	0.1039
λ = 900 W/m^2 *T* = 278.15 K	5409	108.3	0.0964
λ = 900 W/m^2 *T* = 298.15 K	4897	105.1	0.1405
λ = 900 W/m^2 *T* = 338.15 K	3384	97.94	0.1830
λ = 1000 W/m^2 *T* = 298.15 K	5484	108.8	0.1720

Conclusion

In this paper, a fuzzy logic controller is derived and applied to a photovoltaic pumping system in order to track the optimal operating point. The system is consisting of a photovoltaic generator with a power electronic converter that assure maximum power point tracking (MPPT). The converter feed a DC motor coupling with a centrifugal pump. The PV generator is forced to operate at its maximum power point by using fuzzy logic controller that adjusts the duty cycle of the converter to control the motor rotation speed to reach its maximum value. The drive system performance has been simulated at different solar irradiations and temperatures. The simulation shows that the use of the proposed controller gives good results for the maximum power tracking.

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OPTIMIZING THE INTEGRATE OUTPUT OF A WIND ELECTRIC WATER PUMPING SYSTEM

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In this work we are interested in a theoretical analysis of wind electric water pumping system of 1.5 kw and its use to meet the domestic needs for water and irrigation in the arid regions. The monthly flow could be obtained by this system in the area of Adrar is estimated for various heights of the tower and various total heads. The performances of the system depend on several parameters especially of the type of pumps installed. Thus, the use of four pumps of 5, 10, 15 and 19 stages is considered.

Keywords: electric pumping, wind speed, total head, flow rate, centrifugal pump

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Introduction

Water is the primary source of life for mankind and one of the most basic necessities for rural development. The rural demand for water for crop irrigation and domestic water supplies is increasing. At the same time, rainfall is decreasing in many arid countries, so surface water is becoming scarce. Groundwater seems to be the only alternative to this dilemma, but the groundwater table is also decreasing, which makes traditional hand pumping and bucketing difficult. As these trends continue, mechanized water pumping will become the only reliable alternative for lifting water from the ground. Diesel, gasoline, and kerosene pumps (including windmills) have traditionally been used to pump water. However, reliable solar (photovoltaic [PV]) and wind turbine pumps are now emerging on the market and are rapidly becoming more attractive than the traditional power sources. These technologies, powered by renewable energy sources (solar and wind), are especially useful in remote locations where a steady fuel supply is problematic and skilled maintenance personnel are scarce. Although traditional windmills have been used to pump water for centuries, small wind turbines are especially appealing because they

can be located further from the borehole, where the wind is strongest. Because these turbines can directly produce alternating current (AC) power, they lend themselves to applications such as lighting and other infrastructure services when water does not need to be pumped. In this work, a wind pumping system of 1.5 kW nominal output is presented. The performances of this turbine coupled with various pumps are given in [1, 2], in the form of the flow rate variation according to the wind speed for various total heads, these data are used with those of the wind atlas of Algeria. The monthly flows rate which can be obtained with pumps of various stages and for various depths of well are estimated for the site of Adrar; this enables us to determine for each total head the type of pump which is appropriate best.

Estimation of the flow rate

The annual average power provided by an aerogenerator is given in the following form:

$$\overline{P} = \int_0^{\infty} P(V) \cdot f(V) \cdot dV. \qquad (1)$$

The variation of the provided useful output is expressed with the assistance of the system of equations according to, also called quadratic law (2, 3):

$$P(V) = \begin{cases} 0 & si V \langle V_d \\ \alpha + \beta V + \gamma V^2 & si V_d \langle V \langle V_x \\ P_x & si V_x \langle V \langle V_c \\ 0 & si V \rangle V_c \end{cases} \qquad (2)$$

With

$$f(V) = \left(\frac{k}{C}\right) \cdot \left(\frac{V}{C}\right)^{k-1} \cdot \exp\left[-\left(\frac{V}{C}\right)\right]^k. \qquad (3)$$

After having calculated the power, the flow rate is given by the following form (4):

$$Q = \frac{\eta \cdot \overline{P}}{p_c \cdot g H_m}. \qquad (4)$$

Another approach for evaluating the flow rate without passing by the calculation of the power provided by the wind turbine rests on the following relation (4, 5):

$$Q(\nu) = \int_{\nu_d}^{\nu_c} q(\nu) \cdot f(\nu)\, d\nu, \qquad (5)$$

$q(\nu)$: curves expressing the variation of the flow of the used pump according to the speed of the wind.

Results and interpretations

The principal characteristics of the wind turbine chosen in our study are summarized on the following Table 1 [3].

Table 1

Principal characteristics of the wind turbine Bergey 1500

Constructor	Power output (watts)	Number of blades	Speeds (m/s)
Bergey (USA)	1500	3	$V_d = 3.6$ $V_n = 10$ $V_c = 20$

Fig. 1-4 represent the variation of the flow according to the speed of the wind which would provide this wind turbine coupled with a pump of 7, 10, 15 and 19 stages respectively. These pumps are immersed multicellular and of grundfos mark.

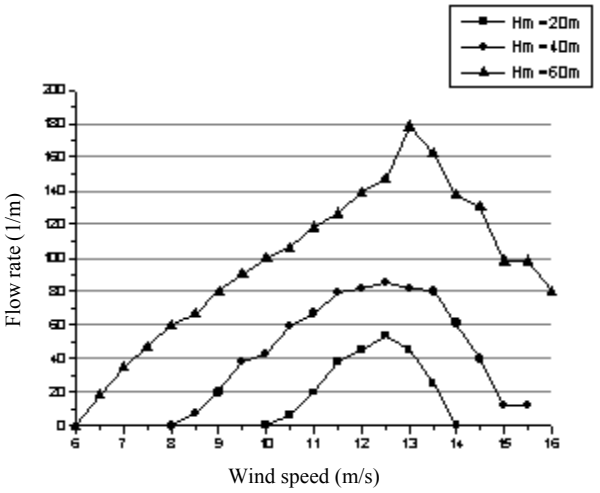

Fig. 1. *Characteristics of a pump of 7 stages coupled with wind turbine Bergey 1500 W*

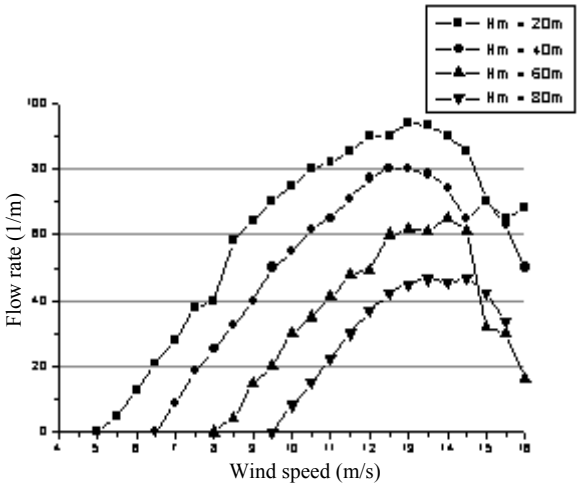

Fig. 2. *Characteristics of a pump of 10 stages coupled with wind turbine Bergey 1500 W*

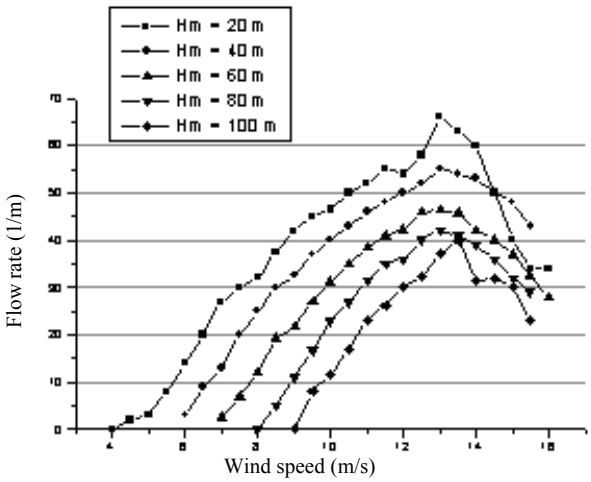

Fig. 3. *Characteristics of a pump of 15 stages coupled with wind turbine Bergey 1500 W*

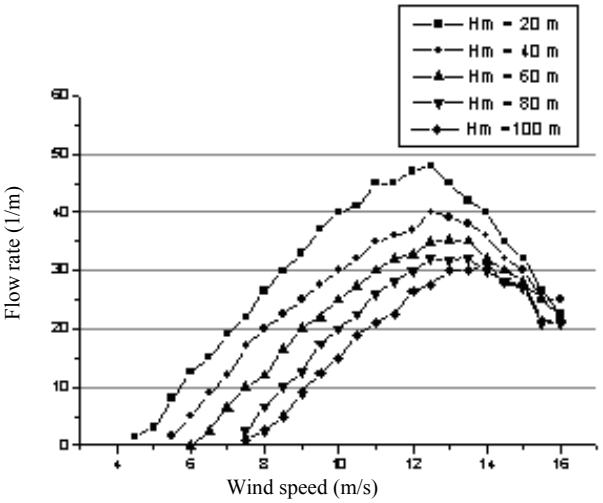

Fig. 4. *Characteristics of a pump of 19 stages coupled with wind turbine Bergey 1500 W*

Estimation of the flow rate in the site of Adrar in Algeria

A study of the wind potential available in the site of Adrar is necessary, is based on the Atlas wind of Algeria established by the ONM (National office of Meteorology).

The wind average annual speed and the annual parameter *K* have as respective values of 5.9 m/s and 2.15 m/s. The evolution of the monthly mean wind speed on the site of Adrar is presented in Fig. 5.

The examination of the curves (Fig. 6) enables us to recognize a relationship between the water flow pumped and the total head on the one hand and the height of the tower of another share. Indeed, the volume of daily water pumped varies according to the height of the pylon and the depth of the well. As an example, installed on a tower of 15 and 30 meters height, this turbine can provide on average 35.75 and 42.30 m^3/d respectively in Adrar, and this for a total head of 70 meters. For a total head of 20 meters, the medium flow provided by this wind turbine is more significant, it is about 125.13 and 148.06 m^3/d with 15 and 30 meters respectively. In Tindouf, having the same heights of the pylon, the flow is respectively 30.57 and 36.58 m^3/d for a total head of 70 meters and 107.00 and 128.05 m^3/d for a height of 20 m, which enables us to deduce what follows:

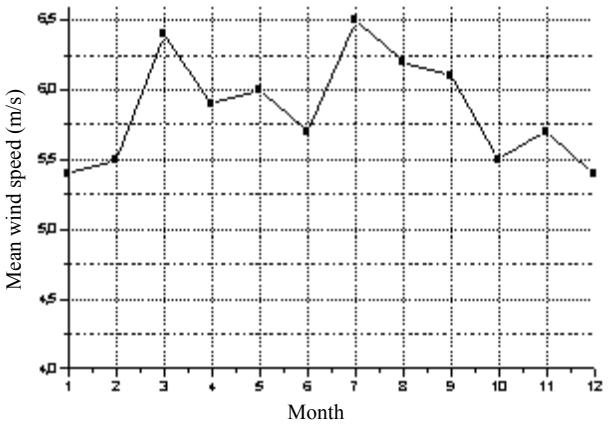

Fig. 5. *Evolution of the monthly mean wind speed in Adrar*

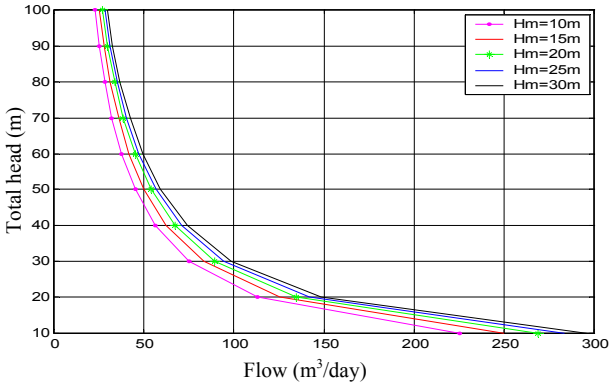

Fig. 6. *Variation of the mean flow rate provided with the total head for various heights of the tower on the site of Adrar (Bergey 1500 W)*

– The mean flow rate proves more significant when the height of the tower is considerable (because the mean power produced by the wind generator increases with the height of the pylon). So the number of hearths supplied with water will be more significant.

– When one pumps with low depths, the medium flows are more significant than those obtained with great depths.

The fact of doubling the height of the tower while passing from 15 to 30 meters makes it possible to gain up to 12 % on the speed of the wind, approximately 20 % on pumping for the two sites (Table 2).

Table 2

Hydraulic and energy profit for two heights of the tower

Height of the tower (m)	Energy profit, %	Hydraulic profit, %
15	11	11
30	16,7	20

Fig. 7-11 represent the daily outputs which a wind electric pumping system of 1500 watts can provide to the level in Adrar. Various total heads were simulated: 20, 40, 60, 80 and 100 m.

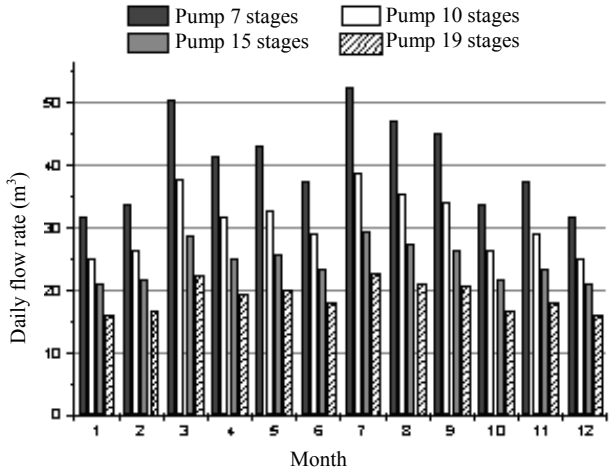

***Fig. 7**. Flow rate for H_m =20 m*

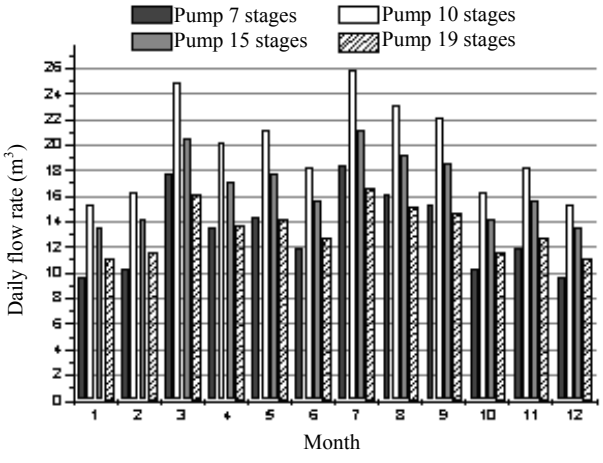

***Fig. 8**. Flow rate for H_m = 40 m*

The quantities of daily water pumped for a total head of 20 m are represented on the Fig. 7. On notices that the flow reached more than 50 m 3 per day for the most been windy months (March and July), we also note that the pump with 7 stages is that which provide the greatest flow and that for every month of the year.

The difference between the flow obtained by the pump on 7 stages and the other pumps having a number of more significant stages exceeds sometimes the double.

For a total head of 40 m, Fig. 8, the quantities of water pumped decreased almost by half compared to the preceding height (20 m). Indeed for the pump of 10 stages, which is the most powerful pump for H_m = 40 m, the flows maximum reached for certain months is 25 m^3/day.

As regards the heads total 60 m and 80 m respectively represented on Fig. 9 and 10, one can say that the pump of 15 stages is the best adapted.

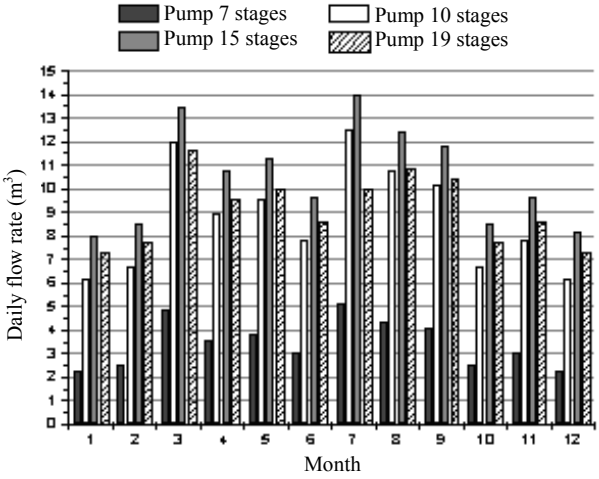

***Fig. 9**. Flow rate for H_m = 60 m*

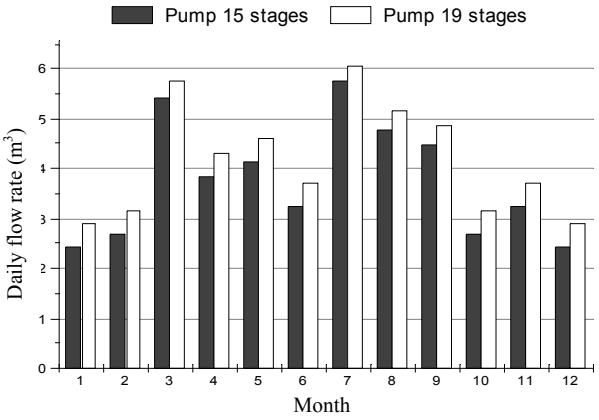

***Fig. 10**. Flow rate for H_m = 80 m*

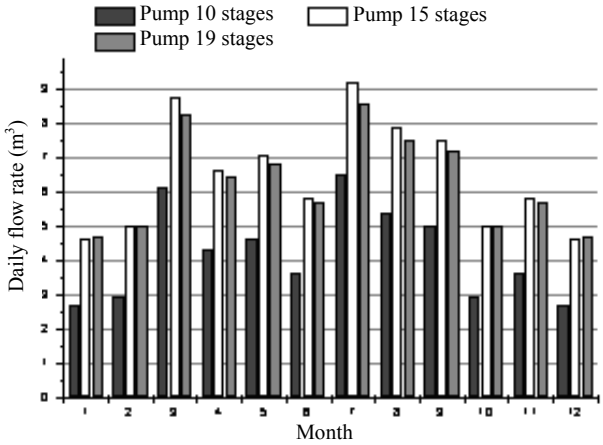

***Fig. 11**. Flow rate for H_m = 100 m*

For Fig. 11 representative of the water flow pumped for a total head of 100 m. We note that the pump of 19 stages provides the best flows. Therefore it is that which is appropriate best for this height, no matter what the quantities of water pumped are rather weak of about 2.4 to 6 m^3/ day.

Conclusion

For an isolated and windy site well, the use of the wind power for pumping water can prove to be essential and very competitive compared to other sources of energy. We presented in this work a method of wind pumping electric starting from wind turbine of 1.5 kw. The monthly flows rate of water were estimated for the area of Adrar, for each simulated total head the optimal pump was obtained, one can note that more the total head is significant more the number of stage of the pump must increase. We have to as show as:

– The mean flow is significant when the height of the pylon is considerable (because the average power produced by the wind generator increases with the height of the pylon). So the number of hearths supplied with water will be more significant.

– When one pumps with low depths, the mean flows more significant than those are obtained with great depths.

Nomenclature

V – Mean wind speed, m/s
V_c – Cut out wind speed, m/s
V_d – Cut in wind speed, m/s
V_n – Rated wind speed, m/s
$f(\nu)$ – The density of probability
C – Scale parameter, m/s
k – Form parameter
Pn – Rated power, Watt
g – Average intensity of gravity, m/s^2
H_m – Total head, m
Q – Average flow rate, m^3/s
ρ – Water mass density, kg/m^3

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A MAJOR INNOVATION: THE VORTEX TOWER POWER STATIONS (SELF SECURE VORTEX TOWERS)

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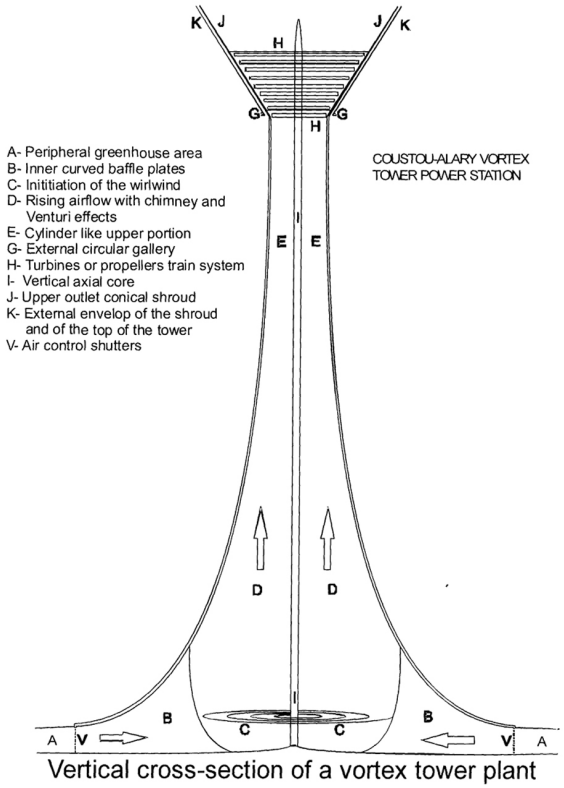
The Vortex Tower Power Stations relates to a continuously mass-producing electric power station without pollution, greenhouse gas emission, consumption of limited natural resources, wastes and independently of irregularity of wind conditions. The invention is embodied in the form of a hollow tower-shaped structure flared at the base thereof, surrounded by a greenhouse area and is optimised in order to combine several natural forces and effects: chimney effect, greenhouse effect, Coriolis force, Venturi effect and wind. The inventive plant comprises, in particular curved structures for activating an artificial and self-sustaining vortex, peripheral flap shutters for involving a wind quantity and pools optimised for storing calories supplied by sun and optionally by effluents of nuclear power plants, different industrial activities or geothermal waters. The production capacity of the inventive power plant is of several hundreds of MW and the production cost of one kW·h could be substantially low.

Alain Coustou

Born in France on 1940, Alain Coustou is lecturer in Bordeaux University. PhD in Economics and university degree of Demography, he is member of the scientific council of the University and officer of the "palmes académiques", a high decoration granted par the French Ministry of Education.
He has been one of the main founders of the Douala University Center (Cameroun) and the founder − and during seven years the first director − of the Economic and Business Sciences School (ESSEC) of Douala, from 1977 to 1984.
Actually, his main scientific interest topics are energy, climate change and sustained development. So, his two major scientific projects research are concerning the vortex towers power stations and the climatic risks.
His most recent publication is "Le réchauffement climatique, un risque majeur" (climate change, a major risk), an important paper published in the "Cahiers de la Security" (Security Journal, No. 3. P. 38-50, France, January 2008).
He is also the author of a book titled "Terre, fin de partie? La dérive climatique, un risque majeur" (Earth, end of game? The climate drift, a major risk) (205 pages, Eons Editions, France, September 2005).



Vertical cross-section of a vortex tower plant

Introduction

The Vortex Tower Power Stations or Self Secure Vortex Towers ("Tours Aérogénératrices" or "Tours Vortex à Sécurité Intrinséque" in french) are an innovative solution for continuous mass production of electrical energy at a low cost, without the emission of greenhouse gas, without the use of scarce natural resources, without waste, and without being adversely affected by the irregularity of wind conditions.
These towers are neither wind turbines nor ordinary solar chimneys, but they belong to the family of the vortex towers, whose geometry is intended for the obtaining and the permanence of a controlled artificial twister (vortex).

Origin of the vortex towers and environmental concerns

The first example of this type of project has been developed forty years ago by the french engineer and precursor Edgard Henry Nazare, who named it "Artificial Cyclone Generator" (1964)[1] or "Aerothermal

[1]French patent No. 1439849/PV 983953, registered at INPI (National Institute of Industrial Property), August 1964.

Power Station" (1982)[2]. The others projects of vortex towers were the one presented in 1975 by the Canadian engineer Louis Marc Michaud (Vortex Power Station)[3] on one hand, and two projects very close to the invention of Nazare on the other hand. The first of them has been proposed in the ex-USSR by Georges Mamulashvili in 1985[4]. A demonstration model of the second is actually experimented by the French engineer François Maugis and the Sumatel Corporation[5].

Meanwhile, in comparison with Nazare's project and with all that have succeeded it, the Vortex Tower Power Stations bring about substantial changes. These changes concern at once the number of the used natural forces and effects, the variety of the heat sources under consideration, numerous structural details, the characteristics of the peripheral greenhouses and of the calories storage system, an unfailing security guaranteed by the absolute control of the artificial twister generated in the structure and, finally, a probably better efficiency than the one of the rival projects.

Those towers have been conceived by the author of the present article, lecturer at the University of Bordeaux (France), energy, climate and sustained development specialist, and by the french computer scientist Paul Alary. They are patented in thirty countries in Europe, America and Asia[6].

Combined with the classic nuclear or thermal power stations, the Self Secure Vortex Towers could at first increase their energy efficiency by a substantial increase of the electric production. So the oldest or the less safe nuclear plants and the most polluting thermal power stations could be shut down quickly.

In addition, the Vortex Tower Power Station can also function in total self-contained operation with only renewable energy supplies, or recover the heat energy lost by the cooling effluents of the industry, while reducing their thermal impact on the environment. And that, whatever the latitude or the climate of the concerned country.

Later, they finally could take the place of the last thermal power stations and guarantee a soft substitution for the nuclear energy.

In the present world, more than the 2/3 of the electricity is generated by the thermal power station, burning coal, oil or gas. Such a situation contributes to intensify dramatically a greenhouse effect, whose the consequences threaten to be beyond all control. In addition, with the oil prices rise, the production costs of thermal electricity often tend toward an increasing, to the detriment of all the users, companies and citizens.

So the creation of really no polluting power stations, capable of producing a low cost kW·h, is a fundamental target towards the aim of a sustained development. All the more because the hydroelectricity is near of its limits, the solar and wind energies at once suffer of a high cost kW·h and a low average availability in the day and the biomass can supply no more than a minor contribution. For its part, the nuclear power is questioned because of the involved worries, particularly about the reprocessing and the long-term safety of the storage of its waste.

A solution happily exists for a short time: the one that's proposed with the Vortex Tower Power Station project, presented in this article. This invention has been patented in France after a demand deposed in 2004[7]. On august 2005, a request for patent has been registered in about thirty others countries.

We expose here the general principles, the description, the functioning, and some of the multiples advantages of this invention.

General principles

The invention is in the form of a hollow tower-shaped structure flared at its base and optimised to combine four and even five forces and natural effects:

− The chimney effect.
− The greenhouse effect.
− The Coriolis force (or effect).
− The Venturi effect.
− Optionally, the wind can add additional energy, without being necessary to the functioning of the tower.
− Lastly, it is possible – and even recommended – to exploit the recovery of heat energy, even low calories, from industry, nuclear power stations, great incinerators or from geothermic, otherwise often needlessly lost.

Description of the structure and functions of the different parts of the plant

The detailed description, the plans and the text of the international patent may be consulted on the Vortex Tower Power Station designer's site[8].

Optimum envisaged measurements

The tower has a minimum height on the order of one hundred meters, and preferably a height on the order of 300 m, not including the outlet shroud. However, it is possible to apply the principle to towers of different sizes. The tower has a base diameter on the order of 150 to 200 meters (for 300-meter tower) and an internal diameter at the base of the conversion means 18 (cylindrical or quasi-cylindrical portion) on the order of 25 to 30 meters (estimation for a 300-m tower).

Summary of the optimum measurements:

− Height: 300 meters.
− Base diameter: 200 meters.

[2]French patent No. 8205544 (publication No. 2524530), registered at INPI, Mars 1982.
[3]US patent No. 2004/0112005A1, belatedly registered in USA. June 2004.
[4]Ex-URSS invention certificates No. 13119654 and 1526335.
[5]SUMATEL, Allée Les Perce-neiges, 73540, La Bathie (France).
[6]International demand No. PCT/FR2005/050659, August 2005.
[7]French patent No. 0408809000, registered at INPI, August 2004.
[8]Http://groups.msn.com/ToursAerogeneratrices2/

− Top internal diameter, at the level of the lower turbine: 25 to 30 meters.
− Greenhouses area, all around the base of the plant: 3 to 5 square kilometers in totally self-contained functioning, infinitely less when combining natural forces and effects with the recovery of industrial cooling calories, or other renewable calories (geothermic).
Lower sizes are conceivable, according to the available calories and the needs, the concept operating effectively with all heights equalizing or exceeding one hundred meters. The concept is valid for different dimensions, with heights exceeding one hundred meters and tours over 300 meters being capable of being envisaged.

Description, from the base to the top

The tower includes, in the lower portion, a plurality of air inlets with baffle walls curved so as to cause the air to rotate and to generate in the tower a whirlwind phenomenon maintained and amplified by the Coriolis force, upstream of the air inlets means for heating the air suctioned into the tower by a chimney effect, means for converting the kinetic energy of the air column into electrical energy, said tower being flared at its base and gradually shrinking so as to accelerate the air by the Venturi effect.
The flared base, which provides perfect stability for the assembly, is painted black. Air inlets are arranged around the periphery of this base and can be screened to prevent the accidental ingress of birds or the suctioning of debris brought by the wind.
Between each of the inlets is an inner and/or outer baffle plate. The inner plates, which may be extended to the outside under the windows, simultaneously have a structural frame function and are interrupted at the central portion of the structure. The inner baffle plates have a curved (plan) form, so as to initiate a rotation movement of the air suctioned in the tower, which rotation (vortex) is amplified in a spiral revolution from the base to the apex and maintains itself by the Coriolis force.
A vertical core is placed in the axis of the tower and ensures the symmetry of the rotation of the air column. This core can join the axis of the turbine or propeller system 18. If necessary, it can be held in the axis of the tower by stretched cables. This core can consist of a hollow structure with a round cross-section, in which the use of cables, a lift and/or an emergency escape is possible.
The base of the tower is surrounded by greenhouses hanging over an area of different type, if the structure is constructed in a region having water resources or not.
In a region having hydraulic resources, communicating basins with a hexagon or quadrangle shape act as relative heat reservoirs for the night. Each basin may be equipped with a black floating cover, intended to prevent evaporation.
In dry or desert areas, a ground surface covered with bitumen or black painted concrete provides the same functions.
In both cases, the area considered is on the order of several km^2 (2 to 3 km^2, for example, in a very sunny area) for a self-contained tower, over which glazing hang. This area can, however, be very substantially reduced when combined with a source of industrial heat energy (nuclear power plants, iron and steel works, etc.).
The diameter of the tower shrinks gradually from the base. This specific feature should cause a considerable acceleration in the rising airflow by a combination with the chimney effect and the Venturi effect.
The upper portion of the tower to the base of the turbines or propellers has a shape similar to a cylinder, possibly slightly truncated or conical, preferably painted a light colour, such as white.
A device for converting the energy of the air column into electricity, capable of being constituted by turbine or propeller stages, controlled by sensors and managed by a computer program, is installed just before the apex of the structure. This device may be accompanied by a flare of the tower at its level so as to better evacuate the air column in spite of the conversion of a large portion of its kinetic energy. This device can optionally be preceded by one or more compressor and discharge valve stages in order to remove any excess pressure.
This cylindrical, quasi-cylindrical or flared portion can be covered by a shroud at the turbine outlet so as to optimise their efficiency and reduce any sound disturbances.

Functioning

Greenhouse effect

In the self-contained operation of the system, the ambient air around the base of the tour, which is generally naturally warmer than that at the apex, is increased in temperature by the greenhouse effect created by the glazings surfaces.
A heat energy reserve is created by the heating of the bitumen ground or black-tinted concrete-covered ground, or, better yet, water basins with a hexagon shape (optimal configuration) or any other shape allowing for regular tessellation of the ground. The capacity for diurnal storage of heat energy is much higher in the case of basins than in the case of bitumen or concrete.
These intercommunicating basins can each be equipped with a floating cover, preferably rigid or semi-rigid. This cover is black, which enables it to absorb solar heat. It would be used as needed to prevent evaporation, depending on the availability of water, which is variable according to the site and possibly the period. Its use would also limit the appearance of a vapour plume at the top of the tower.
To complement the solar heating of the air, the flared base of the tower can itself be painted black and insulated with windows on the portion of which the slope is less than around 60°.
The black absorption and heat energy reserve area surrounding the base of the structure (i.e. an envisaged area on the order of several km^2 of basins and/or bitumen

or concrete) is covered by glazings. The air circulates under them, which air is thus heated before being suctioned by the base of the tower.

This glazing area is encircled by a system of electronically controlled shutters, in order to optimise the use of the heated air according to the possible wind. It is thus possible to obtain a slight overpressure capable of reinforcing the chimney effect. The shutters are normally open in the portion facing the wind and closed in the opposite portion. The opening of these shutters or these valves can be modulated if there is too violent wind, in order to prevent an excess overpressure.

The placement of the tower on the site of a nuclear or classic power plant should enable the use of low heat energy of the water of the external cooling circuit of the power station. In winter, this water would be diverted toward the basins relatively close to the tower, from which it would spread closer and closer to the outer basins. In summer, the process would be reversed, with the water coming from the plants supplying the outer-most basins.

A classic or nuclear plant could thus provide a surplus of energy to one or more towers, surplus varying with the type of plant and with the temperature of the recovered effluents. This solution would have the dual advantage of substantially reducing the area of the greenhouses (therefore reducing the investment cost) and recovering the heat energy unnecessarily discarded into the environment with a hydraulic flow that is often high.

The evaporation would then ensure an evacuation of the heat energy making it possible at least partially to do away with the cooling towers of the plant while increasing the energy of the whirling air, which would increase in humidity. This phenomenon is well known to meteorologists in the case of natural tornadoes, which are often strong above the ocean and weaken or disappear after reaching solid ground.

If the recovered water is hot enough, it may be cost-effective to provide a system for transferring the heat energy from the water to the air that is more effective than the simple interface between the surface of the basins and the suctioned air. Three alternative solutions, among others, may be chosen, optimising the availability of a volume of hot water that is sometimes very large, on the order of some dozens of m^3/second with regard to nuclear power plants in which the cooling is not done in a closed circuit, but uses water from a stream or from the sea.

According to a first solution, a network of more or less narrow pipelines, or even actual radiators, is traversed by the air suctioned by the base of the tower and in which the water circulates, providing heat energy, before it is evacuated into the basins or toward the outside.

According to a second solution, there is a system of cascades from the apex of the greenhouses to the basins. These cascades would constitute water curtains coming from the plant and supplied from pipelines placed under the windows of the greenhouses. An alternative of this solution could consist of creating one or more water jets above each basin or the surface for receiving and discharging water.

According to a third solution, in the ideal case in which the water is available under pressure and/or at a high enough temperature, it could be sprayed directly into the air of the greenhouses (fogging), above the basins or the surface for receiving and discharging water.

In addition, the area of the greenhouses could be further reduced, which would make it possible to envisage the use of double glazings without excessive additional costs. It could even be possible to totally do away with the greenhouse effect if enough hot water is available, and to replace the windows by any material with good mechanical qualities, in which the covered space would then be intended solely to guide the outside air toward the base of the tower while allowing it to be heated by the heat energy extracted from the water.

Finally, it is possible to envisage reducing the flow of the cooling circuit by pumping less water out of the streams, which would be less disruptive for the environment and, by reducing the dilution of the heat energy coming from the plant, would be capable of providing a warmer water flow to the wind turbine tower. In every case, this placement of the towers should allow for a considerable reduction in the cost of the kW·h.

Other activities, such as iron and steel works, cement works, smelting works, incinerators, and so on, produce a flow of heat energy that is often wasted. This heat energy could also be recovered so as to significantly increase the energy production of the towers. Indeed, even low-calorie liquid or gaseous effluents can increase the energy production of the tower with respect to what is possible in a self-contained operation. This production does depends not on the absolute temperature of the air at the base, but on the difference between said temperature and the temperature of the air outside the apex of the plant.

Similarly, it is possible to use a thermal spring or geothermics to provide the basins with comparable advantages at the level of the preheating of the basin water. In every case, even a spring with a temperature lower than that desired for the air at the base of the tower can be advantageous, since its temperature is greater than that of the outside air. The greenhouse then has only to contribute to a complement of the heating, which reduces the number of basins and the windowed area needed.

Combination of chimney effect, Coriolis force and Venturi effect

Chimney effect

The warm air trapped under the greenhouses area and under the flared base of the tower rises in the hollow structure by the chimney effect. This well known phenomenon by itself would not be enough to ensure the efficacy of the device for a tower of which the height is only one to a few hundred meters. A tower using only the chimney effect and the greenhouse effect should reach a prohibitive height of around 500 to 1000 meters in order to be effective, presenting serious problems of placement, construction and cost.

It is here that the very specific architecture of the device of the invention is involved, making it possible to maximise and concentrate the energy produced by using two other complementary natural effects, the Coriolis force and the Venturi effect, and possibly to take advantage of an overpressure effect due to the wind.

Coriolis force (or effect)

The air that enters the base of the tower is guided by curved baffle plates that activate its rotation, this movement being maintained by the Coriolis effect or force. The internal plates, which are formed between each air inlet recess, can also perform a structural frame function. The axial core of the tower contributes to support the alternators and turbines and it is intended to ensure satisfactory symmetry of the air rotation in spite of any variations when it is suctioned into the tower.

A whirlwind (vortex) phenomenon is thus triggered, and is maintained and amplified by the Coriolis effect. In this way, we obtain a captive and self-maintained twister. The warm air no longer needs to rise, but is animated by a rapid rotational movement in the same direction as that set for the turbine stages.

Venturi effect

The Venturi effect is generated by the specific architecture of the tower, flared at the base, with its internal diameter shrinking as the air rises by the chimney effect. This feature causes a considerable acceleration of the rising and rotating airflow, by the Venturi effect. With an internal diameter in the upper portion of the tower equal, for example, to $1/7^{th}$ that of the base, and a temperature difference of some thirty degrees, the speed of the air column can reach several hundred km/h. It is only preferable to prevent this speed from exceeding 0.7 times the speed of sound.

Thus, the energy carried by the air column is considerably concentrated, compared with what would be obtained by the simple chimney effect in a tubular structure with a constant diameter from the base to the apex.

The conversion of the kinetic energy of the air column into electric energy

The energy of the captive and self-maintained air whirlwind is collected in the upper portion of the tower by a train of several turbines or propellers with a variable pitch, with a diameter slightly smaller than the internal diameter of the tower. The blade-span of these turbines or propellers may be on the order of 25 to 30 m for a 300 m height tower. Flaring the highest portion of the tower in the line of the turbine or propeller train, of which the diameter increases from lowest to highest. This increase in the diameter ensures the evacuation of a constant air volume in spite of the disruption of the air column by the turbines, and increases the efficiency of the assembly.

Finally, the upper outlet of the tower can usefully be covered by a shroud intended both to prevent the appearance of turbulence at the outlet of the turbine or propeller train and to minimise any sound disturbances. This shroud has a frusto-conical (truncated) or a progressive shape. It can be a double shroud, intended to cause a cool air suction phenomenon and cool the periphery of the warm air column after it leaves the turbine or propeller train, this solution being capable of effectively reducing the sound disturbances. This double shroud can be extended downward to reach the portion of the tower containing the turbines or propellers. This enveloping shroud would suction a layer of cool air along this portion, which, optionally combined with external radiators, could help to ensure the cooling of the turbines (or any other system for capturing energy. This formula should be particularly advantageous.

The percentage of conversion of the kinetic energy might exceed 75 %. The production of electricity thus obtained is permanent. In particular, it is practically independent of the wind, unlike in conventional wind turbines, limited by the Betz's law. The possible production fluctuations can hardly result from variations in the difference between the temperatures of the air at the base and at the apex of the tower. The wind can nevertheless help to amplify the chimney effect by a double effect of overpressure at the base of the tower and suction at the apex.

The power established can be several hundreds of megawatts for each tower, on the order of 500 MW in optimal activity with some thirty degrees of difference between the air at the base and that at the apex, for a tower 300 m high. The power could be even higher in the case of a vortex tower near a nuclear or thermal power station or a major heat-generating industrial activity. The effluents thereof would ensure the supply of the basins with preheated water and therefore a difference in temperature that is both more stable and greater for the same greenhouse area. They could also be placed directly in contact with the air of the greenhouse area by various methods (spray, cascades, water jets, etc.). According to this hypothesis, it is possible to consider reaching and even exceeding a power on the order of 700 to 1000 MW, reaching the order of magnitude of the power of a nuclear reactor for a particularly low cost.

Certain industrial plants sometimes simultaneously have large electrical energy requirements and a need for cooling water. The placement of a wind turbine tower can in this case both generate the energy needed for the plant and reduce the thermal waste in the environment.

Some bonus and conclusions

Some bonus

Outside, the structure may comprise a station for surveillance, maintenance and/or control, places for antennas, transmitters and retransmitters. The access to the base of the lifts and the tower can be provided underground so as to avoid the need to pass through an overheated greenhouse space.

In regular wind areas, annular wind turbines, wind turbines with vertical-axis cups or other wind turbine devices can

optionally encircle the cylindrical or quasi-cylindrical portion of the structure, with the tower constituting the axis of rotation of at least one wind turbine device.

Conclusions

To conclude, the mass production of electrical energy at a particularly low cost (on the order of 2 cents per kW·h in the first estimation) by the new aerothermal power plants, i.e. the Vortex Tower Power Stations, would constitute an extremely beneficial economic advantage.

They would also have the advantage of making it possible to recover the heat energy lost both by the power plants and by other industrial plants and to reduce the thermal disturbances of said plants while supplying them with energy.

They can produce electricity with excellent efficiency from low-temperature sources, since a temperature some thirty degrees higher than room temperature is already enough to allow them to perform very well.

There are no environmental hazards. The artificial whirlwind absolutely cannot escape the tower since it is self-maintained by the specific structure of the plant and most of its energy is converted into electricity. In addition, the tower uses the heat energy available, provided by the Sun, geothermics or an industrial plant, without producing it itself and without generating waste or greenhouse gases.

The power range is relatively broad between the 100 m tower and the over 300 m tower so as to provide a wide variety of uses, and the power of a 300-m tower with preheating by recovery of heat energy is capable of reaching up to several hundred MW, and even approach the power of a nuclear reactor, while improving its overall efficiency and making it economically and environmentally more beneficial.

ANALYSIS OF THE POWER OUTPUT OF A WIND TURBINES CLUSTER IN THE GUADELOUPEAN ARCHIPELAGO

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This article presents the result of an experimental investigation of the wind speed − power output transfer function of a Squirrel Cage Induction Generator (SCIG) wind turbines cluster in the Guadeloupean archipelago. The analysis shows that the fluctuations of the power output and the wind speed are correlated only for time scales larger than 8 minutes. A probabilistic transfer function, based on the conditional cumulative distribution function of the power output, given the mean wind speed, is also presented. It gives a synthetic view of the dispersion of the aggregated power output.

Keywords: wind energy, power curve, wind variability

Introduction

Throughout the last two decades, wind energy has become a common component for electricity generation in many energy systems [1-4]. Wind energy is currently the world's fastest growing renewable power source. In Europe, the wind energy installed capacity has grown 600 % between 1997 and 2003. Wind energy with 60 TW·h, already represents 2.3 % of European electrical energy consumption [1]. Worldwide, wind energy capacity rises from 4,800 MW in 1995 to 73,904 MW at the end of 2006 [3]. The technological evolution of wind energy conversion systems has been fast. Today, conventional wind turbine's rated power often exceeds 2 MW, almost ten times the rated power of a state of the art wind turbines fifteen years ago [5].

Although wind energy is often described as an unreliable energy source because of its variability, it can be argued however, that many component of a power system (both on the supply and on the demand side) are indeed variable and some drawbacks can be hardly predictable [1, 6]. Moreover, wind energy is not the only electrical network component that varies with the meteorological conditions: the electrical demand is also dependent on the weather; a heat wave may induce consumption peak, a thermal power plant may be affected by a thunderstorm, tree falls on power lines can cause sudden interruptions of supply.

Network operators have long experience in dealing with variability within the power system; they have, routinely, to cope with changeable demand and unanticipated transmission and power generation breakdown.

Efficient forecasting scheme based on a better knowledge of the wind variations characteristics along with their influence on power output variation is of key importance for the optimal integration of wind energy in power system. It is the uncertainty of the forecasts that cause balancing difficult, not the variability of the wind power [7]. Numerous studies have been devoted to wind power forecasting [8-16]. Hourly averaged wind speed data variations can be predicted to a great extent [13].

Concerning the wind speed to electrical power conversion, many studies have investigated wind turbines response to wind variations. Under the influence of meteorological conditions wind speed fluctuates over time. These variations occur on different time scales: from seconds to years. The response of a wind turbine, in term of power output variations, depends on the wind turbine technology [5, 17-19]. Some smoothing effect can also be obtained due to the turbine inertia and size. For a group of turbines; further smoothing can be expected due to the spatial distribution of the turbine within the area. For large area, wind energy overall variability can be much lower than the variability of a single wind turbine since the meteorological fluctuations do not affect each wind cluster at the same time [1].

To anticipate for wind power variability is even more crucial for island power system management. Their small size and the fact that they are not connected to large utility network impose supplementary constraints to wind power integration. In the Guadeloupean archipelago (French West-Indies), by the end of 2006, the total installed wind energy capacity reached 21 MW. Moreover, wind power can already contribute up to 5 % of the instantaneous electricity consumption. At this level, wind energy contribution can be equivalent to the current network primary control reserve. Increasing wind power penetration rate could make it necessary to provide some warranty on wind power production in order to optimize the conventional back-up capacity intended to palliate wind production shortages.

The common approach to investigate wind farms power output is based on wind measurement within the site. Often, a single point wind speed measurement campaign is used to assess the site's wind power potential. However, the electrical power variations observed for a wind farm are the consequences of the actual wind variations as seen by each wind turbine as well as the electricity network shortcomings and the various maintenance problems that may affect the wind turbines efficiency. Therefore, it is necessary to complete the power curve obtained for the group of wind turbines with a probabilistic approach that gives for a specified wind speed range, the distribution of the expected wind farm power output.

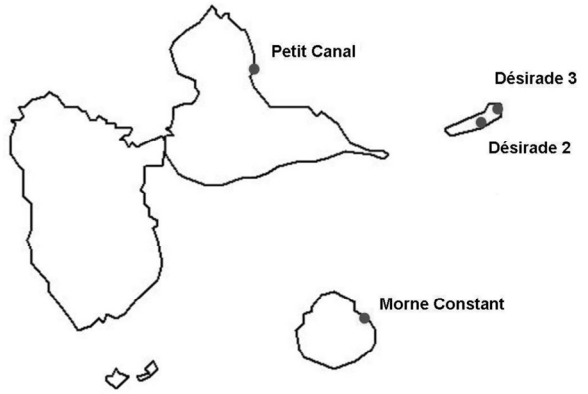

Fig. 1. *Schematic view of the Guadeloupean archipelago; the dots point to the location of the major wind turbines clusters*

In this article, we present the result of an experimental investigation of the wind to power output transfer function of the larger wind cluster of the Guadeloupean archipelago. This wind turbine cluster consists of 32 SCIG (Squirrel Cage Induction Generator) wind turbines positioned at the top of a sea cliff at Petit-Canal, on the east coast of Guadeloupe (see location on Fig.1).
The proposed analysis is based on an experimental data set that consists of wind speed and electrical power output samples measured simultaneously during a one and a half year measurement campaign within the wind farm site.

The wind energy production site

The measurement campaign was conducted at the wind energy production site of Petit-Canal in Guadeloupe Operated by the Vergnet Caraïbes Company (Fig. 1). The wind turbines are provided by the Vergnet Company and have been designed to resist wind speed intensity of more than 200 km/h. The turbines are mounted on 60 m masts that can be lowered, in case of a major hurricane, with an attached motorized hosting gear. They can be promptly dismantled and laid on the ground. No particular equipment is needed for their installation.
These wind turbines are fixed speed Squirrel Cage Induction Generator (SCIG). Therefore, their rotational speed is dictated by the electrical grid frequency (in Guadeloupe the grid frequency is 50 Hz). Consequently, at the lower end of its wind speed operational range the turbine rotates too fast, and at the higher end it rotates too slowly in respect with its optimal angular speed. Therefore, the SCIG operates below its maximum efficiency at most wind speeds. Nevertheless, the SCIG technology is proven to be robust and cost-effective. The rotor blades are rigidly fixed to the hub and are designed to stall for wind speed above 25 m/s. The stalled regulation is intended to limit the rotor angular speed in case of high wind speed.

Experimental set up

The measurements were carried out during one year and a half from December 2003 to June 2005. Wind speed and direction along with the wind turbines cluster electrical power output were collected during this measurement campaign. The wind speed V_{wind} was measured, in a horizontal plane, with a three-cup anemometer (model A100L2 from Vector Instruments). The anemometer was mounted on a 40 m (131 ft) tall mast erected 20 m (66 ft) from the cliff edge, at 38 m (125 ft) from the ground. The response time of the anemometer is 0.15 s. This remains compatible with a sampling rate of 1 Hertz for the sake of a statistical analysis of the wind speed variations. Table 1 gives the specifications of both the anemometer and the wind vane.

Table 1

Anemometer and wind vane specifications

	A100L2R	**W200P**
Size	Height = 200 mm; Diameter = 55 mm; Weight = 350 g	Height = 270 mm; Diameter = 56 mm; Weight = 350 g
Supply Voltage	12 V (6,5 V to 28 V)	5 V (20 V max)
Materials	Anodized aluminium, stainless steels and ABS plastics for all exposed parts	
Range of Operation	Threshold: 0.15 m/s; starting speed: 0.2 m/s; stopping speed: 0.1 m/s; Max. wind speed: 75 m/s	Max. Speed: > 75 m/s; range: 360° mechanical angle Accuracy: ±2° obtainable in steady winds over 5 m/s (3.5° gap at North)
Analogue Output	Calibration: 0 to 2.500 V DC for 0 to 75 m/s (32,4 mv per m/s).	0 to 5 V for 0° to 360°
Response Time	150 ms first order lag typical	

The electrical power of a cluster of 32 wind turbines was measured simultaneously with the wind speed; a power-to-volt converter was used to gauge the electrical power. In this paper, the electrical power $P_{cluster}$ is expressed as a percentage of the total power capacity of the wind turbines cluster.

The measured data were downloaded to a PC connected to the RS232 port of a Campbell Scientific CR23X data logger. This data acquisition system was set-up to operate continuously and the PC can be administrated via a phone line, which allows a remote control of the data acquisition operation. The data analysis is performed using the Matlab® software package.

Wind velocity and electrical power Fourier analysis

A one week sample of wind speed and electrical power signals are plotted in Fig. 2 and Fig. 3. Both signals exhibit variations on various time scales. On large time scales (larger than 1 hour), the temporal behaviour of V_{wind} and $P_{cluster}$ are almost similar as seen on Fig. 4 where the 1-hour-moving-average wind speed and power output are plotted. But for the shortest time scales, the two signals exhibit different behaviour.

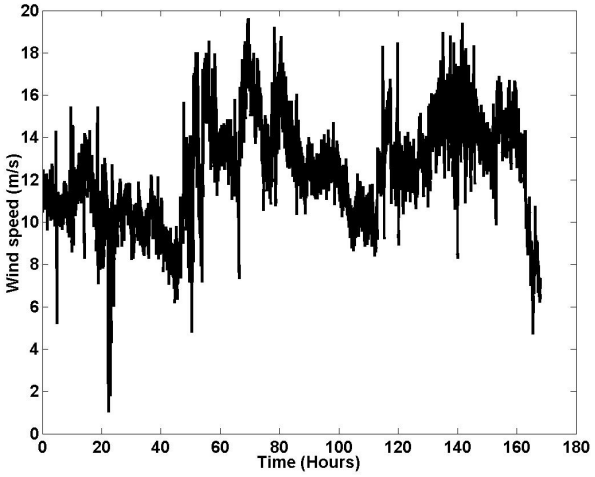

Fig. 2. *One week sample of wind speed*

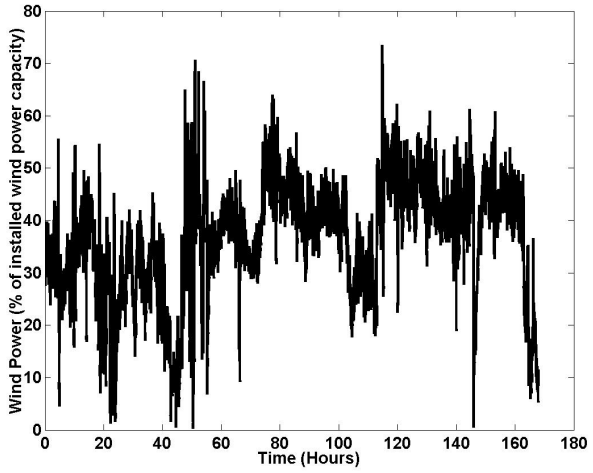

Fig. 3. *One week sample of wind farm electrical power*

To go further into the investigation of the wind speed – electrical power relationship for the short time scales, we use various tools from the Fourier analysis. The plots in figure 4 are the power spectral density of both V_{wind} and $P_{cluster}$. The spectra are plotted for the frequency range between 1/2 hours ($1.3 \cdot 10^{-4}$ Hz) and 1/1 minutes ($2 \cdot 10^{-2}$ Hz) using the periodogram method. Within this frequency range, no frequency peak can be observed from the two spectra. Moreover, we calculated the magnitude square coherence between the wind velocity V_{wind} and the power signal $P_{cluster}$. The magnitude square coherence is defined by:

$$C_{VP}(f) = \frac{\left|P_{vp}(f)\right|^2}{P_{vv}(f)P_{pp}(f)}.$$

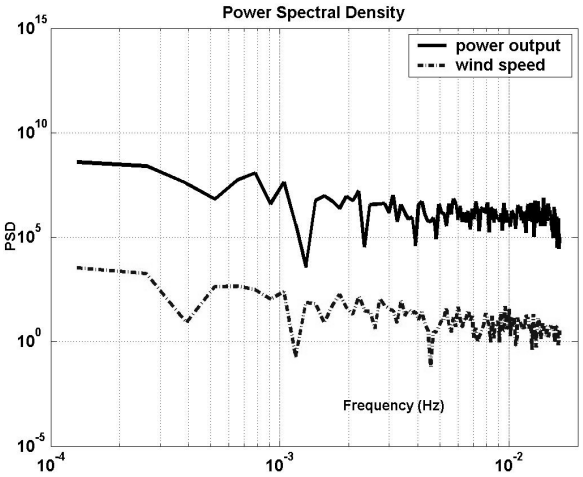

Fig. 4. *Power spectral density of the wind speed and the wind cluster power output*

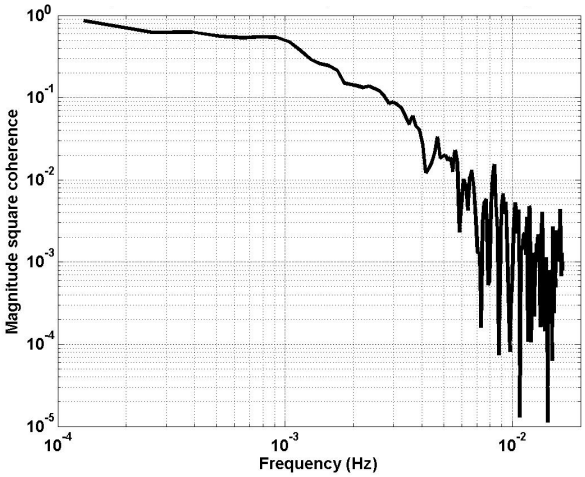

Fig. 5. *Magnitude square coherence between wind speed and electrical power as a function of wind oscillations frequency*

It is equal to the cross spectrum of V_{wind} and $P_{cluster}$ divided by the product of the power spectra of V_{wind} and $P_{cluster}$. This quotient is a real number between 0 and 1 that measures the correlation between V_{wind} and $P_{cluster}$ at the frequency f. The plot of Fig. 5 shows the coherence C_{VP} to drop below 0.2 for frequency above 1/8 minutes ($2 \cdot 10^{-3}$ Hz). This indicates the coherence between wind

speed and power fluctuations associated with time scales lower than 8 minutes are low (frequencies larger than $2 \cdot 10^{-3}$ Hz). The plot of the magnitude square coherence is completed by the plot of the gain of the wind speed (V_{wind}) – wind turbine cluster electrical power output ($P_{cluster}$) transfer function. The transfer function is the quotient of the cross spectrum of v and $P_{cluster}$ and the power spectrum of V_{wind}. The gain of this transfer function, plotted in Fig. 6, drops by more than 10 dB below its maximum value (obtained for large time scales) for frequencies larger than 1/8 minutes ($2 \cdot 10^{3}$ Hz). The phase of the transfer function, plotted in Fig. 7 remains close to zero for frequencies below $2 \cdot 10^{3}$ Hz. From both the magnitude square coherence and the transfer function plots, one can deduce that on large time scales, power variations are well correlated with wind speed variations; the large time scales wind variations affect the whole wind farm almost simultaneously. On the other hand, the variations on the short time scales of the power output are not correlated with those of the wind speed.

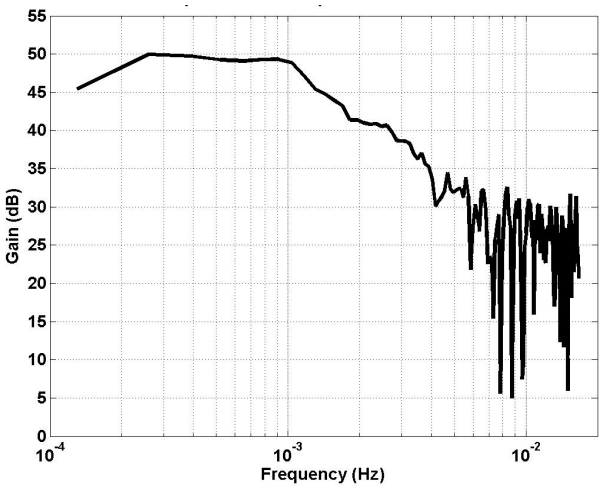

Fig. 6. *Gain of the Transfer Function between wind speed and electrical power as a function of wind oscillations frequency*

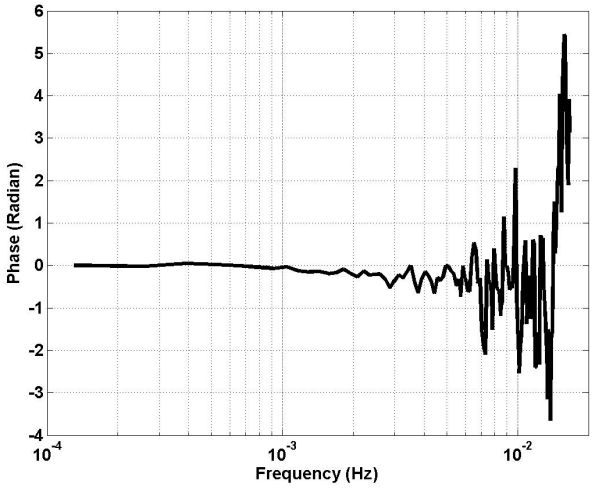

Fig. 7. *Phase of the Transfer Function between wind speed and electrical power as a function of wind oscillations frequency*

Wind velocity and electrical power statistical analysis

So far we have investigated the response of the wind cluster to wind variations in term of frequency response. In this section, we examine the distribution of the wind cluster power output $P_{cluster}$ and its relation with the wind speed. The power generated by a wind turbine is a function of both the properties of the wind and the turbine electromechanical characteristics. For a wind cluster, the power output also depends on the turbines scattering within the production site. In Fig. 8, the 10 minutes averaged power output $\overline{P}_{cluster}$ is plotted versus the 10 minutes averaged wind speed $\overline{V}_{wind}$. This plot displays a cloud of points, thus showing evidence that the mapping between the electrical power and the wind speed is not a bijective function.

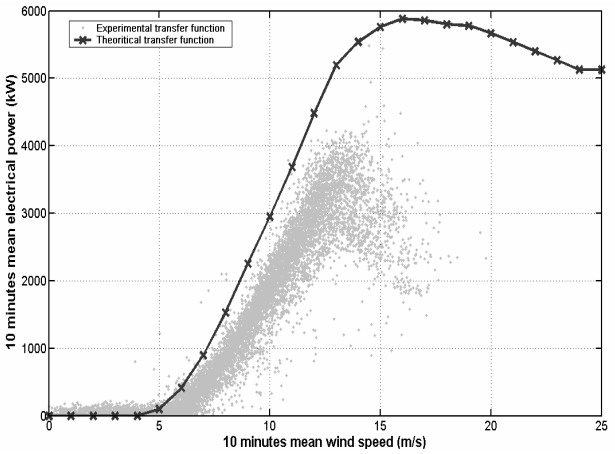

Fig. 8. *10 minutes averaged power versus wind speed*

The theoretical power curve of the wind turbines cluster, obtained by considering that each wind turbine is affected by the same wind speed and operates simultaneously, is also plotted in Fig. 8. The theoretical power curve remains greater than the clouds of points except for low mean wind speed value. The observed dispersion of the power output highlights:

1) The existence of turbulence on wind energy production site. The site faces the wind along the coast line on approximately 2 km. It is likely that the wind turbines are not affected by the same wind.

2) The variation in the number of wind turbines actually available. Maintenance operations can require shutting down one or several wind turbines, in that case, the aggregated power capacity is reduced.

3) The unsteady meteorological conditions that induce fast wind speed fluctuations.

Another way to represent this wind to power mapping is to consider the conditional probability that the observed mean electrical power $\overline{P}_{cluster}$ takes on a value less than or equal to a given threshold P, given a mean wind speed $\overline{V}_{wind}$. This conditional probability is the conditional cumulative distribution function noted

$F\left(P|\overline{V}_{wind}\right)= prob\left(\overline{P}_{cluster} \le P|\overline{V}_{wind}\right)$ and is expressed in percentage. In Fig. 9, the iso-percentages of the function $F\left(P|\overline{V}_{wind}\right)$ are plotted in the $\left(\overline{V}_{wind}, P\right)$ plane for an averaging time equal to 10 minutes. The value of the threshold P is expressed as a fraction of $P_{capacity}$.
Also in Fig. 9, we have plotted three power curves associated with 60 %, 50 % and 40 % of the installed power capacity of the turbines cluster. For mean wind speed between the cut-in wind speed and 10 m/s, the actual power output stays below the 60 % power curve. For mean wind speed ranging from 10 m/s to 14 m/s, the actual power output varies mainly between 40 % and 60 % of the cluster's capacity. For wind speed large than 14 m/s, the wind output decrease faster than the theoretical power curves as the mean wind speed increases. Works is continuing to better characterise and understand the wind turbines cluster behaviour.

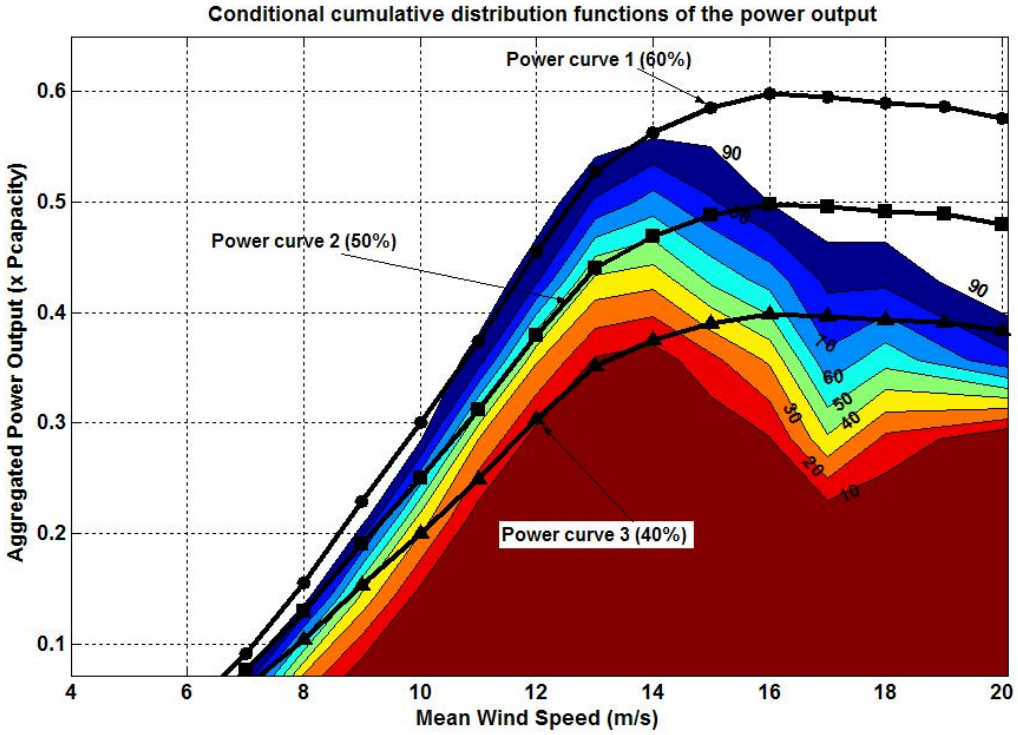

Fig. 9. *Conditional cumulative distribution functions of the wind turbines cluster power output plotted along with 60, 50 and 40 % power curve*

Conclusion

This paper presents the first experimental results of an investigation of the wind speed to power output transfer function of a wind turbines cluster in Guadeloupe (FWI). A first approach, based on Fourier analysis, shows that the fluctuation of the cluster's power output is correlated to those of the wind speed only for time scales larger than 8 minutes. For short time scales, the two signals are not correlated. In order to evaluate the actual production of a wind farm, we have plotted the conditional cumulative distribution of the electrical power provided by a SCIG wind turbines cluster, given the mean wind speed. This plot gives a quantitative view of the power output dispersion. During the measurement campaign, the probability to have the 10 minutes averaged electrical power to take on a value larger than 50 % of $P_{capacity}$ equals 11 %. This probabilistic transfer function gives a practical estimation of the electrical power produced by a cluster of wind turbines as a function of the mean wind speed. Future works should address the unsteadiness of this map throughout the year.

Acknowledgements

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MODELING OF WIND TURBINES USING HYBRID MODELS

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A hybrid model of kind "actuator surface" has been developed to represent the flow past a wind turbine rotor. The model uses a Navier-Stokes solver and permits calculation of rotor power and wake if the aerodynamic properties of the blade sections are known. The rotor geometry is simplified; the blades are replaced by their mean surfaces and a "pressure jump" boundary condition is applied to these surfaces. Thus, the proposed model is economic compared to full geometry simulation, because it is not needed to have fine grid around the blade. The hybrid model couples the Navier-Stokes solver with a blade element method (BEM). The solving process is iterative: at the beginning of each iteration a BEM determines the pressure discontinuities on the blade by means of rotor inflow and blade section performances. Then the CFD solver applies this pressure discontinuity in order to model the blade forces and calculate the flow past the rotor. The obtained velocity field is compared with results of previous iterations and if the required precision is attained, the calculation stops. The proposed hybrid model is tested in the case of a horizontal axis wind turbine (HAWT). The obtained results for rotor power and axial trust are satisfactory. Thus, this model can be employed for simulation of aerodynamic interaction between the wind turbines installed in the wind farm.

Keywords: wind energy equipment

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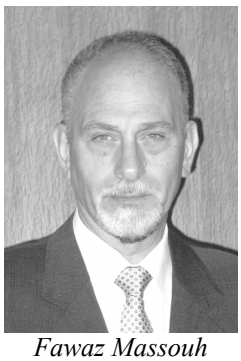

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Introduction

The proximity between the wind turbines installed in wind farm creates problems of aerodynamic interactions. Generally the wind farm development is complex problem and multiplicity of factors comes in play when the wind turbines are positioned. To optimize the energy production and the operation costs, engineers use software tools developed especially for wind farm design. These software tools take into account wind turbine data, wind speed and direction, site topography, etc. However, in all cases it is needed to avoid the negative effect of aerodynamic interference between the wind turbines.

The simplified aerodynamic models used for wind farm design are not well adapted and cannot describe correctly

the behavior of wind turbine rotor. These models cannot obtain with sufficient precision the velocity field downstream the rotor and therefore they are not capable to evaluate the development of the wind turbine wake. To obtain numerical results with sufficient quality, a CFD simulation with an appropriate fine grid mesh is needed, but the solution is computationally very expensive. As result, modeling the interaction between more than two machines is impossible in practice. To reduce the computational cost, it is possible to use a simplified equivalent representation of the real rotor blades geometry that needs less grid points. This representation must be able to describe the behavior of the wind turbine rotor without modeling the exact blade geometry in the CFD computations. This kind of numerical modeling belongs to what is called hybrid modeling.

The hybrid models comprise two modules. In the first module a CFD solver computes the velocity field around the wind turbine rotor. Here, the presence of the rotor is modeled with source terms, pressure or velocity discontinuity. To prescribe these source terms or discontinuities, one second module uses a conventional method based usually on the blade element method (BEM). Here, the forces applied to the blades are calculated using the upstream velocity field and also the drag and lift coefficients of the blade sections. Thus, there is no need to model the flow around real blade geometry and the grid around the rotor may be coarsened. As results the need of computer power is reduced significantly.

In the field of wind turbine aerodynamics, [1] presents a comprehensive review on wake aerodynamics of wind turbines and several hybrid models are discussed. It is shown that many hybrid models use an actuator disk with the application of pressure or source terms. In these axisymmetric models, the source terms are distributed uniformly in the azimuthal direction and as a result the individual presence of blades is lost.

To overcome this limitation and to represent more realistically the flow field downstream the rotor, a three-dimensional representation of the rotor blades is developed in [2]. In this model named as "actuator line", the geometry of real blades is replaced in CFD by source terms distributed radially along the blade axis. Here, the blade forces are determined by means of two dimensional airfoil data and the results of CFD computations are used to obtain the relative velocity and angle of attack. Compared to actuator disk, this model permits to represent individually each blade with its tip and root vortices and thus to improve rotor wake representation. The comparison of the actuator line with experimental data reveals the effectiveness of this proposed model in case of yaw and non-yaw compared to actuator disk model [3].

This paper is intended to develop the model of "actuator surface" proposed by authors in [4] and [5]. Compared to actuator line model the actuator surface model goes further in the blade representation. Here, each blade is replaced by a surface of pressure discontinuity. The distribution of this discontinuity varies along the span but also along the chord. Thus the actuator surface model improve the blade representation and therefore the initial conditions of wake development compared to active line. Finally, to validate the proposed model, the results of hybrid calculation in the case of wind turbine will be presented and will be compared with experimental data.

Hybrid modeling

Hybrid models like actuator disc and actuators line, are presented in details in [3] and therefore no additional explanations are required. However, the active surface model has some differences and this paper is intended to present them. Actuator surface model like other hybrid models also combines a blade element method with a Navier-Stokes solver. In the CFD domain, the rotor geometry is simplified and the blades are replaced by thin surfaces. The specified boundary condition on these surfaces is "pressure discontinuity". Hence, the imposed surface forces replace the rigid blade wall and the number of nodes is significantly reduced, as there is no need to model the blade boundary layer.

In the beginning of each iteration from the upstream velocity, the blade geometry and the airfoil data, the BEM module calculates the pressure jump distribution on the surface replacing the blade. Then the CFD module computes the flow velocity field, using as boundary condition the pressure distribution previously obtained from the BEM module. The solution is carried out iteratively, exchanging data between the BEM and CFD modules; it stops after convergence is reached.

The calculation of pressure discontinuity is based on the blade element approach. At the blade radius r, the elementary forces acting in the normal and tangential directions on a blade element with span dr and chord c are:

$$dF_n = \frac{1}{2}\rho W^2 C_n(\alpha) c dr \qquad (1)$$

and

$$dF_t = \frac{1}{2}\rho W^2 C_t(\alpha) c dr. \qquad (2)$$

In the above formulas the force coefficients C_n and C_t are determined using the aerodynamic blade sections performances $C_n = C_n(\alpha)$ and $C_t = C_t(\alpha)$. The angle of attack α may be expressed as:

$$\alpha = \varphi - \beta, \qquad (3)$$

where β is the blade section pitch angle and φ is the angle between the plane of rotation and the reference relative velocity W. In the vortex line methods or BEM the flow angle is easy to evaluate because the axial induced velocity w_{ia} and tangential velocity w_{it} are known explicitly:

$$\varphi = \arctan\left[\frac{V_0 - w_{ia}(r)}{\Omega r - w_{it}(r)}\right], \quad (4)$$

where V_0 is upstream velocity and Ω is rotor angular velocity.

However, in actuator surface model the angle of attack α cannot be calculated explicitly because in the case of CFD modeling there is no means to separate the induced velocities in equation (4) from the rest of velocity field. Also the exact location, where flow angle must be calculated is not possible to define. Thus a different approach is needed to obtain the angle of attack.

The flow around the wind turbine may be presented as the sum of a non-perturbed flow and another flow induced by the rotor blades. Then, the induced velocity field by the rotor also may be presented as a sum of two components:

– Local induced flow, created by the presence of the blade airfoils.

– Global induced flow, due to the presence of the rotor like an actuator that extracts kinetic energy from the wind and that slows down the velocity of the mass of air, which passes through the disk.

Upstream of the blades sections, at a distance of some chord lengths, the flow is slightly perturbed by the presence of local blade section. Therefore for the reference place, where the velocity and angle of attack must be determined, it is acceptable to use one line located upstream of the blades, where the flow is slightly perturbed by the presence of blade sections. However, this line must be sufficiently close to the rotor plane of rotation to have the same global induced field.

Obviously, the proposed line is closer to the airfoil compared to the appropriate plane usually specified in "infinity". Therefore, for the same airfoil force coefficients the reference angles of attack are different and the airfoil performances must be corrected.

However, this approach is very advantageous when airfoil performances are known from experiment in case of rotating blades [6] or from numerical simulations. In this case the normal and tangential force coefficients are obtained after normalizing the blade forces with velocities measured close to the blade. Thus the results may be used immediately without any correction if the same reference place is used.

In the BEM module the obtained normal force from equation (1) permits to calculated the force applied to blade element. Usually, in the case of HAWT, the blade section tangential forces are low compared to normal forces and therefore may be neglected. Then normal force is used to calculate the pressure discontinuity along the chord. In order to make the velocity induced by this discontinuity more adequate, it is preferable to use a chordwise distribution proposed in [4]. The pressure shape is close to the thin flat plate pressure distribution but at leading edge the pressure have no singularity. The pressure is linear in the intervals between leading edge and 1/4 chord and also between 1/4 chord and trailing edge. The pressure value is $4p$ at the leading edge, p at the 1/4 chord and zero at the trailing edge. Hence, the normal force F_n is equal to pc and also the moment of pressure forces with respect to the point at 1/4 of the chord is equal to zero.

The hybrid model proposed, Fig. 1, is based on the CFD code Fluent 6.3 and the solution is obtained iteratively. In the CFD model, which computes flow field around the wind turbine, the blades are replaced by surfaces defined as "fan" boundary condition. This boundary condition corresponds to an imposed pressure difference between adjacent cells, located at the opposite sides of the boundary. Once at the beginning of the current iteration the CFD code executes a user-defined function UDF in C language. This function plays the role of the BEM solver and calculates the pressure distribution from blade geometry, rotor inflow and aerodynamic data of blade sections.

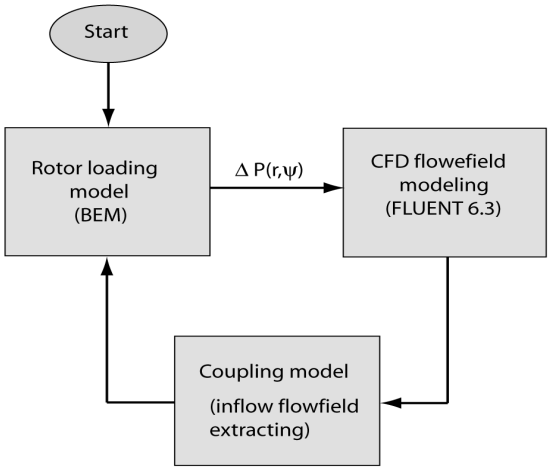

***Fig. 1**. Hybrid modeling*

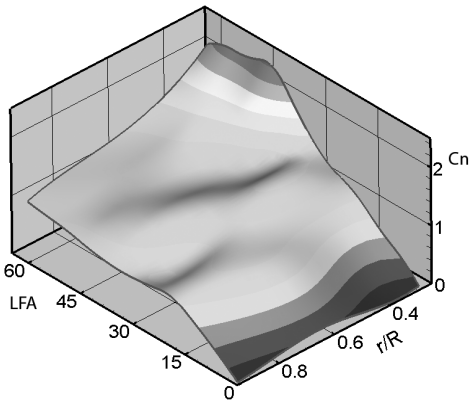

***Fig. 2.** Normal force coefficient along the blade radius depending of local flow angle*

The UDF function has access to all flow variables, which are needed to calculate the relative velocity vector along one reference line. Consequently, the normal force coefficient for all blade section along the span is interpolated from the blade geometry and airfoil data, Fig. 2. Then the resulting pressure is imposed on the

blade equivalent surfaces using the simplified pressure distribution. The solution is obtained after thousands of iterations depending of the number of nodes, demanded residuals, etc.

Numerical results

The studied wind turbine is the NREL Phase VI case. The turbine has two-bladed rotor of 10-meter diameter with blade sections of S809 airfoil [6]. The choice of NREL wind turbine was made because of its large experimental database obtained in NASA Ames wind tunnel. There are available inflow measurements at five blade radii for different upstream velocities between 5 and 25 m/s. For these five blade sections, there are also measurements of the pressure distribution both on suction and pressure side. These measurements permit to calculate for each upstream velocity the coefficients of normal force reduced with measured local velocity. For each upstream velocity corresponds different local flow angle (LFA) and using techniques of interpolation a two-dimensional function $C_n = C_n$ (LFA, r/R) can be created, Fig. 2.

It must be noted that the reference velocity is measured only at 0.5 chords upstream of the blade section leading edge. Thus, the local perturbation caused by the blade is relatively important. However, in [4] it is shown that the velocities induced by a line with pressure discontinuity are very close to the velocities induced by an airfoil upstream of leading edge for distances greater than 0.5 chords. This similarity between the induced velocities permits to apply the obtained experimental relations between the normal force coefficient and local flow angle directly without any correction.

During calculation in order to obtain the pressure distribution, for each node of pressure discontinuity surface the velocity, the LFA, the relative distance s/c from the leading edge and the relative radius r/R are determined, Fig. 3. Using the r/R and LFA, the force coefficients can be obtained from the experimental data, Fig. 2. Then using the distance s/c and the shape of chordwise pressure distribution it is possible to calculate the node value of pressure discontinuity that Fluent will apply as "fan" boundary condition.

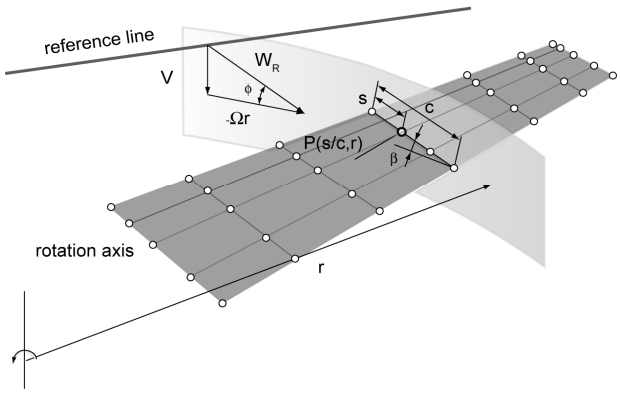

Fig. 3. *Blade representation*

The simulation model presents case "H" of the NREL test [6]. Here the rotor is in upwind position with blade tip pitch of 3° and average section Reynolds number about $1 \cdot 10^6$. A cylinder that has a radius of $3.316R$ represents the flow field around the wind turbine rotor with radius R. It has also the length of $6R$ upstream and of $25R$ downstream the rotor plane. Here the value 3.316 is used because it leads to the same ratio as between the wind tunnel cross-section and the area of the wind turbine rotor. Hence, experiments and numerical simulations have the same coefficient of blockage.

The actuator surface replacing the blade is represented by 4.000 nodes from the 500.000 ones used for the whole model. This surface is divided in the chordwise direction into 40 intervals, which are refined near the leading edge, where the pressure discontinuity gradient is strongest. In spanwise direction the blade is divided into 100 intervals equally spaced. The initial cells size in normal direction is 0.01 chords and the growth factor of 1.5 is used. To improve the wake calculation the mesh enclosed in a cylinder with length of $10R$ and diameter of $1.25R$ downstream the rotor is refined. The applied interpolation function, Fig. 2, for the normal force coefficients is based on the inflow measurements at five spanwise stations (r/R = 0.30, 0.47, 0.63, 0.80, 0.95) obtained for the case "H" [6]. To apply these data without any correction, the reference line passes through the same geometrical points where experimental coefficients are obtained.

Calculation is carried out iteratively. After numerous iterations, according to the number of the nodes and the required residual value, the convergence process is achieved. Usually, the computed rotor power reaches a constant value quickly, but additional iterations are needed to obtain the wake development.

The comparison between wind turbine performances obtained experimentally and numerically by means of actuator surface is presented in Fig. 4 for the power and Fig. 5 for the axial trust. Some incertitude is involved because it is difficult to extrapolate the force coefficients near tip and root regions. To overcome this problem, more experimental or additional CFD results are needed. It must be noted that the numerical result for the power is close to measured values for upstream velocities up to 12 m/s. The disagreement in case of high velocities is due to the fact that the effect of "centrifugal pumping" is not modeled. In this case the flow in vicinity of the blade ends becomes highly three-dimensional and the hybrid model is non-adequate, similarly of all models that use the airfoil performances. However, it is useful to employ a correction for the circulation distribution near the blade tip and root region and also for the induced velocity angles. The comparison between the measured and the computed angles of local flow is shown in Fig. 6. The obtained results are good but there exist some discrepancy near the root, where the effect of "centrifugal pumping" is important.

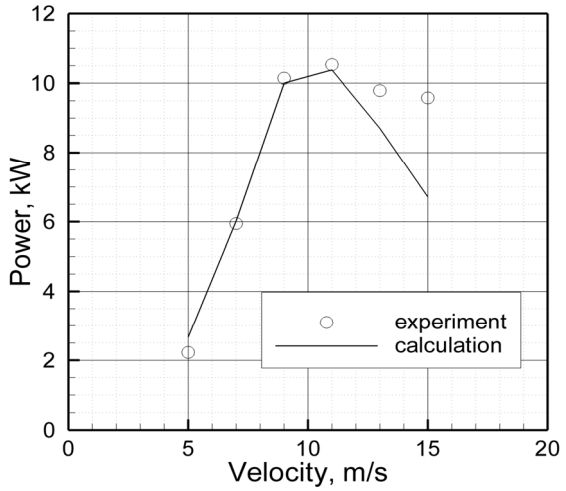

Fig. 4. *Wind turbine power*

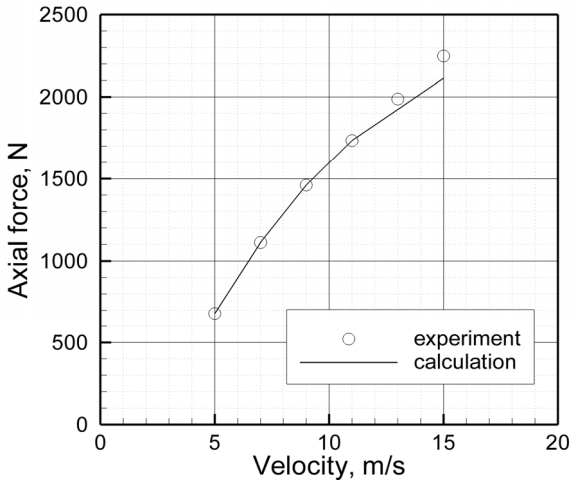

Fig. 5. *Axial force*

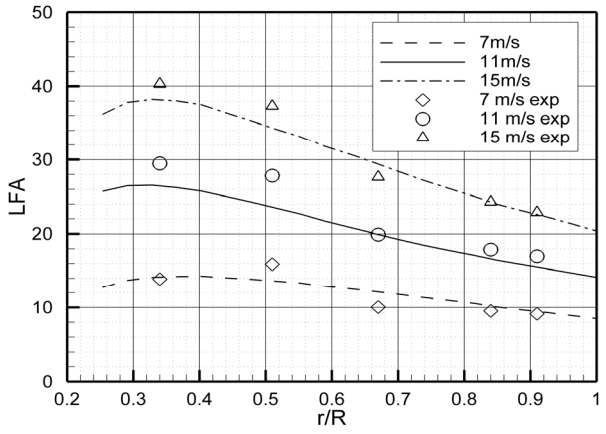

Fig. 6*. Local flow angle along the blade span*

Conclusion

In this paper the new hybrid model based on the actuator surfaces is proposed for simplified CFD calculation of the flow around wind turbine rotors. The objective is to validate the feasibility of this model to calculate the aerodynamic performance of rotor. The rotor is simplified; the blades are replaced by thin surfaces constituted by the blade mean surfaces. Thus, the surface that replaces blade has the same pitch angle and chord as the original. On these surfaces, a pressure discontinuity is applied. This discontinuity is similar to thin flat plate chordwise pressure distribution, but without singularity in the leading edge point. The applied pressure discontinuity is calculated from aerodynamic properties of the blade section airfoils, the local flow angle and local velocity. Compared to active line model the present model improve the initial conditions of the wind turbine wake development because chordwise pressure is variable. Also the pressure discontinuity is comparable to that created by the real blade. This permits to create a velocity field similar to that around a blade section with the same normal force coefficient.

In the case of wind turbine simulation the actuator surface model is capable to reproduce rotor mechanical power and forces, but for high wind velocity some disagreement with experimental results is revealed. This is due to fact that in case of high wind velocity the flow is detached. Therefore the flow is highly three-dimensional and the actuator surface model is non-adequate.

The suggested model here has two significant advantages compared to the other hybrid models. The first advantage is the possibility of using the 3-D airfoil data without applying any correction. The second advantage is that the velocity field downstream the blades is closer to reality compared to the models that use actuator disk or actuator line. Compared to the CFD methods, which use the complete three-dimensional rotor geometry, this model have the advantage of using a limited number of nodes. Hence, the size of the model is now suitable for studying wind farm design.

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STUDY OF THE REGULATION OF A MICRO HYDROELECTRIC POWER PLANT PROTOTYPE

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In this article we present the study of the regulation of a micro hydroelectric power plant (MHPP) prototype. The Prototype is installed in our laboratory in the Faculty of Science and Technology. A model of the MHPP was developed with simulink based on some of our preceding works. The downstream regulation ensures good frequency regulation results. The used controllers are the "P" and "PI". The practical results obtained are not far from those in simulation. Measurement and the command are done by an acquisition card controlled by computer.

Keywords: micro hydroelectric power plant, modelling, regulation, simulation.

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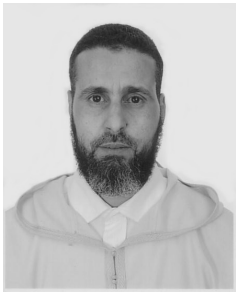

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Introduction

A Micro Hydroelectric Power Plant (MHPP) is equipped generally with an upstream hydraulic system which forwards water to the turbine equipped with a motorized injector which controls the turbine's flow. The MHPP is coupled with a generator that supplies a mini electrical network. The regulation system must guarantee a good level of voltage with an industrial frequency (50 Hz). In the event of low consumption, it act on the opening of the injector to adapt the production to the needed power. The surplus of energy is switched on a resistance. Some departures are disconnected in the moment of overload.
In this article, we present a model of the MHPP developed with simulink [1, 2]. The simulation results of the downstream regulation are compared with the practical ones used on a prototype of the MHPP. The downstream regulation used on the prototype uses a resistance of dissipation controlled by an electronic variator. Measurement is made by a acquisition card and the regulations used are P (proportional) and PI (proportional and integral) implemented in computer and control permanently the system.

Description of the MHPP

Real MHPP

The upstream hydraulic part of the MHPP consists of [3]: water supply on a river, a feeder canal, a regulation basin, a pressure pipeline whose section is accorded to the flow and the available power.

Nozzles direct water jet against a series of spoon-shaped buckets mounted around the edge of a turbine. The system ensures the hydraulic energy transformation into mechanical energy. The wheel of the turbine is coupled to a generator. The general diagram of this system is represented in Fig. 1. The servo-motor related to the nozzle must be relatively slow to minimize the water hammers effect.

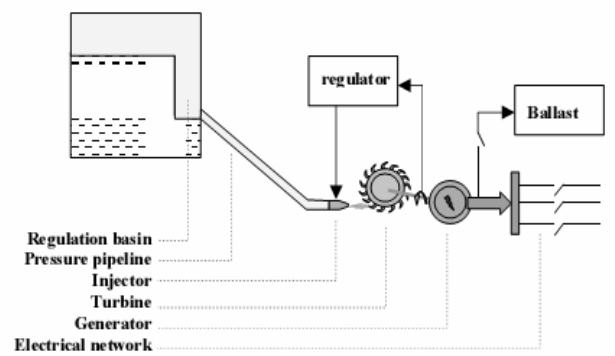

Fig. 1. *Synoptic diagram of a micro hydroelectric power plant*

Description of the MHPP prototype

The nominal values of the system parameters are:

Electric power:	185 W
Frequency:	50 Hz
Voltage:	220 V
Flow:	10 l/s
Speed of racing:	1400 tr/min

The installation allows to impose a variable flow between 0 and 20 l/s. The functional plan of the installation is represented in Fig. 2. The used turbine is of type "Pelton". The generator is a synchronous machine which feeds directly a load formed by lamps. The frequency is measured by a frequency sensor "ARDETEM DIP 605". The numeric regulation is done using an acquisition card. The actuator is an analogue power controller "Type ACI 30-1". In the Fig. 3, we give the real system prototype photo.

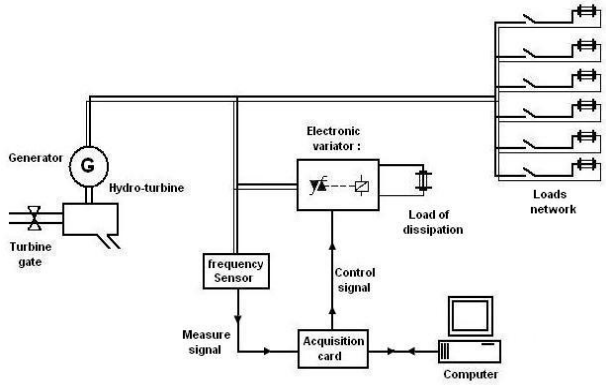

Fig. 2. *The functional plan of the installation*

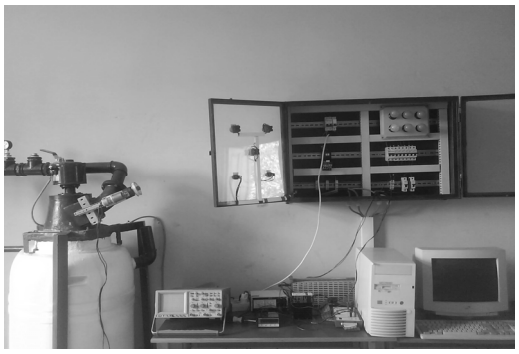

Fig. 3. *The real prototype*

Modelling of the MHPP

Model of the Pelton turbine

The Pelton turbine is used for the high falls and small flows. It Consists of a set of specially shaped buckets mounted on the periphery of a circular disc. It is turned by jets of water discharged from one or many nozzles which strike the buckets (see Fig. 4).

The flow is adjustable using a mobile needle inside the nozzle, which is moved by an electric servo-motor.

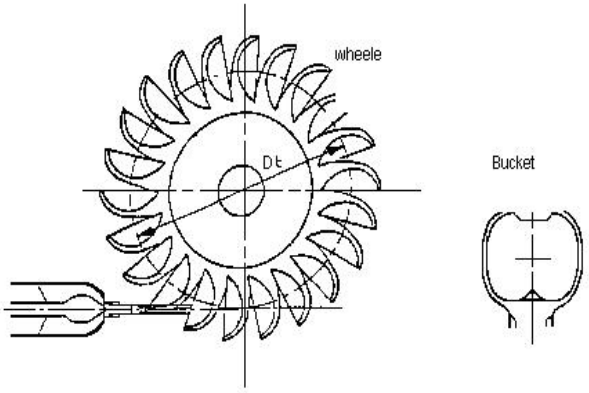

Fig. 4. *The geometrical shape of a Pelton turbine*

The water fall power is given by:

$$P_t = \rho g Q_t H_e \qquad (1)$$

with: P_t – turbine power [W], Q_t – water flow of the turbine [m^3/s], g – gravity acceleration [m/s^2], ρ = = 1000 kg/m^3 – water's density, H_e – effective high [m].

The parameter H_e in (1) is calculated by the following expression [2, 4, 5]:

$$H_e = \frac{U}{g}(V_1 - U)(1 + m\cos\beta) \qquad (2)$$

with: U – drive speed of the turbine, V_1 – water speed in the contact of the jet with buckets, m – report of V_1 and V_2 the water speed at the exit of the bouckets, β – angle between $\vec{V}_1$ and $\vec{V}_2$.

The torque provided by the turbine is:

$$C_t = \frac{P_t}{\Omega_t} \quad (3)$$

with: Ω_t – angular speed of the turbine (rd/s).
The linear speed of the turbine expression is:

$$U = \Omega_t \frac{D_t}{2} \quad (4)$$

with: D_t – Diameter of the turbine (m).
With the relations (1) – (4) we obtain:

$$C_t = \rho Q_t \frac{U}{\Omega_t}\left(V_1 - \frac{D_t}{2}\Omega_t\right)(1 + m\cos\beta). \quad (5)$$

In this paper we use the "IS" unities for the physical values and the reduced sizes "per unit system: pu" for the model.
q_t – Turbine flow (pu), γ_t – Jet speed (pu), n_t – Turbine speed (pu), c_t – Turbine torque (pu), Q_{tn} – nominal flow of the turbine (m^3/s), C_{tn} – nominal torque of the turbine (N.m), V_{1n} – nominal speed of the jet (m/s), Ω_{tn} – nominal speed of the turbine (rd/s).
The relation (5) becomes:

$$c_t = \rho q_t Q_{tn} \frac{D_t}{2C_{tn}}\left(\gamma_t V_{1n} - \frac{D_t}{2}\Omega_{tn} n_t\right)(1 + m\cos\beta). \quad (6)$$

We note:

$$k_t = \frac{D_t \Omega_{tn}}{2V_{1n}}. \quad (7)$$

For nominal values: $q_t = 1$; $\gamma_t = 1$; $n_t = 1$; $c_t = 1$.
From the relations (6), (7) we can write:

$$Q_{tn} = \frac{2C_{tn}}{\rho D_t V_{1n}(1 - k_t)(1 + m\cos\beta)}. \quad (8)$$

Replacing Q_{tn} in (6) by its expression in (8) we end at:

$$c_t = \frac{q_t(\gamma_t - k_t n_t)}{1 - k_t}. \quad (9)$$

The turbine power is given by:

$$p_m = c_t n_t. \quad (10)$$

By considering some approximations, we have:

$$V_1 = \sqrt{2gH_t}, \quad (11)$$

where H_t the effective fall is given by:

$$H_t = h_t H_{tn} \quad (12)$$

with: H_{tn} – nominal fall, h_t – effective fall in "pu".
The relation (11) is written by using "pu" units as:

$$V_1 = \gamma_t V_{1n} \quad (13)$$

from where the expression of the turbine speed in (pu) is:

$$\gamma_t = \sqrt{h_t}. \quad (14)$$

The turbine can be represented by the following model (Fig. 5):

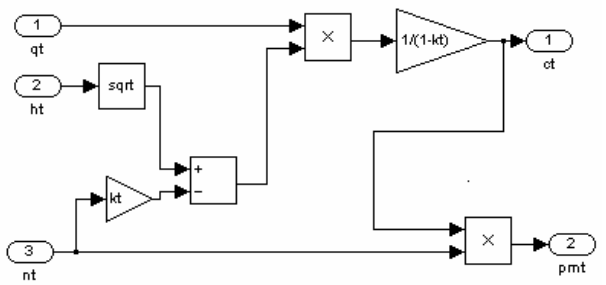

Fig. 5. *Simulink model of a Pelton turbine*

Model of the injector

The injector is formed by a needle which moves in a conical form, its model is obtained by calculation of the area trough which the water jet passes [4, 5]. By taking an injector with the following form (Fig. 6):

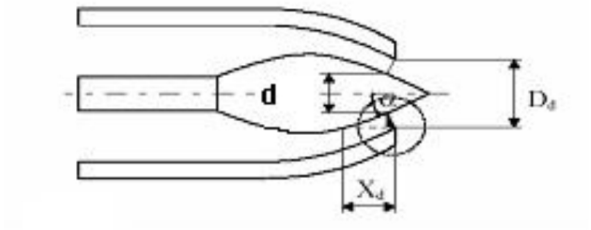

Fig. 6. *Diagram of an injector*

The surface by which water passes is:

$$S_d = \pi \frac{D_d - d}{2} X_d \sin\alpha \quad (15)$$

with: D_d – external diameter of the injector, d – tangential diameter of the needle with the opening of the injector, α – aperture angle of the punch, X_d – opening in meter of the punch (advance).
However:

$$d = D_d - 2X_d \cdot \sin\alpha \cdot \cos\alpha. \quad (16)$$

By replacing d in (16) we obtain S_d:

$$S_d = \pi \sin\alpha\left(D_d X_d - X_d^2 \frac{\sin 2\alpha}{2}\right). \quad (17)$$

The flow in the turbine is:

$$Q_t = S_d V_1. \quad (18)$$

In pu, surface S_d and the needle advance X_d are expressed by:

$$S_d = s_d D_{dn}, \quad (19)$$

$$X_d = x_d X_{dn}. \quad (20)$$

By combining the relations (19), (20) and (17) we end:

$$s_d = \frac{\pi D_d X_{dn} \sin\alpha}{S_{dn}} \left(x_d - k_d x_d^2\right) \quad (21)$$

with: $$k_d = \frac{\sin 2\alpha}{2D_d}^2 X_{dn}. \quad (22)$$

For nominal values: $s_d = 1$; $x_d = 1$ we have:

$$1 = \frac{\pi D_d X_{dn} \sin\alpha}{S_{dn}} (1 - k_d). \quad (23)$$

Thus:

$$S_{dn} = \pi \sin\alpha D_d X_{dn} (1 - kd). \quad (24)$$

After replacing S_{dn} by his value we will have:

$$S_d = \frac{x_d (1 - k_d x_d)}{1 - k_d}, \quad (25)$$

and:

$$q_t = S_d \gamma_t \quad (26)$$

from where the following model of the injector (Fig. 7):

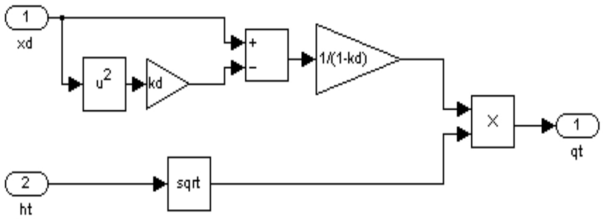

Fig. 7. *Simulink model of the injector*

Regulation of the MHPP and simulation results

Speed regulation of the MHPP

The regulation of a MHPP consists in maintaining fixed the frequency of the electrical network by action on the injector position [2, 5, 6]. This usual regulation is represented in Fig. 8.

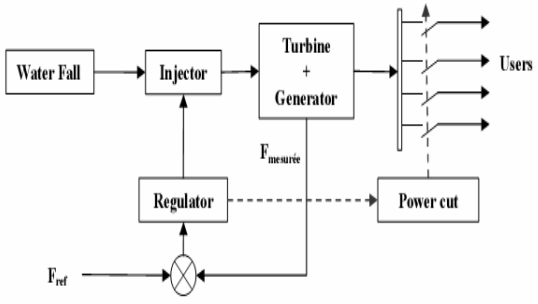

Fig. 8. *Synoptic of an upstream regulation with PID*

The regulation based on a simple PID becomes insufficient in case of an important discharges [5, 7] (see Fig. 9). At the moment of important overload, the needle's speed saturates and generates oscillations of frequency. The stability of the system can be completely lost as show in Fig. 10, 11.

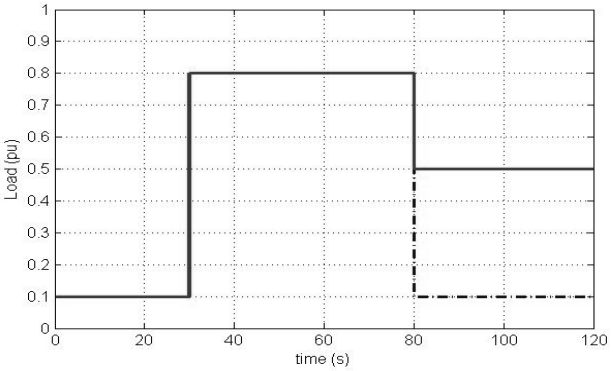

Fig. 9. *Charge and discharges implemented to the turbine: discharge from 70 % (dotted line) and 30 % (solid line)*

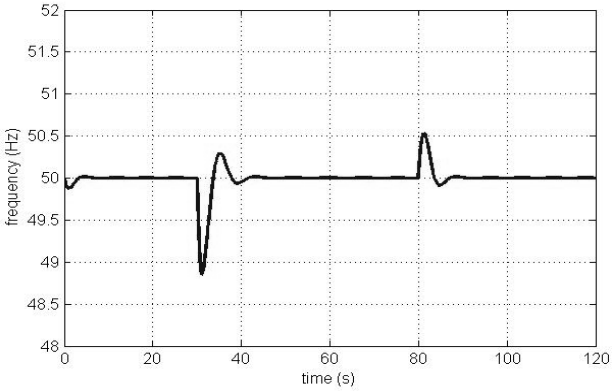

Fig. 10. *Upstream regulation with PID: stability for the small discharges*

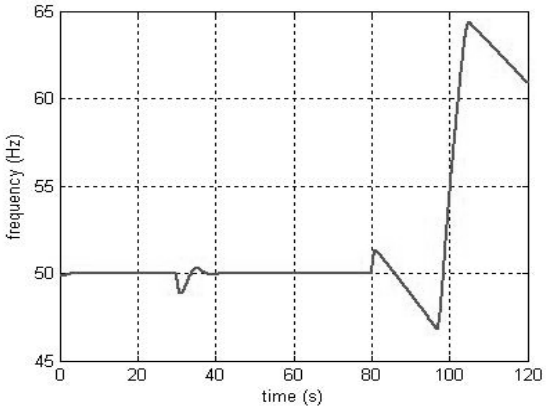

Fig. 11. *Upstream regulation with PID: instability for the important discharges*

Downstream regulation

The downstream regulation is used in order to simplify the MHPP regulation systems and to limit damages caused by the motorized injector [8]. It consists in putting a resistance of dissipation in parallel with the

mini electrical supply network (see Fig. 2). The regulator ordres an electronic variator whose time reponse is very short, that makes it possible to absorb immediately the disturbances of the netwark and guarantee a better stability.

The injector is opened to the maximum then the stability is obtained by the dispatching of the electrical power between the load and the resistance of dissipation.

The P controller gives good simulation results with a tiny static error. PI controller cancels the static error and gives good simulation results [9-10] (Fig. 12).

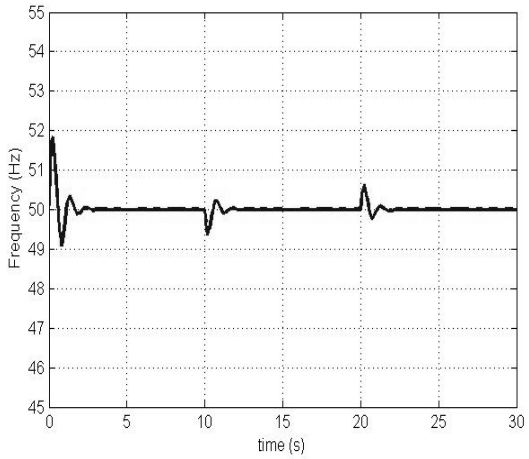

Fig. 12. *Downstream regulation with PI controller: stability after an important discharge at 20 s*

Practical results and discussion

The practical study is made on MHPP prototype described previously. The electrical load will be considered as a disturbance. It causes the variation of prototype's output (Frequency), as shows in the following Fig. 13.

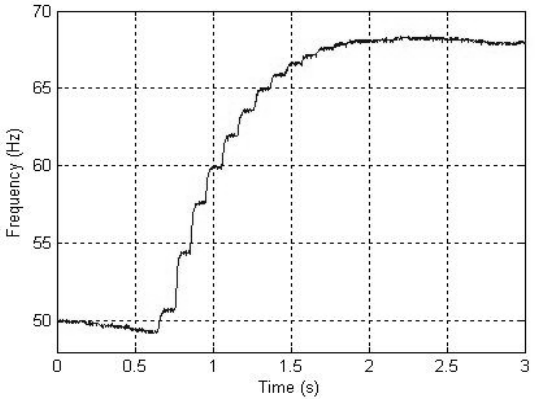

Fig. 13. *Evolution of real system's output after a variation of disturbance (P = – 85W) in open loop*

The functional plan of our system regulation which we proposed, is given by the Fig. 14. The Fig. 15 shows the components of the real chain of regulation.

Simulation with measured or calculated parameters of the MHPP, gives good result of regulation.

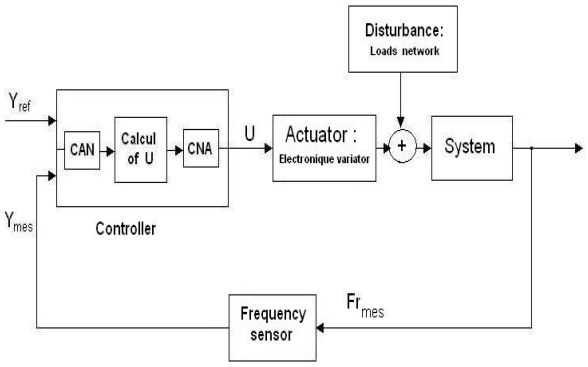

Fig. 14. *Functional diagram of the regulation chain*

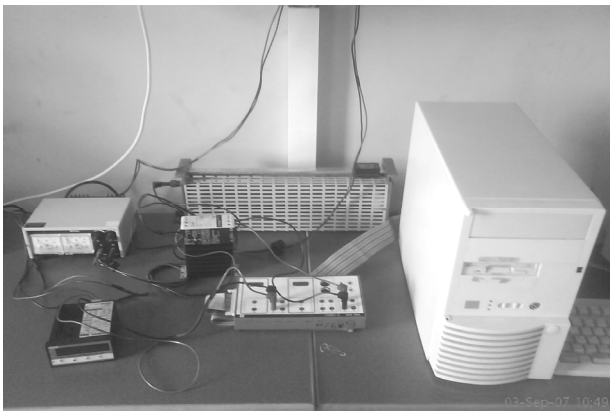

Fig. 15. *The real chain of regulation*

regulator gives an excellent frequency response after an important discharge (see Fig. 12).

This is practically confirmed with the MHPP prototype (see Fig. 16). The system finds stability in approximately 2 s after the important discharge at 0.3 s and the important overload at 5 s.

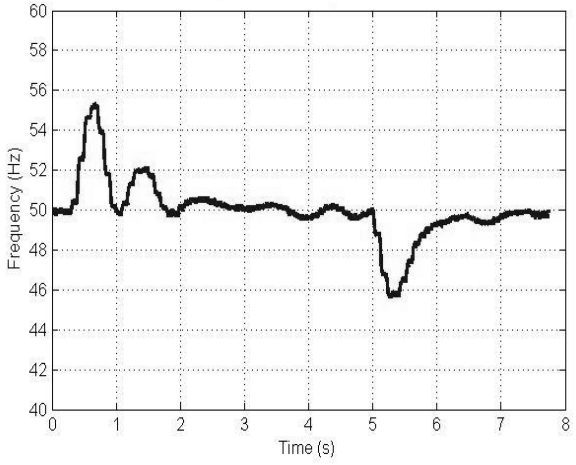

Fig. 16. *Downstream regulation with PI (MHPP prototype): stability after the important discharge at 5 s*

Conclusion

Hydroelectric energy is renewable, clean and free. Its exploitation requires good regulation systems to produce alternative current with an industrial frequency (50 Hertz). The simulation allows us to test various techniques of regulation: upstream regulation, mixed and downstream regulation.

The technique tested practically and in the simulation is the downstream regulation. It gives good results with few equipments.

The prototype allows the realization of the simulation; the obtained results are satisfying with a PI controller. The regulation is implemented on a PC connected to an acquisition card. Our system can be installed on the existing MHPP and ensure an alternative replacement solution of the complicated and irreparable systems after failure.

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CHEMICAL AND PHYSICAL ACTIVATION OF OLIVE-MILL WASTE WATER TO PRODUCE ACTIVATED CARBONS

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Olive-mill waste water is produced in large quantities during the manufacture process of the olive oil in mills. This by-product has been used as raw material to produce activated carbons by both chemical and physical activation methods. In the first case, $ZnCl_2$ and H_3PO_4 were used as activating agent and in the second case, CO_2 at 600 °C for different periods of time. Obtained results indicate that the chemical activation with $ZnCl_2$ and H_3PO_4 at 600 °C, in an inert atmosphere, yielded activated carbons with the highest area and more developed microporosity, mesoporosity and macroporosity. Adsorption of rate of phenol onto activated olive-mill was studied as a function of several physical-chemical parameters such as temperature, initial concentration in solution and hydrodynamic conditions. Equilibrium parameters of adsorption have been determined using Langmuir constant K.

Keywords: adsorbent, valorisation, olive-mill, activated carbon, waste

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Introduction

The origin of our research has as valorisation of olive-mill in the field of effluent treatment. This waste is produced each day in huge quantities in several countries and rejected in the nature. But, currently, there is no specific utilisation for it. This type of waste has, however, all the characteristics needed to be processed by means of chemical and heat treatments, in order to produce an adsorbing material valuable in different fields because of its physical structure, its adsorbent carbon compounds and the polar and non-polar properties of its constituting molecules [1]. We have then noticed that the activated material presents an important adsorbing power toward organic compound. We decided therefore to apply this type of valorisation in the domain of liquid effluents purification. Furthermore, this type of treatment could be used with several other waste products of vegetal origin.

We must emphasise also that activated carbon is a substance of great interest, its adsorbing properties are used in to separate mineral and organic compounds or to purify liquid solutions by extraction of pollutants [2, 3]. There are numerous industrial applications for this product such as water treatment, sugar refining and precious metal recovery [4]. Activated carbon can also be used for the adsorption of numerous trace organic compounds present in treatable drinking water such as chlorinated phenol after pre-chlorinating [5, 6, 7].
Nowadays, industrial water rejects containing large quantities of phenol are of great concern. During normal activity, a refinery can reject 0,5 mg/l of phenol whereas catalytic cracking of hydrocarbons can reject up to 1 mg/l [8] knowing that the allowed phenol concentration in drinking water is up to 0,001 mg/l [9].
Among the interesting references dealing with adsorption of phenol on activated carbon, are those of the analysis of adsorption isotherms at different temperature putting into evidence a physical process [10, 11].

The making of activated carbon can be done from different materials: woods, coconut, pets, mineral carbon, bone and blood [12, 13]. Commercial activated carbons are activated under atmospheres of CO_2, O_2, vapour of water or other gases at temperatures between 800 °C and 1100 °C [14, 15] or by chemical activation using oxidising agents such as: H_2SO_4, H_3PO_4, HCL, NaOH [16, 17] burned after exposure to temperatures between 300 °C and 700 °C. The activation of activated carbons causes the elimination of volatile substances and a partial internal consumption giving therefore important physical and chemical properties. Activated carbons present at their surface some functional groupings dependent on their preparation mode [18] which can be considered as adsorption sites of ions.

The objective of this work is to valorise olive-mill in the field of water treatment. We have been particularly interested in adsorption of phenol. We will present the results obtained successively for this purpose during the study of conditions of the phenol adsorption realised under static system. We would like to point out that preliminalary to this study a work has been done to adapt an experimental protocol of activation. Conclusions hence established have allowed us to do our experimentation on adsorption of phenol using activated olive-mill with a maximum of information.

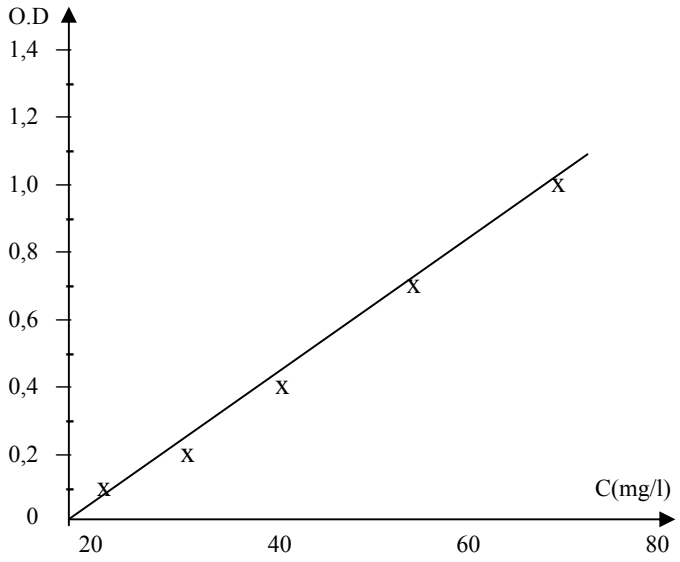


Fig. 1. *Evolution of the optical density (O.D) against phenol concentration (mg / l)*
(C varying 0 to 60 mg / l and O.D of 0 to 1,2 to pH = 8,5)

Experimental part

Products

Activated carbon (A) used comes from a MERCK granulated carbon (diameter between 0,4 and 1,7 mm) that has been grounded, and sifted to get a particle size below or equal to 50 µm. The dimension of the specific area given by the manufacturer is 1100 m^2/g, determined by B.E.T. The dimension of the specific area determined by a micro-calorimeter [19] is 1075 and the meso-porous volume between 2 to 50 nm would be 37 % [20].

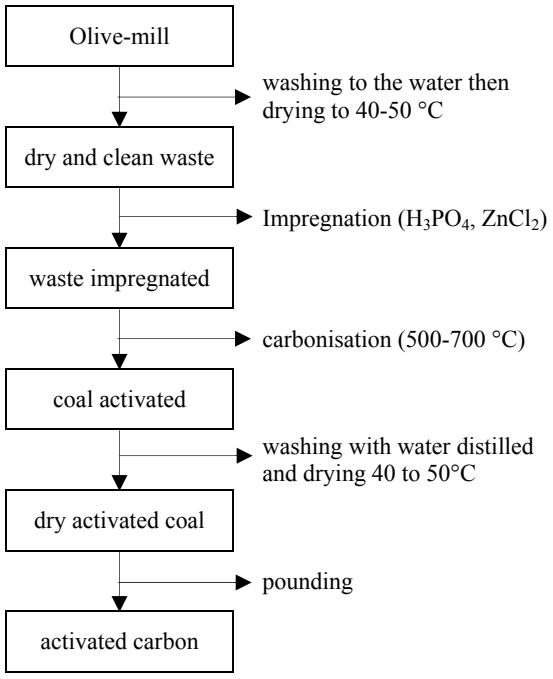
The activated olive-mill is finely pulverised and sifted in PROLABO equipment with AFNOR standardised sieves. The particle size is then less or equal to 50 µm. Since low concentrations of activated carbon and small size particles have been used, there has not been any noticeable change in particle size of olive-mill at the end of the experiment. The phenol used comes from a PROLABO pure product (99 %).

Titration

The olive-mill is mixed at 1/4 (W/W) with a blend of chemical agents of activation (H_3PO_4 + $ZnCl_2$), and burned at 600 °C in muffle furnace for 30 min. Assays in series of adsorption (of power activated carbon) are done on 1 l distilled water volumes (pH = 8,5) containing phenol at different concentrations. The mixture is stirred in an air free container and after a given period of time, filtered in a mill-porous filter. The residual concentration of phenol C_R is determined by spectrophotometer. A standard curve (Fig. 1) is then drawn by optical density (OD) at 269.7 nm of aqueous solutions of phenol at different concentrations (0 to 60 mg / l).

Preparation process of activated carbon

The raw material used is a waste of olive-mill. This product must undergo several treatments that will affect drastically its physical-chemical properties which become more efficient to the de-pollution of waters.



Schema. *Preparation process of activated carbon from coffee grounds*

Adsorption capacity of the activated olive-mill

The adsorption capacity depends on several parameters. Hence, in order to understand the mechanisms of optical usage of the adsorbent, it was necessary to study the effects of these parameters. Some assays on activation of olive-mill have taken place and given the following results.

– Carbonisation temperature 600 °C

– Carbonisation time period 30 min

– The mass ratio $\frac{\text{coffee grounds quantity}}{\text{oxidising agent quantity}} = \frac{1}{4}$

Consequently, this material has become able to adsorb solutes because:

– of its physical structure (as a result of heat and chemical activation): the macro-porous allows diffusion of solutes. Small particle size gives the material an important specific area.

– of its chemical structure for:

- the presence of numerous functional chemical groupings capable of establishing links.
- polarless characteristics of coffee grounds macromolecular allowing hydrophobic interactions with other molecular.

This activated material should have a great affinity with organic solutes such as phenol.

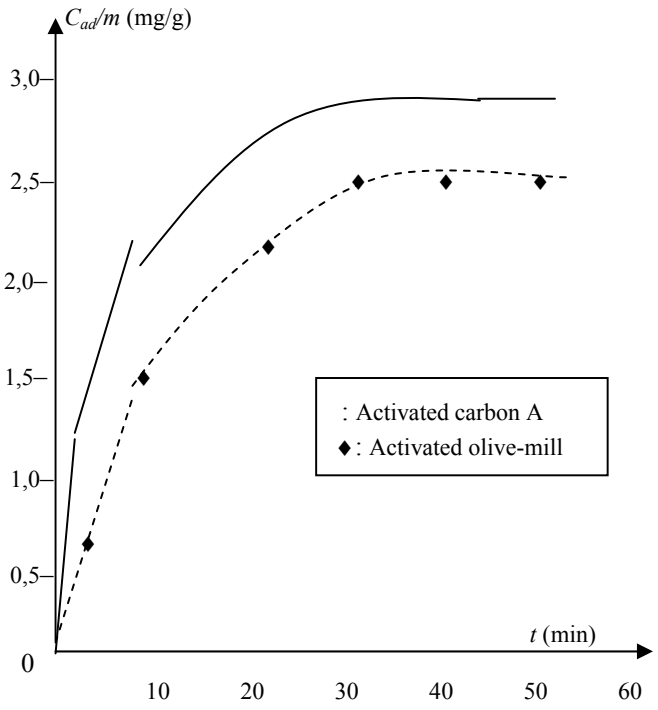


Fig. 2. *Adsorption kinetic of phenol: Evolution of the adsorbed quantity C_{ad}/m against time (C_0 = 30 mg/l; m = 1 g)*

Adsorption protocol

Experiments on adsorption have been done in discontinuous "batch process". It is by treating constant volume solutions of different concentrations of pollutants prepared with distilled water and pure pollutant (from 1 to 30 mg/l) with a constant quantity of activated carbon (1g) that we obtain different residual quantities in solution (C_R). For this purpose we stir the solution and activated carbon during a period of time corresponding to a pseudo-equilibrium, at a constant temperature, we separate the adsorbing material by filtration.

Results and discussion

Kinetic study

From experimental results of the adsorption, we obtain the adsorption kinetic C_{ad}/m against time (Fig. 2). The examination of both curves puts into evidence the affinity of such compound with both adsorbing materials (activated carbon A and activated olive-mill); the equilibrium is obtained after 30 to 40 min. This can lead to the conclusion that not only retention on hydrophobic sites is easier but also that there is a further interaction of the electron donor-acceptor between aromatic cycles of the graphitic network and those of phenol. The hydrophobic adsorption is obtained by a horizontal orientation of the solute at the surface of the substrate in such a manner that the number of hydrophobic interactions between solute and substrate is maximum. The curve therefore presents a horizontal levelling corresponding to the formation of a single layer of solute at the surface of the material.

Effect of temperature

Fig. 3 shows a marked effect of temperature on the rate of adsorption. The influence of this parameter is highly significant. The temperature increase disturbs the existing physical forms. It affects mainly the adsorption equilibrium of the activated coffee grounds. Furthermore, this parameter acts on the structure of the substrate. Its increase causes pores expansion. In such conditions, the solute diffuses more easily in the material and the adsorbing area increases. Hence, the number of adsorbing sites increases. These must therefore be as much important as the molecule of solute is big, to allow its diffusion. Improvement of phenol fixing when the temperature increases can be explained by intervening of endothermic-bonds such as hydrophobic interactions. Note that this influence of temperature appears between 15 and 25 °C as well as between 25 °C and 40 °C even though the increase in temperature is lower.

These results are in accordance with those on adsorption of phenol type compounds [21] that show their great adsorbing power on either granulated or powdered activated carbon. However, the result is reversed when the adsorbing material is more polar (i.e. carbonised wool) hence increasing retention capabilities of polar molecules.

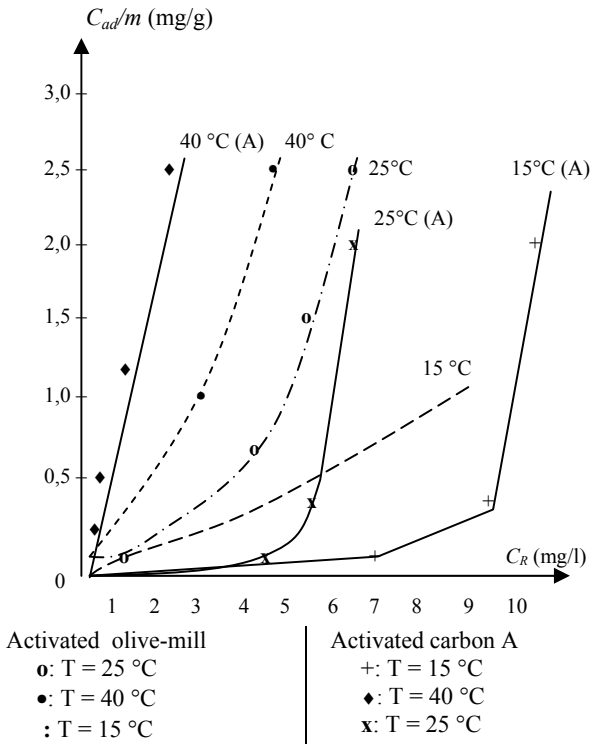


Fig. 3. *Saturation curves of the activated olive-mill and activated carbon A by phenol at varying temperatures*

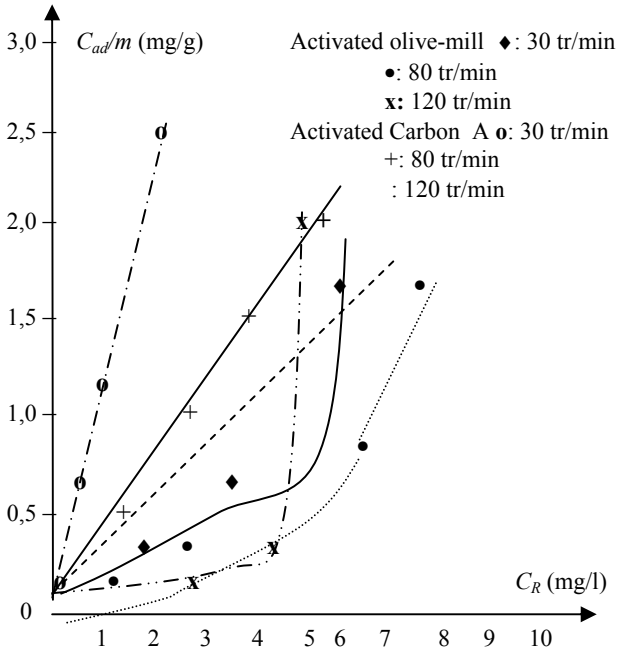


Fig. 4. *Saturation curves of the activated olive-mill and activated carbon (A) with variable stirring speed*

Effect of stirring

Examination of experimental results shows that the greater the adsorbed quantity of phenol, the higher the speed of agitation for a given concentration.

This can be explained by the fact that the speed reduces the limit layer of the system and increases therefore, the external diffusion of mass flow.

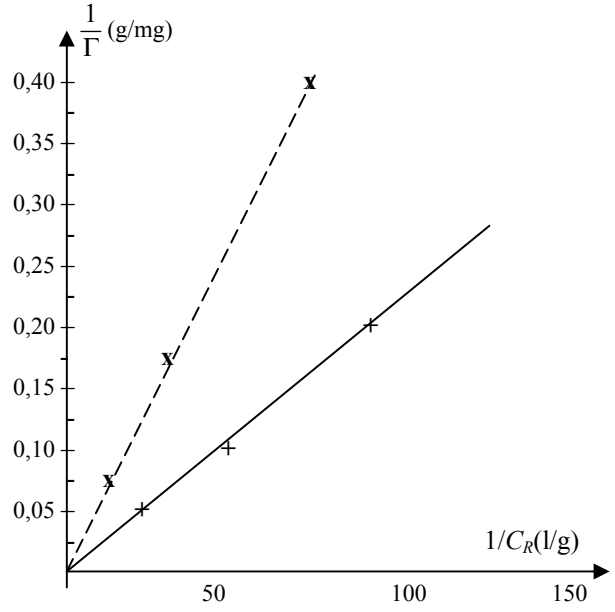


Fig. 5. *Langmuir isotherm in reverse co-ordinates invert: evolution of $1/\Gamma$ against $1/C_R$ for phenolics of initial concentration: C_0 = 10 mg/l of the temperature (+: 22 °C and x: 40 °C)*

The different isotherms obtained during adsorption assays of phenol are drawn on Fig. 5 and the Γ^{∞} values and K are reported in Table 1.

Table 1

The extrapolated ultimate values adsorption capacity Γ^{∞} from the Langmuir isotherms for different temperatures and the values of the K constant corresponding to the adsorption equilibrium

Temperature, °C	Langmuir		Freundlich	
	Γ^{∞} (mg/g)	K (l/g)	K (l/g)	1/n
22	27,77	9,61	121,50	0,65
40	42,86	52,64	104,58	0,527

Thermodynamic study

Determination of the enthalpy or heat of adsorption:

Assumptions:

$1 < H_{ads} < 10$ Kcal (physical-sorption)

$10 < H_{ads} < 25$ Kcal (chemical-sorption)

The heat of adsorption is determined by a relationship linking the constant relative to the adsorption energy K and the temperature T which is given by:

$$K = K_0 e^{\frac{-H_{ads}}{RT}}, \quad \mathrm{Ln}k = \mathrm{Ln}K_0 - \frac{H_{ads}}{RT},$$

where R – Perfect gas constant (cal/mol.°K), T – absolute temperature (°K).

In drawing Ln*k* against 1/*T*, we get a straight line the slope of which can determine ΔH_{ads} and the ordinate at the origin allows us to calculate adsorption entropy ΔS_{ads} (Fig. 6).

The slope of this line is ΔH_{ads} = 11.40 Kcal / weak.

According to the value ΔH_{ads}, we can conclude that the adsorption is chemical where reactions in the surface are endothermic, which confirms our previous results (effect of temperature).

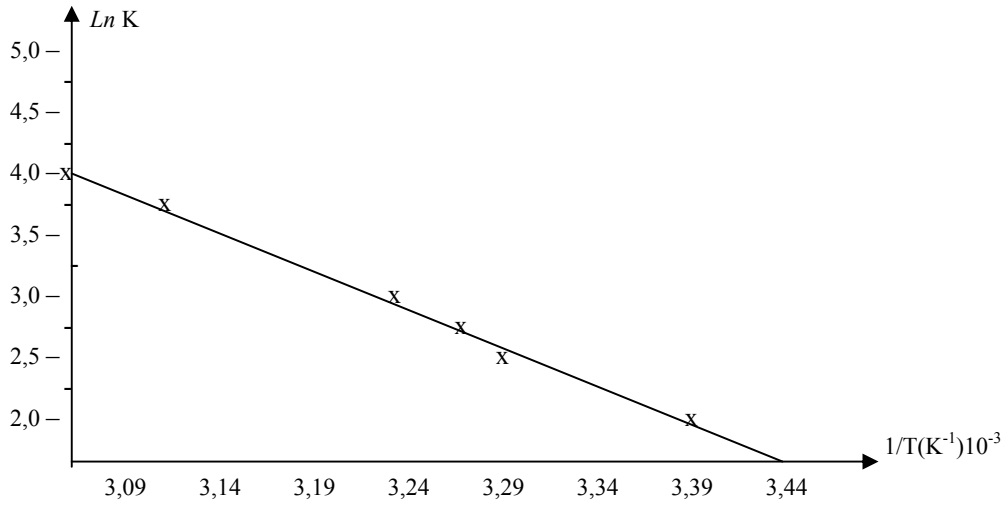


Fig. 6. *Determination of the heat of adsorption*

Conclusion

The olive-mill, considered up until now as waste, can be valorised by adapting an activation protocol in view of its use in the field of liquid effluent treatment. In this study, we have focused on the adsorption of phenol with concentration levels usually found in waters by using powdered activated olive-mill. The experimental results obtained under static conditions show a great retention power of phenol on activated olive-mill, which leaves us to suppose the existence of specific interactions between aromatic compounds and the graphitic network of substrate. However, the adsorption capacity of this material remains low compared to the commercial activated carbon. The experimental assays we have done have given good results and show that the activated olive-mill has a significant de-polluting action and its use could offer real advantages. The extension of these results to other food industry wastes is promising as far as the application of this type of valorisation to all food industry wastes is concerned.

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EFFECT OF THE STRONG MAGNETIC FIELD ON THE MOTT-VARIABLE RANGE HOPPING PARAMETERS IN *N*-TYPE COPPER INDIUM DISELENIDE

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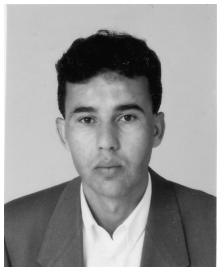
We have measured the electrical resistivity ρ and the magnetoresistance in *n*-type $CuInSe_2$ samples with dopant concentration below the critical concentration for the metal insulator transition. Electrical conduction by variable range hopping (VRH) mechanism of Mott type is observed below 20 K in the same sample of *n*-type $CuInSe_2$. The strong magnetic field dependence of the positive magnetoresistance, which shows a saturation behaviour, is analyzed with the existing theoretical models. Good agreement with the theory of the variation of the Mott VRH parameters T_0 and ξ with B is found up to 35 T from the analysis of the interpolated magnetoresistance data obtained from the linearly extrapolated plot of Ln $\rho(B)/\rho(0)$ against $B^{1/3}$. This suggests that the departure of the hopping parameters from the expected variation with B above 10 T is due to the effect of saturation of the magnetoresistance whose origin is not yet clear.

Keywords: semiconductor, variable range hopping, magnetoresistance



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Introduction

The electrical conductivity of *n*-type $CuInSe_2$ (CIS), a promising material for opto-electronic and photovoltaic devices [1-3], down to liquid helium temperature in the variable range hopping (VRH) of Mott type and metallic conduction regimes are studied extensively [4-6]. Experimental efforts have been concentrated mainly to study in the low temperature range the magnetic field and temperature dependence of both negative magnetoresistance (NMR) observed at lower fields and positive magnetoresistance (PMR) observed at higher fields. Strong evidence supporting the validity of quantum interference model, that explains the origin of NMR in very low fields, is observed [7]. At higher fields, above the critical field B_c that defines the crossover from the weak to strong field regime, the PMR can be explained quite satisfactorily by the expression proposed by Efros and Shklovskii [8] that takes into account the shrinkage of the wave functions. It is also observed that at low temperatures the magnetoresistance at very high fields ($B >> B_c$) tends to saturate [4]. This saturation of the magnetoresistance, whose origin is not yet clear, has strong effect on the magnetic field dependence of the localization length ξ.

Continuing our earlier works on Mott type VRH conduction in *n*-CIS [4-7], we report in the present paper a detailed analysis of high field magnetoresistance data up to 35 T in the temperature range between 1.9 and 20 K. The effect of saturation of the magnetoresistance on the localization length is discussed. The results are compared with the existing theoretical models.

The samples used in the present work were cut from the ingot that was grown by the vertical Bridgman technique using elements of at least 5N purity. Slight excess of indium in the stoichiometry was used to produce *n*-type CIS. Electrical measurements were made with current flowing either perpendicular or along the <112> axis. The samples are accordingly named CIS1 and CIS2, respectively. Other experimental details about the sample preparation and contacts are reported elsewhere [9].

Experimental results

The donor concentration N_D, the compensating acceptor concentration N_A and the activation energy E_D were calculated, using the approach of Emel'yanenko et al. [10] for the two bands model, from the temperature dependence of the Hall coefficient of CIS1 and CIS2 samples. These are, respectively, $6.82 \cdot 10^{16}$ cm^{-3}, $1.82 \cdot 10^{16}$ cm^{-3} and 6.50 meV for CIS1, and $4.74 \cdot 10^{16}$ cm^{-3}, $7.40 \cdot 10^{15}$ cm^{-3} and 8.64 meV for CIS2. With the dielectric constant $\varepsilon_0 = 9.3$, the electron effective mass $m_e^* = 0.09\ m_e$, the Bohr radius is calculated to be $a = 54.3$ Å. The critical concentration n_c, calculated from the Mott's criterion $n_c a^{1/3} \approx 0.25$ for the metal-insulator (MI) transition, is found to be $9.80 \cdot 10^{16}$ cm^{-3}.

This indicates that both samples are in the strong localization regime on the insulator side of the MI transition. The logarithmic variation of the electrical resistivity ρ of a representative sample CIS1 of *n*-$CuInSe_2$ is plotted in Fig. 1 as a function of $T^{-1/4}$ at different values of the magnetic field B up to 35 T. The straight lines, in the temperature range between 1.9 and 20 K, agree with Mott's law $\rho = \rho_0 \exp[T_0(B)/T]^{1/4}$ for the VRH conduction in the impurity band when the density of the localized states at the Fermi level is constant.

The values of the pre-exponential factor ρ_0 and the localization temperature T_0, obtained from the least square fit to the experimental data of Fig. 1, are given in Table 1. Their variations, as a function of B, are shown in curve *a* of Fig. 2. The localization temperature T_0 can be expressed in terms of the localized density of states $N(E_F)$ at the Fermi level and the localization length ξ by the relation [8]

$$T_0 = \frac{\beta}{k_B N(E_F) \xi^3}, \qquad (1)$$

where β is a numerical coefficient and k_B is the Boltzmann constant.

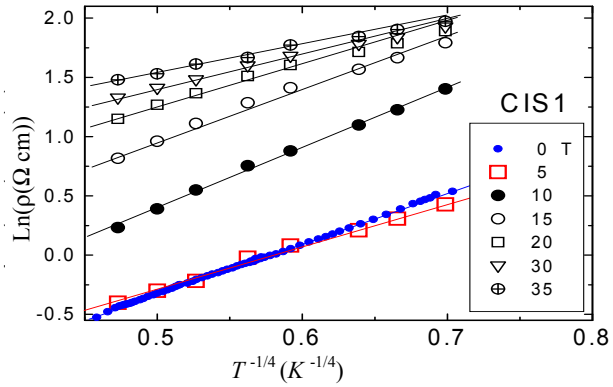

Fig. 1. *The variation of the electrical resistivity ρ of a representative sample CIS1 as a function of temperature in the range 1.9-20 K at different fixed magnetic field values up to 35 T. The straight lines show the linear behavior*

Table 1

Values of the parameters ρ_0 and T_0 in the Mott's law $\rho = \rho_0 \exp[T_0(B)/T]^{1/4}$ at different magnetic fields, obtained from a theoretical fit to the experimental data in the temperature range 4.2 – 20 K

***B*(*T*)**	**0**	**1.5**	**5**	**8**	**10**	**15**	**20**	**30**	**35**
ρ_0 (Ω cm) ($\cdot 10^{-4}$)	866	925	1172	963	1000	2587	6062	12484	14044
$\Delta\rho_0$ (Ω cm) ($\cdot 10^{-4}$)	70	10	70	63	100	300	700	1100	900
T_0 (K)	324	278	187	557	813	440	147	39	7
ΔT_0 (K)	4	8	21	50	60	55	35	9	0.9

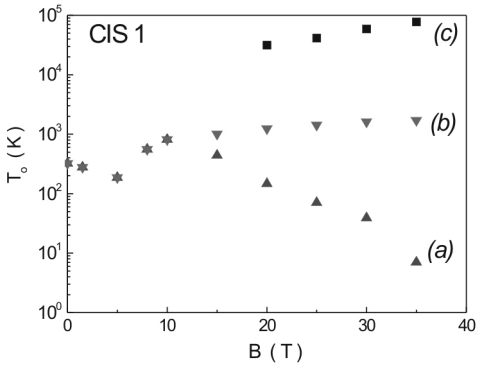

Fig. 2. *The variation of the localization temperature T_0 as a function of magnetic field. The values T_0 obtained from the fit by the Mott's law $\rho \propto \exp[T_0/T]^{1/4}$ to the experimental data are shown in curve a and those obtained from extrapolation up to 35 T of $\mathrm{Ln}\rho(B) \propto B^{1/3}$ data in curve b. The values of T_0 calculated with the method of Tokumoto et al. [11] are represented in curve c*

It is assumed, for the analysis of the data, that $N(E_F)$ does not vary with the magnetic field and the variation of T_0, depending on Eq. (1), is entirely due to the change in the localization length ξ. As observed in curve *a* of Fig. 2, the field dependence of T_0 can be separated into three well – defined regions that are between 0 to 5 T, 5 to 10 T and 10 to 35 T. For the analysis, these ranges will be referred to as I, II and III, respectively. In the region I of low field, where NMR is observed (see reference [7]), T_0 decreases with the increases of B.

This implies, from Eq. (1), that the localization length at first increases with the magnetic field. This increase of ξ with B is associated with the magnetic field induced delocalization effect that originates NMR. In the range II, above 5 T, the shrinkage of the wave functions of the impurity states is expected to decrease the localization length ξ and thereby increase T_0. However, at higher field above 10 T, in range III, T_0, as in range I, decreases

with B. This abnormal behavior is in contradiction with the theoretical predictions [8, 11] of the magnetic field dependence of the localization temperature. In the high field region, above the critical field B_c, when the magnetoresistance is completely positive, the localization length ξ decreases, T_0 increases and tend to saturate at very high fields [11].

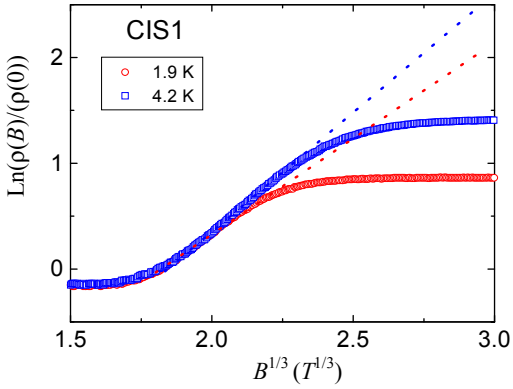

Fig. 3. *A plot of* ln[ρ(*B*)/ρ(0)] *of a representative sample CIS1 as a function of* $B^{1/3}$ *at 1.9 and 4.2 K. The dotted lines show the linear behavior*

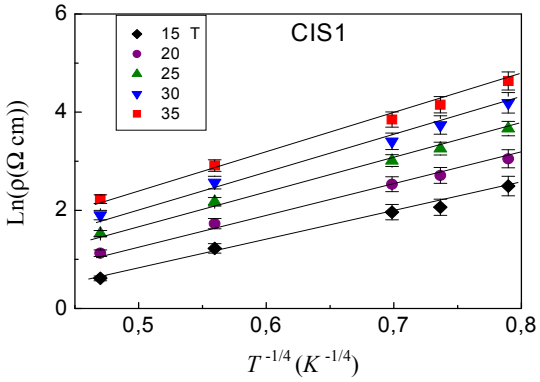

Fig. 4. *The variation of* lnρ *of a representative sample CIS1 as a function of* $T^{-1/4}$ *at different fixed magnetic fields. The data are obtained from extrapolating the* $Ln\rho(B) \propto B^{1/3}$ *curves up to 35 T. The straight lines show the linear behavior*

The observed anomaly of T_0, decreasing with B in range III is, according to our interpretation, related to the fact that the magnetoresistance saturates below 10 K and above 10 T. This can be observed clearly in Fig. 3. A similar behavior has also been reported in other works [12-14]. The physical origin of this saturation is not yet clear. It is shown that at fields greater than B_c, the logarithmic variation of the magnetoresistance in two samples CIS1 and CIS2 of n-type $CuInSe_2$ [4] is proportional to $B^{1/3}$. This is in agreement with the theory of Efros and Shklovskii [8]. The expected magnetoresistance, in the absence of the effect of saturation, is obtained from the experimental data in the high magnetic field region from the linear part of Lnρ(*B*)/ρ(0) versus $B^{1/3}$ curves at different temperatures that are extrapolated up to 35 T. This is shown for two representative temperatures at 1.9 and 4.2 K in Fig. 3 by dotted lines. The values of Lnρ, thus obtained, are plotted in Fig. 4 as a function of $T^{1/4}$ for different values of B up to 35 T. The observed linear dependence at fixed B indicates that the electrical resistivity follows Mott's law. It can also be noticed that the slope of the corresponding straight line increases with increasing B. This means that, contrary to what is shown in curve *a* of Fig. 2, T_0 increases with B if the effect of saturation were not present and would thus be consistent with the decrease of the localization length ξ with the increase of the magnetic field. This is shown in curve *b* of Fig. 2.

It is mentioned that in the low magnetic field, the effect of correlations increases the dielectric constant ε_o which increases the density of states at the Fermi level and decreases T_0 [11]. However, as the magnetic field is increased, the correlation effect is reduced and T_0 increases. In the literature, different expressions for the field dependence of T_0 are proposed but only for the high field region where the shrinkage of the wave functions becomes important and the magnetoresistance is completely positive, that is, it is not affected by the negative component. In this regime, according to Shklovskii and Efros [8], T_0 is expected to vary with B through the relation $T_0(B) \propto B/a(B)$, where $a(B)$ is the effective Bohr radius at a given field. This is expressed as:

$$a(B) = \hbar / \left(2m_e^* E_d(B)\right)^{1/2}, \qquad (2)$$

where m_e^* is the effective mass of the electron and $E_d(B)$ is the ionization energy at field B.

Thus, the increase in T_0 with the field can be explained by the increase in $E_d(B)$ and thereby the decrease in $a(B)$. In a recent work [15], in the same sample CIS1, we have shown, from the analysis of the temperature and magnetic field dependence up to 35 T of the Hall coefficient data, that E_d remains practically constant at low fields and increases as $B^{1/3}$ at higher fields above around 8 T.

In the case of a sufficiently weak field defined by $\lambda >> a$, where a is the state radius in zero field and $\lambda = (c\hbar / eB)^{1/2}$ is the magnetic length, the magnetic potential, which is proportional to λ^{-4}, is small compared to the Coulomb term $-e^2/\varepsilon_0 r$ at distances of the order of a. Hence, for low field ($\lambda >> a$), the electron wave function should not be affected and as reported in reference 15, the ground state ionization energy $E_d(B)$ should remain the same as $E_d(0)$ in zero field.

In the high field regime where $\lambda << a$, the magnetic field localizes an electron in a much narrower region than does the Coulomb potential. Hasegawa and Howard [16] proposed to express the wave function ψ(*r*, *z*) in the form $\psi_0(r)F(z)$, where $\psi_0(r) = \frac{1}{\lambda\sqrt{2\pi}} \exp\left(-\frac{r^2}{4\lambda^2}\right)$.

The corresponding expression for the ionization energy is given by

$$E_d(B) = E_d(0)\left[\ln (a/\lambda)^2\right]^2. \qquad (3)$$

This increases with B but only for fields greater than the field B_0 where $B_0 = c\, m_e^{*2} e^3 / \varepsilon_0^2 \hbar^3$ is obtained from the condition $\lambda = a$. In the case of *n*-$CuInSe_2$, with $m_e^* = 0.09\, m_e$ and $\varepsilon_0 = 9.3$, B_0 is calculated to be 22 T. The increase in E_d with B corresponds to the condition $\ln (a/\lambda)^2 > 1$ and thereby $B > 2.7B_0$. This condition leads to $B > 60$ T for *n*-$CuInSe_2$. Since our measurements are only up to 35 T, this requirement is not satisfied in our case.

Tokumoto et al. [11], using the percolation model, have proposed another relation for the localization temperature. This is expressed as

$$k_B T_0(B) = 0.372\left[N(E_F) a_\perp^2 a_{ll}\right]^{-1}, \qquad (4)$$

where $a_\perp$ and a_{ll} are the two principal electronic orbital radii in the presence of the magnetic field. To calculate the field dependence of T_0 the values of $N(E_F)$, $a_\perp$ and a_{ll} are needed. By assuming a constant density of states for the impurity band and an energy spread comparable to the effective Rydberg, $N(E_F)$ for *n*-$CuInSe_2$ is estimated by employing the method used in the case of *n*-CdSe [17]. This is calculated to be $7.0 \cdot 10^{18}$ $eV^{-1}cm^{-3}$. The values of $a_\perp$ and a_{ll} for different values of B are obtained from the hydrogen-like impurity formalism used by Yafet, Keyes and Adams [18]. These values are shown in Table 2 together with the calculated values of T_0 for some representative field values of 20, 25, 30 and 35 T.

Table 2

Values of the two principal electronic orbital radii with the corresponding calculated values of T_0 for the representative fields of 20, 25, 30 and 35 T

***B* (*T*)**	**20**	**25**	**30**	**35**
$a_\perp$ (Å)	23.91	21.42	18.43	16.44
a_{ll} (Å)	34.37	32.38	30.89	29.39
T_0 (K)	31396	41523	58796	77662

The values of T_0 thus obtained by this method for different values of B are plotted in curve *c* of Fig. 2. Although the experimental and theoretical curves are very nearly parallel above 20 *T*, discrepancy of nearly one order of magnitude is noted. This could be related to the approximation used in the calculation of $N(E_F)$. A similar behavior has also been reported in InSb [18].

In conclusion, it is established that the electrical resistivity below 20 K in *n*-type $CuInSe_2$ at different field values up to 35 *T* follows Mott type variable range hopping conduction mechanism. The field dependence of the localization length ξ and the localization temperature T_0 below 5 *T* can be explained as due to the presence of the negative magnetoresistance that is associated with the magnetic field induced delocalization effect. However, the observed decrease of T_0 with increasing B above 10 *T* is in contradiction with the theoretical models. It is suggested that this behavior has its origin in the tendency of the magnetoresistance to saturate at higher field values. The expected variation of the localization temperature with the magnetic field is found when T_0 is estimated from the linear extrapolation of the magnetoresistance above 10 *T*, in the region of saturation. The variation of T_0 with B above 20 *T* shows the same tendency as predicted by the theory. However, smaller magnitude could be related to the estimated values of $N(E_F)$, $a_\perp$ and a_{ll} used in the calculation.

Acknowledgements

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MOTT-VARIABLE RANGE HOPPING MECHANISM IN *N*-TYPE $CuIn_3Se_5$

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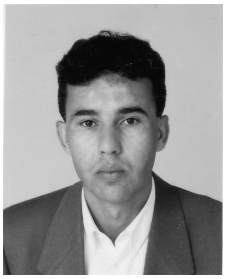
Variable range hopping conduction of Mott type, where the magnetoresistance follows the relation $\rho(B) = \rho_0 \exp[T_0(B)/T]^{1/4}$, is observed in *n*-type $CuIn_3Se_5$ in two different temperature ranges at different magnetic field values up to 27 tesla. The positive magnetoresistance data are analyzed using the theoretical models of Shklovskii and Efros. We obtained a good but only in the lower temperature range. The observed discrepancy in range I needs to be investigated.

Keywords: ordered defect compounds, variable range hopping, magnetoresistance



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Introduction

Electrical conduction due to Mott type variable range hopping mechanism of (M-VRH) has been reported in many materials [1, 2] and explained as a result of the presence of strong localization of the charge carriers in the impurity band. Under this mechanism, electrical resistivity (ρ) follows the relation $\rho = \rho_0 \exp [T_0/T]^{1/4}$, where T_0 is the characteristic temperature and ρ_0 is taken as a constant. This is for a 3-D system when the electron density of states around the Fermi energy level is constant or varies very slowly.

In the present work, we report on the effect of the presence of ordered arrays of donor-acceptor defect pair (DADP) on the localized states in *n*-type $CuIn_3Se_5$ samples. The ordered defect compound (ODC) $CuIn_3Se_5$ can be derived from a repeat of one unit of the interacting donor-acceptor ($InCu^{+2}$, $2VCu^{-1}$) defect pair in each 5 units of $CuInSe_2$ (CIS) [3, 4]. The temperature dependence of the electrical resistivity (ρ) below 70 K and the positive magnetoresistance (PMR) up to 27 T are measured. The experimental results are analysed with the existing theoretical models. The details about the crystal growth and the techniques used to measure ρ and PMR are reported earlier [5].

Experimental results

In Fig. 1, we plot the logarithmic variation of ρ with $T^{-1/4}$. This variation can be separated into three well-defined temperature regions that are between 67 and 24.5 K, 24.5 and 9 K, and below 9 K. These are referred to as I, II, and III, respectively. The linear dependenceon this plot establishes that the electrical conduction by VRH mechanism of Mott type (M-VRH), where $\rho = \rho_0 \exp [T_0/T]^{1/4}$, is dominant in the first two ranges. From the theoretical fits, we find $\rho_{0I} = 2.37 \cdot 10^{-7} \Omega^{-cm}$, $T_{0I} = 8.01 \cdot 10^6$ K and $\rho_{0II} = 3.01 \cdot 10^{-2}$ Ω^{-cm}, $T_{0II} = 2.44 \cdot 10^5$ K in I and II, respectively. This suggests that the localized states, caused by the ordered arrays of DADPs or defects, start to form just below 70 K. Tne variations of the relative magnetoresistance $\Delta\rho/\rho = (\rho(B) - \rho(0))/\rho(0)$ as a function of the magnetic field *B* up to 27 *T* for different fixed temperatures from 10 to 77 K is shown in the insert. The magnetoresistance is positive and decreases when the temperature increases.

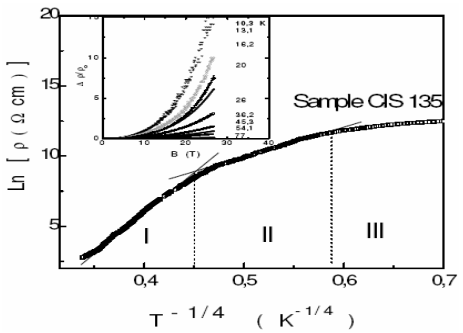

Fig. 1. *The electrical resistivity ρ and the magnetoresistance of a representative sample of n-$CuIn_3Se_5$*

A similar behaviour around 20 K in *n*-$CuInSe_2$ with conduction by a M-VRH mechanism both above and below this temperature with different T_0 has been reported [6]. PMR in the hopping regime is caused by the shrinkage of the electronic wave function in a direction perpendicular to the applied magnetic field. To analyze the data, the model proposed by Efros and Shklovskii [7] for the field and temperature dependence of the PMR in the variable range hopping conduction regime is used. The main mathematical expressions, although reported by us earlier [5], are as follows:

$$\ln\left[\frac{\rho(B)}{\rho(0)}\right] = K_S B^2 ;\ B < B_c \qquad (1)$$

and

$$\ln\left[\frac{\rho(B)}{\rho(0)}\right] = \left[\frac{T_0(B)}{T}\right]^{1/3} = PB^{1/3} ;\ B > B_c. \qquad (2)$$

In these expressions K_s is proportional to $T^{-3/4}$ and depends on the effective Bohr radius a_H^* and the zero field characteristic temperature T_0, whereas $T_0(B)$, in the high field region, is proportional to B and depends on the constant density of states $N(E_F)$ at the Fermi level and a_H^*. The critical field B_c that separates the low from high field regime is expected to vary with the temperature as $T^{-1/4}$ [5]. From Eq. (1) and (2) one should expect that at fixed temperatures $\ln[\rho(B)/\rho(0)]$ should vary as B^2 and $B^{1/3}$ below and above B_c in the case of Mott type VRH conduction and at fixed magnetic fields it should be proportional to $T^{-3/4}$ and $T^{-1/3}$, respectively. Also, the variation of $\ln K_s$ and $\ln P$ with $\ln T$ should give a respective slope of -3/4 and -1/3. As in Fig. 1 of Ref. 5, we plot in Fig. 2 $\mathrm{Ln}[\rho(B)/\rho(0)]$ as a function B^2 and $B^{1/3}$ at several fixed temperatures from 10 to 54 K.

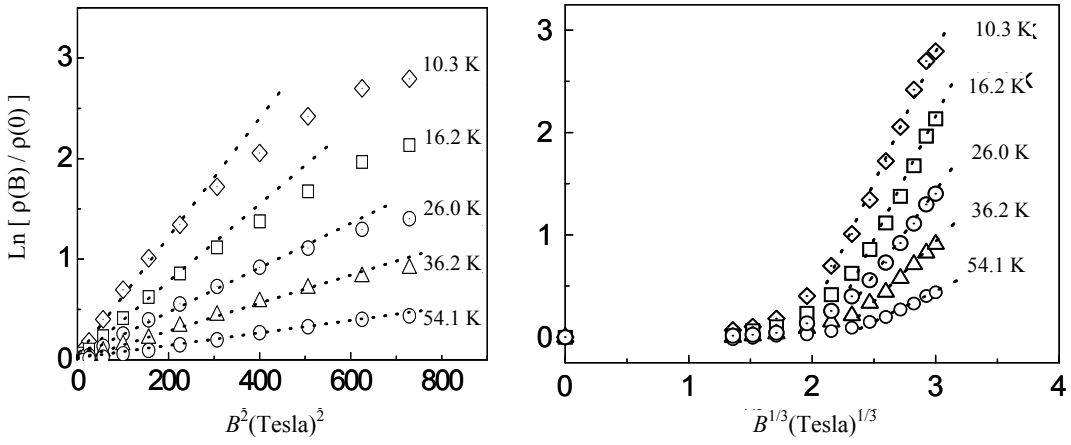

Fig. 2. *Ln [ρ(B)/ρ(0)] as a function of B^2 (a) and $B^{1/3}$ (b) at various fixed temperatures*

We can see the linear dependence, represented by the straight dotted lines, of Ln [ρ(*B*)/ρ(0)] with B^2 for lower fields and $B^{1/3}$ for higher values of *B*. The cross-over from B^2 to $B^{1/3}$ dependence occurs at a critical field B_c that separates the low from the high field regime. As in the case of *n*-$CuInSe_2$ [5], these linear behaviours thus observed in low fields (Fig. 2, *a*) and in high field region (Fig. 2, *b*) show that our data are in agreement with the variable range hopping theoretical model of Shklovskii and Efros [7].

In Fig. 3, we plot $\mathrm{Ln}K_S$ (left scale) and Ln*P* (right scale), where K_S and *P* are the slopes of $\mathrm{Ln}[\rho(B)/\rho(0)]$ vs B^2 and $\mathrm{Ln}[\rho(B)/\rho(0)]$ vs $B^{1/3}$ dependence, against Ln*T*.

The expected theoretical dependence [7] is shown by straight lines. An excellent agreement is found, but only, in range II. Although M-VRH conduction is also valid in range I, the origin of nearly three times higher slope of K_S and *P* is noted and yet not clear.

In conclusion, it is established that the electrical resistivity in *n*-type $CuIn_3Se_5$ follows M-VRH conduction in two different temperature ranges. The observed variation of $\mathrm{Ln}[\rho_{(B)}/\rho_{(0)}]$ with the magnetic field is in complete agreement with the theoretical model. However, the corresponding temperature variation of the slopes agrees only with the data of range II. The observed discrepancy in range I needs to be investigated.

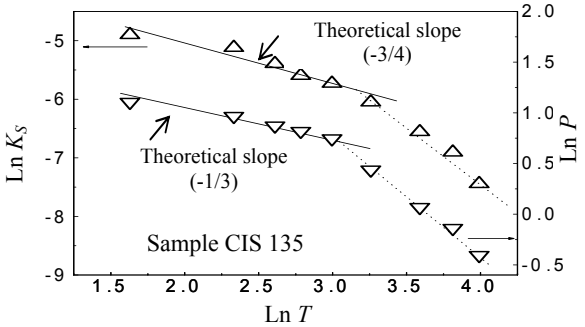

Fig. 3. *$\mathrm{Ln}K_S$ (left scale) and LnP (right scale) as a function of LnT*

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NUMERICAL STUDY OF COUPLED HEAT TRANSFERS THROUGH A VERTICAL CAVITY WITH ALVEOLAR WALLS

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In this work, we study numerically the two dimensional coupled heat transfers through a honeycomb structure formed by a vertical cavity separating two alveolar walls. Heat transfers are assumed to be two-dimensional and the air motion in all cavities of the system is laminar. The left and right vertical sides of the hollow structure are considered isothermal. The top and bottom horizontal sides are adiabatic. Equations governing natural convection in the cavities, heat exchange by radiation between the surfaces of the different cavities and heat conduction in the solid partitions are solved by the SIMPLE algorithm. Effects of convection and radiation on the linearity of the global heat transfer through the system are studied. Overall heat exchange coefficients for the hollow structure are derived based on the simulation results.

Keywords: honeycomb structure, vertical cavity, coupled heat transfers, conduction, convection, radiation, numerical simulation

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Introduction

The honeycomb structures intervene in several thermal systems. In particular, they are used very currently in the construction of building walls because of the advantages that they present on the material and energetic plans. The prediction of the heat flow through such building components using the analytical transfer functions methods is not possible because of the non-linearity of the heat transfers by convection and radiation in the alveolar of hollow blocks.

The heat transfer within such structures is done simultaneously by conduction in the different solid partitions, by natural convection inside the cavities and by radiation between the internal faces of the last ones. These three heat transfer processes are intimately bound. Therefore, a fine study of the thermal behavior of the hollow blocks needs a simultaneous resolution of the complex and non linear equations modeling the different mechanisms of heat transfer.

However, the available studies in the literature are generally limited to simple configurations consisting in rectangular cavities with one or several conducting walls. Earlier investigations were conducted by Balvanz and Kuehn [1] and Kim and Viskanta [2] on the interaction between the natural convection in a square cavity and the heat conduction in the adjacent walls. Effects of surface radiation on natural convection in a square enclosure filled with air were studied by Balaji and Venkateshan [3, 4], Akiyama and Chong [5], Ramesh and Venkateshan [6] and Ramesh et al. [7]. In these studies, it has been shown that natural convection heat transfer is significantly reduced by conduction in the walls and/or radiation exchange between the cavity surfaces. Coupled heat transfers by conduction, natural convection and radiation in cellular structures with two vertical series of square cavities has been studied numerically by Abdelbaki and Zrikem [8]. Application was presented for building walls made of hollow clay tiles. Later, numerical solution of combined heat transfers in hollow clay tiles, with two air cells deep, submitted to transient thermal excitations was performed by Abdelbaki et al. [9]. Based on the simulation results the authors derived empirical transfer function coefficients (TFC) for the hollow clay tiles by applying an identification technique. It should be noted that such TFC cannot be derived using analytical or semi-analytical algorithms available in the literature [10, 11].

In the present work, we study numerically the two dimensional coupled heat transfers through a honeycomb structure formed by a vertical cavity separating two alveolar walls. Analysis of the flow structures and the temperature fields in the different alveolar is presented. The influence of the non linearity of convection and radiation heat transfer on the global heat transfer through the honeycomb structure is studied. Finally, appropriate overall heat exchange coefficients are determined.

Mathematical formulation

The geometry of the two dimensional configuration to be studied is presented in Fig. 1. It represents a honeycomb structure of width L and height H formed by a vertical cavity confined with air and separating two cellular walls. The width and height of the vertical cavity are respectively l and h. Each cellular wall is formed by a vertical range of Ny rectangular alveolar of width l' and height h'. The total numbers of cavities of he studied honeycomb structure in x and y directions are respectively Nx and Ny. The different cavities are surrounded by vertical solid partitions of thickness ex_i ($1 \le i \le 4$) and horizontal ones of thickness ey_j ($1 \le j \le Ny + 1$).

For the thermal boundary conditions of the problem, the left and right vertical sides of the honeycomb structure are considered isothermal and are maintained at constant temperatures T_o and T_i respectively. The top and bottom horizontal sides are assumed to be adiabatic.

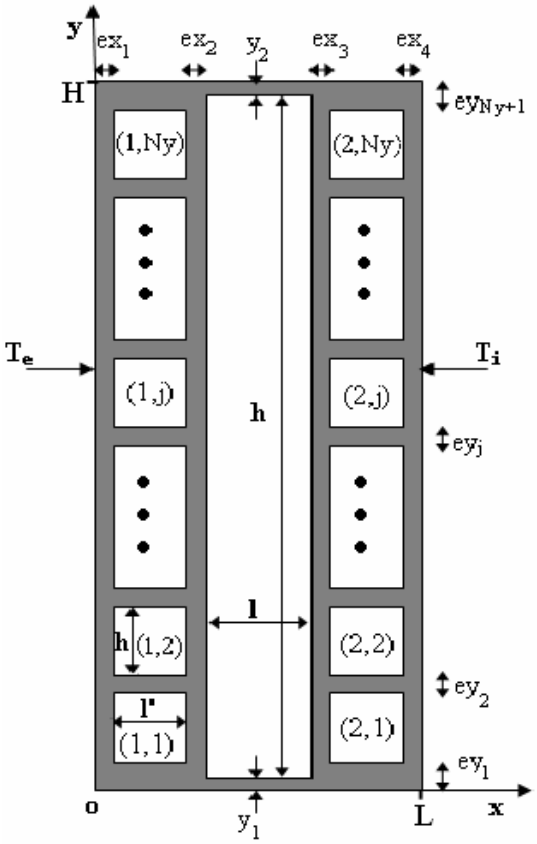


Fig. 1. *Schematic diagram of the studied honeycomb structure*

In formulating governing equations, the fluid motion and the heat transfer are considered to be two-dimensional and laminar. The solid and fluid properties are assumed to be constant except for the density in the buoyancy term where the Boussinesq approximation is utilized. Viscous heat dissipation in the fluid is neglected. The fluid is assumed to be non-participating to radiation and the cavities inside surfaces are considered diffuse-grey. Dimensionless equations governing the conservation of

mass, momentum and energy for the air in the internal cavities are given by:

$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}=0\,, \qquad (1)$$

$$\frac{\partial U}{\partial \tau}+U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}=-\frac{\partial P}{\partial X}+Pr\left(\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}\right), \qquad (2)$$

$$\frac{\partial V}{\partial \tau}+U\frac{\partial V}{\partial X}+V\frac{\partial V}{\partial Y}= =-\frac{\partial P}{\partial Y}+Pr\left(\frac{\partial^2 V}{\partial X^2}+\frac{\partial^2 V}{\partial Y^2}\right)+Ra\cdot Pr\cdot\theta_f\,, \qquad (3)$$

$$\frac{\partial \theta_f}{\partial \tau}+U\frac{\partial \theta_f}{\partial X}+V\frac{\partial \theta_f}{\partial Y}=\frac{\partial^2 \theta_f}{\partial X^2}+\frac{\partial^2 \theta_f}{\partial Y^2}\,, \qquad (4)$$

where U, V, P and θ_f are the dimensionless variables associated, respectively, with the velocity components in X and Y directions respectively, the pressure, and the fluid temperature, Pr is the Prandtl number and Ra is the Rayleigh number given by: $Ra=\frac{g\beta L^3(Te-Ti)}{\nu^2}Pr$, $Pr=\frac{\nu}{\alpha_f}$, where ν and α_f are respectively the fluid kinematic viscosity and the thermal diffusivity.

The dimensionless equation of heat conduction in the solid walls is:

$$\frac{\alpha_f}{\alpha_s}\frac{\partial \theta_s}{\partial \tau}=\frac{\partial^2 \theta_s}{\partial X^2}+\frac{\partial^2 \theta_s}{\partial Y^2}\,, \qquad (5)$$

where α_s is the solid thermal diffusivity and θ_s is the dimensionless solid temperature. The boundary conditions of the problem are:

* $U = V = 0$ on the inner sides of each cavity.
* $\theta_s(0,Y)=1$ *and* $\theta_s(1,Y)=0$ $(0 \le Y \le A = H/L)$

$$\left.\frac{\partial \theta_s}{\partial Y}\right|_{Y=0}=\left.\frac{\partial \theta_s}{\partial Y}\right|_{Y=A}=0 \qquad * (0\le X\le 1).$$

The continuity of the temperature and the heat flux at the fluid-solid interfaces gives:

$$\theta_s(X,Y)=\theta_f(X,Y)\,, \qquad (6)$$

$$-\frac{\partial \theta_s}{\partial \eta}=-N_k\frac{\partial \theta_f}{\partial \eta}+N_r Q_r\,, \qquad (7)$$

where η represents the dimensionless coordinate normal to the wall, N_k is the thermal conductivity ratio K_f/K_s, Q_r is the dimensionless radiative heat flux and N_r is the dimensionless radiation to conduction parameter defined by: $N_r=\frac{\sigma T_e^4 L}{k_s(T_e-T_i)}$.

The dimensionless radiative heat flux Q_r is related to the radiative heat flux q_r by: $Q_r=\frac{q_r}{\sigma T_e^4}$.

The net radiative heat flux $q_{r,k}(r_k)$ exchanged by the finite area dS_k, located at a position r_k on the surface k, is given by:

$$q_{r,k}(r_k)=J_k(r_k)-E_k(r_k)\,, \qquad (8)$$

where $J_k(r_k)$ is the radiosity and $E_k(r_k)$ is the incident radiative heat flux on the surface dS_k given respectively by:

$$J_k(r_k)=\varepsilon_k\sigma(T_k(r_k))^4+(1-\varepsilon_k)E_k(r_k)\,, \qquad (9)$$

$$E_k(r_k)=\sum_{j=1}^{4}\int_{A_j}J_j(r_j)dF_{dS_k-dS_j(r_k,r_j)}\,, \qquad (10)$$

where ε_k is the emissivity of the surface k and $dF_{dS_k-dS_j}$ is the view factor between the finite surfaces dS_k and dS_j located at r_k and r_j respectively. Taking into account equations (8) to (10), the dimensionless radiative heat flux can be expressed as:

$$Q_{r,k}(r_k')=\varepsilon_k(G-1)^4\left(\theta_k(r_k')+\frac{1}{G-1}\right)^4- -\varepsilon_k\sum_{j=1}^{4}\int_{S_j}J_j'(r_j')dF_{dS_k-dS_j}\,, \qquad (11)$$

where G is the temperature ratio T_e/T_i, $J_j'(r_j')$ is the dimensionless radiosity at the position r_j on surface j. By dividing the walls into finite isothermal surfaces, equation (11) leads to a set of linear equation where the unknowns are the dimensionless radiosities $J_j'(r_j')$.

The dimensionless average heat flux across the structure is given by:

$$Q_a=-\frac{1}{A}\int_0^A\left.\frac{\partial \theta_S}{\partial X}\right|_{X=0}dX=-\frac{1}{A}\int_0^A\left.\frac{\partial \theta_S}{\partial X}\right|_{X=1}dX \qquad (12)$$

The previous equations are discretized using the finite differences method based on the control volumes approach with a power law scheme and are solved by the SIMPLE algorithm. The resulting system of algebraic equations is solved by the Tri-Diagonal-Matrix-Algorithm. To accelerate the convergence of solutions, the governing equations are solved in their instationary form. The numerical code had been tested in previous studies [8, 9, 12]. A study on the effects of both grid spacing and time step on the simulation results has been conducted. The compromise between accuracy and computation time is found for a 75×91 non-uniform grid with a 16×16 non-uniform grid in each small cavity and 29×85 in the big cavity. The dimensionless time used in the simulation is 10^{-4}. The convergence criterion is based on the relative changes in the variables U, V, P, θ and Q_r at the different nodes of the calculation domain:

$\left|\frac{f^{n+1}(i,j)-f^{n}(i,j)}{f^{n}(i,j)}\right| \le 10^{-5}$, where $f^{n}(i, j)$ is the variable f value at node (i, j) calculated in the iteration n.

Results and discussion

Results presented in this study are obtained for structures having the geometrical parameters given in Table 1.The values of H and h depend on the number of alveolar in the vertical direction *(Ny)* and are calculated from the values of ey_j, y_1, y_2 and h'. The solid partitions thermal conductivity and emissivity are respectively K_s = 1 W/mK and ε = 0.8. The dimensionless parameter Nr depends on the temperature difference $\Delta T = (T_e - T_i)$ that takes values between 5 °C and 40 °C in accordance with the practical conditions. The air thermal conductivity K_f is equal to 0.0262 W/mK and the Prandtl number is Pr = 0.71.

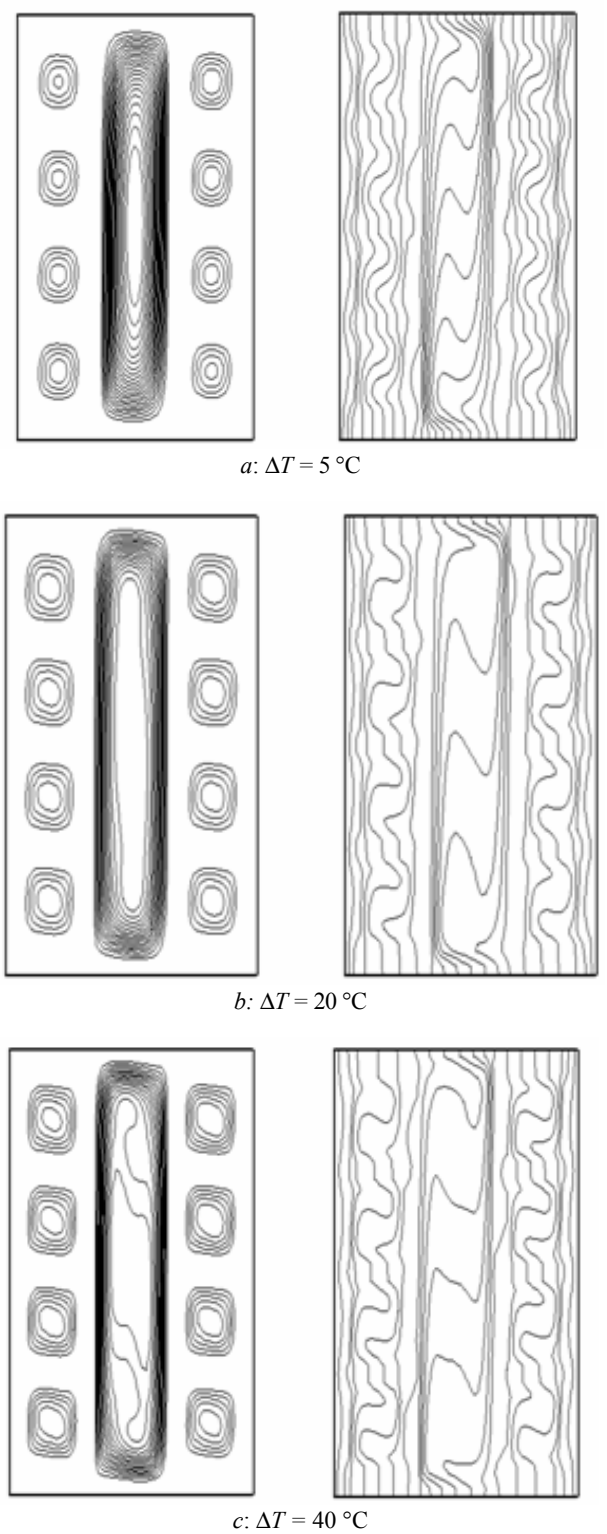
Table 1

Geometrical dimensions of the different components of the honeycomb structure, cm

l	l'	h'	ex_i	ey_1	ey_i	ey_n	y_1	y_2
5	3,5	3,5	1	1,5	1	1,5	0,5	0,5

Streamlines and isotherms

Fig. 2 presents the streamlines contours (at the left) and the isotherms (at the right) obtained for a structure of (Nx = 2)×(Ny = 4) alveolar in addition to the big cavity and for the temperature differences ΔT = 5 °C, ΔT = 20 °C and ΔT = 40 °C. The results of Fig. 2 show that the nature of the flow structures is characterized by a single cell turning clock-wise as well in the small alveolar that in the big cavity. As foreseen, the distortion of the streamlines in the big cavity becomes more pronounced when ΔT increases indicating an increase of the natural convection intensity. In fact, the values of the maximal stream function Ψ_{max} in the big cavity are 20.2, 25.3 and 28.8 for ΔT = 5 °C, ΔT = 20 °C and ΔT = 40 °C respectively. The exam of the streamlines in the first vertical rows of alveolar shows that the size of the central cell deceases slightly when moving from the low cavity (j = 1) toward the one situated in top of the structure (j = 4) indicating a weak reduction of the intensity of the flow in this sense. This can be assigned to the interaction between the heat transfer by convection and radiation. This situation is reversed for the other vertical row of alveolar located at the right of the vertical cavity where the size of the flow intensity increases slightly from the cavity (j = 1) toward the cavity (j = 4). Concerning the temperature field, the distortion of the isotherms in the central regions of the different cavities reveals a very marked two dimensional heat transfer that becomes nearly unidirectional in the solid partitions separating the cavities where the isotherms are perpendicular to the main direction of heat transfer (direction ox). As expected, near the walls of the central cavity, the movement of air is faster and the gradients of temperature are more important. Then, the convective heat transfer is relatively important in these regions.



a: ΔT = 5 °C

b: ΔT = 20 °C

c: ΔT = 40 °C

Fig. 2. *The streamlines contours (at the left) and the isotherms (at the right) obtained for a structure of (Nx = 2)×(Ny = 4) alveolar*

Heat transfer

In order to show the effect of the number of alveolar in the vertical direction (*Ny*) on the global heat transfer through the honeycomb structure, the Fig. 3 presents the variation of the dimensional heat flux crossing the structure Q (W/m^2) as a function of the temperature difference ΔT between the vertical sides of the latter. Fig. 3 gives the results obtained for different values of *Ny* using adiabatic boundary condition. As it can be seen, the differences between heat fluxes obtained for *Ny* = 4, 8 and 16 are negligible especially for temperature differences lower than 25 °C. Discrepancies that appear for ΔT superior than 25 °C are lower than 10 %. It should be noted that the global variation of Q as a function of ΔT is almost linear because of the predominance of the conduction heat transfer which represents more than 50 % of the overall heat transfer through the honeycomb structure.

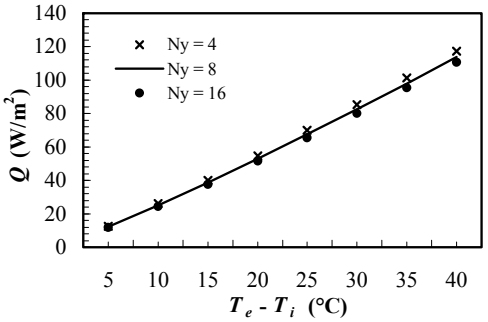


Fig. 3. *Effect of the alveolar number in the vertical direction Ny on the average heat transfer through the alveolar structures*

The linear behavior of Q with ΔT is very important because it permits to derive a overall heat exchange coefficient (overall conductance U) for the studied honeycomb structure. This overall conductance permits a fast and accurate prediction of the heat transfer through the system without solving the complex equations governing the heat transfer mechanisms which are coupled and locally non linear: $Q = (U \cdot \Delta T)$. For a honeycomb structure with *Ny* = 4, the overall conductance value obtained here is: $U_{present}$ = = 2.59 W/m^2. This value is markedly inferior to the overall conductance given in reference [12] ($U_{[12]}$ = 3.01 W/m^2) that corresponds to a hollow clay tile with three vertical ranges of alveolar constructed from the same material and having the same dimensions as the honeycomb structure treated here with *Ny* = 4. This result is expected because the central range of alveolar of the hollow block in reference [12] is replaced here by the vertical cavity. Then, the hollow clay tile studied in the present work permits a reduction of heat transfer about 15 % with respect to the hollow clay tile with three ranges of air cells deep mostly used in practice to construct building envelopes.

Conclusion

Coupled heat transfers by conduction, natural convection, and radiation in a vertical cavity with alveolar walls have been studied numerically. Analysis for the temperature differences that occur in practice shows that the flow structures in the different cavities are characterized by a single cell turning clock-wise. The variation of the number of alveolar of the vertical walls between *Ny* = 4 and *Ny* = 16 have not large effect on the global heat exchange through the honeycomb structure. The variation of the overall heat flux through the structure is found to be almost linear. Based on this result overall heat exchange coefficient had been derived for hollow clay tiles formed by a vertical cavity separating two alveolar walls. Also, it had been shown that the latter reduces considerably the heat transfer compared to the hollow clay tiles with three air cells in the horizontal direction which are mostly used in the construction of building envelopes.

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INCREASING PUBLIC AWARENESS OF RENEWABLE ENERGIES AND ELECTRICAL CONSUMPTION REDUCTION: ESTIA'S APPROACH

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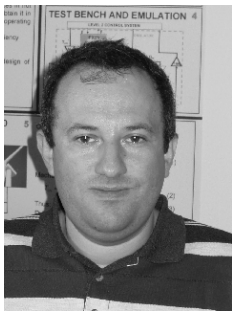
This paper presents an approach leaded in ESTIA these last years, in order to increase public awareness of renewable energy and of the need to reduce electricity consumption. The core of this approach has been the design, manufacturing and installation of a public awareness Kit. ESTIA, LIPSI research department and some renewable energies installation are presented first. Then the methodology of designing the Kit and the various software and hardware components are described. Finally, other initiatives carried out in the frame of this approach are given before concluding the paper.

Keywords: alternative energy and ecology, philosophy of alternative energy and ecology, wind-solar energy plants, public awareness of renewable energies



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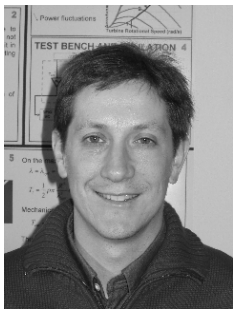

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Introduction

The global warming is everyday a bigger problem for the inhabitant of our planet. Even if nobody can still precisely predict all the consequences of the warming, some of them are already visible, as for instance the thawing of glacier. Thus, more and more people are realizing the huge environmental, economical and social impact of this phenomenon. Some important commitments, as the Kyoto protocol [1], have been made to cope with the warming effects. Unfortunately these commitments seem to be insufficient, and moreover, they are often not honored. It is why it is very important to increase the public awareness of this problem.

The causes of the global warming are various [2]. The increase of energy consumption is one of these causes. The processes for the generation of electricity which produce greenhouse effect gases are another cause. These processes generate, unfortunately still most of electricity [3]. Thus two measures against the global warming could be to decrease energy consumption, and in particular electrical energy consumption, and to generate electricity with processes which does not produce greenhouse effect gases. Among these processes renewable energies are the cleanest ones, and generally those which respect the best the environment.

Everybody is concerned by the global warming and the attitude of each person influences, in the positive or negative sense, this warming. Nevertheless, it is obvious that some persons have more influence than other ones on these problems. Politicians have for instance a big influence, as they can vote and apply laws which could have an appreciable positive or negative effect on the global warming. To a lesser but still important extent, engineers can also take decisions which affect this problem.

The precedent analysis explains why ESTIA has carried out, these last years, some measures in order to reduce its electricity consumption and to increase public awareness of renewable energies. As you could see below, ESTIA is an engineering school. Some professors and lecturers from ESTIA have formed, in the frame of the LIPSI research department, the EneR-GEA research group working on renewable energy issues. This group has been the instigator of a project whose objective was to promote renewable energies for the generation of electricity, and the reduction of the electricity consumption

The following chapter describes ESTIA, EneR-GEA research group and some renewable energy installations. The third section presents a Public Awareness Kit designed and constructed in ESTIA. Some other approaches for the reduction of the electrical energy consumed in ESTIA are described in chapter 4 and section 5 gives the conclusions of the paper.

Presentation of ESTIA

ESTIA [4] (Ecole Supérieure des Technologies Industrielles Avancées, Institute of Advanced Industrial Technology) has been built as a tool of economic development of its territory, the Basque Country. It regroups several realities today:

- A school of engineers and a research laboratory (500 students and 70 employees and researchers).
- A technology transfer team (ESTIA Innovation, 10 persons).
- An incubator and a cluster of firms.

The school trains trilingual engineers with solid scientific and technological foundations in mechanics, electronics, energetics, advanced computer science and telecommunications.

Three specialized fields are proposed to students choosing this curriculum:

- Mechanical and electronic products design.
- Mastery of automatized processes.
- Industrial organization and management.

Basic knowledge on renewable energies for the generation of electricity is introduced in some courses of ESTIA. For instance, in the electronics, control and electrical engineering courses, the theoretical parts of the courses are often illustrated by examples related to renewable energies, in the frame of practical classes and works. These classes are designed to help the students to develop skills for implementing renewable energy applications based on PV panels, wind turbines, Hybrid Power Systems (HPS)… Thus, these courses are used to increase students' knowledge and awareness of these alternative energy sources.

The ORLI department, which is the maintenance service of ESTIA, has an important role in the approach presented in this paper. It is in particular responsible for buying all the electrical equipment of ESTIA. Thus, its choices have an appreciable influence on the electrical consumption of ESTIA.

As part of ESTIA, LIPSI research department [5] (Laboratoire en Ingénierie des Processus et des Services Industriels, Industrial Services and Process Engineering Laboratory) contains different research groups. EneR-GEA [6] is one of these groups made up of PhDs, PhD students and technicians who use their skills on control engineering, electrical engineering and power electronics for renewable energies development. They specially work on wind turbines control, renewable energy integration in weak grids or HPS applications. Another important aspect treated by the EneR-GEA team is the increase of public awareness of renewable energies and on the need of managing better the electrical energy consumption.

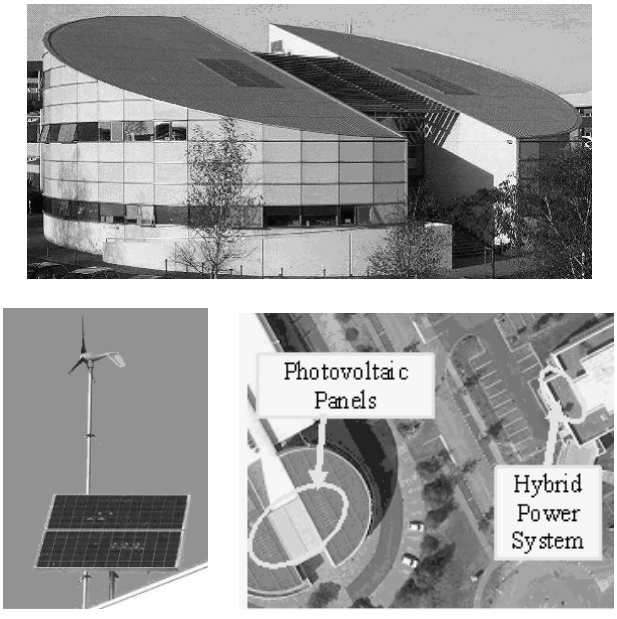

Fig. 1. *Grid connected PV system and Hybrid Power System (HPS) installed in ESTIA 1 and ESTIA 2 buildings*

To validate the research work and increase public awareness of renewable energies, EneR-GEA has installed two renewable energy systems on the roof of the two ESTIA's buildings. The first installation is based on PV panels connected to the grid with a rated power of 5.6 kWc in ESTIA 1 building. The second one is a HPS based on two PV panels with a rated power of 330 Wc, a small wind turbine with a rated power of 400 Wc and storage batteries in ESTIA 2 building. Both installations are illustrated in Fig. 1.

A Kit has been made by EneR-GEA group in the frame of the approach of increasing public awareness of renewable energy and managing of energy consumption. The Kit constantly monitors the electrical production of both systems illustrated in Fig. 1. The renewable energy sources are equipped with sensors and data communication units (signals conditioning, digital controllers…). All the information concerning the renewable energy production (power production, rejection of CO_2 avoided…) is presented to the public in general and to the students in particular, through some graphic interfaces. The details of the hardware and the software parts of the system that allows monitoring the renewable energy production, hereafter called Public Awareness Kit are presented henceforward.

Public Awareness Kit

The Public Awareness Kit is the core of the approach presented in this paper. The whole of the Kit has been designed and made in ESTIA. Fig. 2 presents its different components. Two data acquisition modules allow capturing produced electrical energy from the PV panels of ESTIA 1 building and from the HPS of ESTIA 2 building. The energy produced by the HPS is transmitted to the EneR-GEA laboratory of ESTIA 2 building.

The two acquisition modules transmit the captured data to a server containing a database where all the history of the produced energy is stored. A PC with a specific screen saver has been installed in the hall of ESTIA 1 in order to show the produced energy to all the users of ESTIA 1 and in particular to the students. As shown below, the produced energy is compared, in terms of its impact on the environment, to the same quantity of energy produced by processes which produce greenhouse effect gases. The captured data can also be seen and analyzed from a web site specially made for this [7]. Moreover, every month, a Newsletter showing the same kind of information of that of the web and the screen saver is sent to every students and employees of ESTIA, as well as to every people registered to the mailing list from the Kit web site.

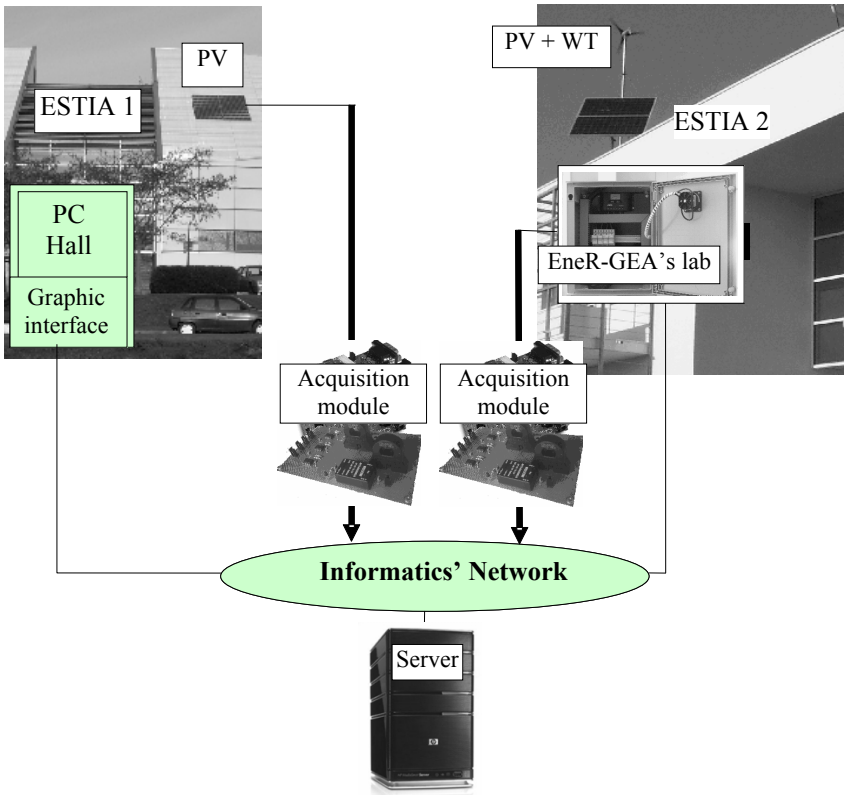

Fig. 2. *Presentation of the different components of the Public Awareness Kit designed and made in ESTIA*

Used methodology to design the Kit

Special attention has been paid to the methodology used to design the Kit. Actually, taking into account that the objective is public awareness by the means of didactic interfaces, it was difficult to define some design specifications in order to be sure that the awareness objective would be reached. The success of the Kit is specially linked to the graphic interfaces. It is why they have been specified first. The definition of the interfaces' specifications has allowed specifying the database and the data acquisition module.

The first step in the design of the graphic interfaces was to draw up a list of ergonomic criteria to be respected, among the standards in the fields of ergonomics and informatics. Thus were defined the adequate bills of character, the colors to be avoided, the maximum size of the pages of the web site, the presence of a title in each paragraph or of the names of suitable HyperText bonds in relation to the dependent pages.

After, it was decided to solicit the personnel and the students of ESTIA to assess their knowledge on topics such as global warming, renewable energies, reduction of energy consumption or energy in general, and to obtain their needs for information on these topics. On the one hand an interview of ten people (employees having various functions and students of ESTIA) has been carried out. In addition, a questionnaire was sent to all the members of ESTIA (personal and students). The results of the study made it possible to adapt the contents of the interfaces according to the concerns of the public.

Lastly, the potential users were still solicited to evaluate the designed interfaces. After the definition of a protocol of evaluation including tasks to carry out and questions of debriefing, the users were timed on the various tasks and were encouraged to formulate their thought and their criticisms on the interface which they were testing. The evaluations gave considerable results on the level of comprehension (vocabulary) and use (in particular navigation on the web site) of the interfaces.

Finally, it must be highlighted that many students have participated in the design and the manufacturing of the Kit during their training-courses.

The user interfaces

As written before, the public awareness Kit has two interfaces, a screen saver and a web site. Moreover a Newsletter is spread every month to a mailing list.

The screen saver

The screen saver is a non-interactive interface (only reading and automatic transition to the next page) which:

- **Describes the Kit**: the screen saver proposes a dynamic description of the Kit (Fig. 3).

Fig. 3. *Presentation of the Kit in the screen save*

- **Increases public awareness of renewable energies**: during a short time (more or less 4 minutes), public is informed about the potential of renewable energies for generating electricity, as an alternative energy to conventional polluting sources. The production of ESTIA's PV panels and wind turbine is compared with the consumption of domestic electrical devices. With this comparison, people from very varied backgrounds can have a better idea of the benefits of using renewable energies. Moreover the public is informed about the CO_2 emissions avoided by the use of renewable energies in comparison with traditional polluting sources (coal, fuel, gas), as shown in Fig. 4.

Fig. 4. *CO_2 emissions avoided shown in the screen saver*

- **Increases public awareness of electricity consumption reduction:** for the daily production, the screen saver highlights the consumption of a classical incandescence bulb of 100 W in comparison with a low consumption bulb of 20 W, equivalent in luminosity.

The screen saver uses information contained in the database. The corresponding data are restored in each page changing. Like this, the production of renewable energies and the avoided CO_2 emissions are shown in live. Moreover, for tehcnical reasons, the screen saver needs a permanent access to internet.

The content of the screen saver can be fully parameterised from a web site designed for the system administrator. Thus, it is possible to answer to the expectations of different kind of public.

The web site

The Kit web site [7], whose address is given in the screen saver, allows completing the information given by the screen saver. The following section can be accessed from the site:

- **Presentation**: this page presents the project and the Kit, explaining what are the objectives, the resources, the participants and the locations, and giving the list of the different components.
- **The production**: an interactive interface allows seeing the actual and the passed production data acquired by the Kit (Fig. 5). These data can be observed daily, monthly or annually. They can be compared with the time needed for different electrical devices to consume the same energy. Other kinds of comparisons can be made from the *En comparaison* subsection. The produced energy, since the installation of the Kit, can be analyzed in different ways:
  - Avoided CO_2 emissions: the CO_2 emissions corresponding to the same amount of the produced energy in ESTIA for gas, fuel, coal or combined cycle plant are shown.
  - Equivalent trees: the page shows the number of trees necessaries to absorb the CO_2 emissions of gas, coal, fuel and combined cycle plants to produce the energy produced by ESTIA's generators.
  - Money: the site shows the sum of money corresponding to the sold energy for PV panels integrated or not in the building (the price is different for each case, French government having voted a law to encourage PV installation integrated in the buildings). The sum corresponding to the money which would be spent to buy the same quantity of energy is also shown.
  - Raw materials: this section gives the equivalent volume or mass of gas, coal and fuel for the produced energy.

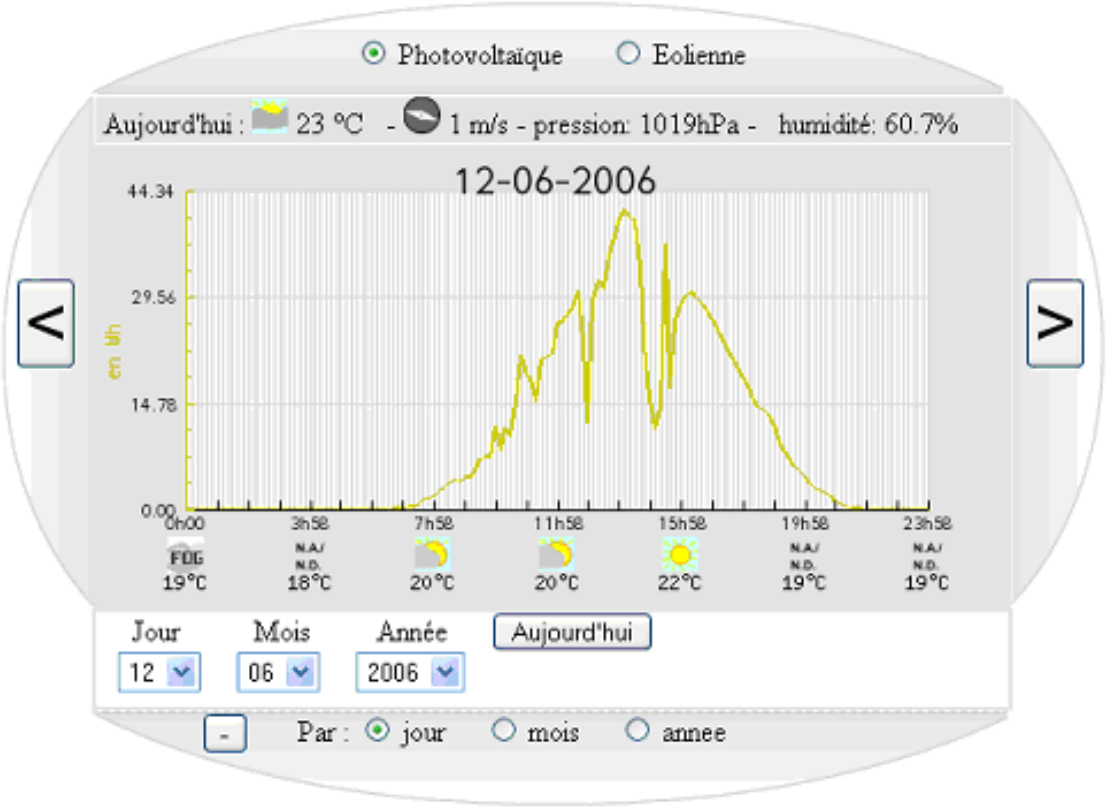

Fig. 5. *Presentation of the produced energy in the web site*

- **Contacts**: this section allows the user contacting the administrator and the persons who took part in the project.
- **Glossary**: technical and non usual terms are explained in this section in order to do the site understandable to any kind of user.
- **Links**: the users can find more information about renewable energies, global warming, associations, institutions, events... Moreover, visitors can propose new links to the web manager.

The Newsletter

A Newsletter showing some production data is sent to a mailing list every month. The Newsletter gives the energy produced by each generator installed in ESTIA (PV panels of ESTIA 1, PV panels of ESTIA 2 and wind turbine) during the actual day, the actual month and the actual year. The avoided CO_2 emissions comparing the emissions of ESTIA's generators with those of a gas, fuel, coal or combined cycle plant are also shown, as in the web site. Similarly, some equivalent of money, trees or raw materials for the produced energy in ESTIA can be observed, as explained in the precedent section.
Finally, important news about renewable energies, global warming and ecology in the whole are introduced in the Newsletter.

Links with the data server and used software tools

In order to compute the energy value, the voltages and the currents given by the sources are measured with a period of 1 second. The instantaneous power obtained by multiplying the voltage by the current is integrated on a 10 minutes interval to obtain the energy information. A text message containing this information must go to the data server.
Our system uses the ESTIA informatics network to send the text message to the data server. Finally the information is presented to the public using a real time graphic interface in HTML format. This interface is also available for the computers connected to the local area network (LAN) of the school (ESTIA users) or for external users by means of Internet network.
The routing, recording, storage, representation and disclosure of the information contained in the character string (energy produced by the renewable systems) provided by the hardware module are the principal objectives of this part. The information disclosure is made using a dynamic interface which shows in a didactic way the evolution of the energy production in real time.
This part of the system is made up of five stages illustrated in Fig. 6.

- The starting point is the recovering and the recording of the character string provided by the hardware module. For that, a Visual Basic program which automatically directs the data towards a database has been developed. These data are received and recorded every 10 minutes. The Visual Basic program that runs on the server receives the message, extract the information and put it in the MySQL databases.

The header of the message contains the sender identifier and this permit to choose the adequate Table.

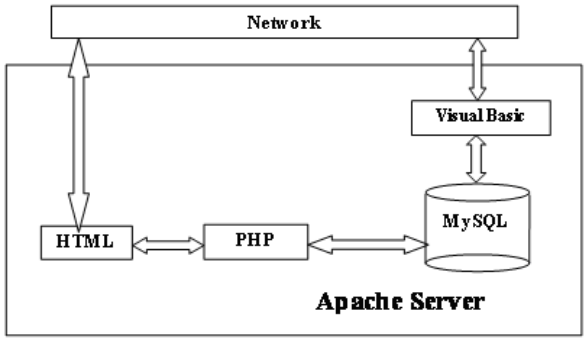

Fig. 7. *Routing, recording, storage, representation and information disclosure*

- The management of the database is made by the open source MySQL software. MySQL can manage a great quantity of data by organizing them in tables. Simple instructions permits to add, remove, update and search data. This software is very often used with the PHP language.
- The PHP language is used for the creation of the dynamic Web pages. PHP allows executing easily the repetitive tasks, in particular those related to the communication with the database.
- The development of the graphic interfaces is made in HTML language for posting information of the database which must be accessible from the ESTIA internal network and providing a comparative illustration between the pollution avoided by the renewable system and other types of energy production.
- Finally, Apache is used as Web server. On this server are installed the MySQL database and various components (PHP scripts, HTML pages) of the graphic interface allowing customers (Web navigators) to reach information of the project.

Apache is software able to interpret HTTP requests arriving on the port associated with HTTP protocol (normally the port 80) and to provide an answer with this same protocol.

The hardware module

As shown in Fig. 7, the acquisition, data processing and communication system is composed by:.

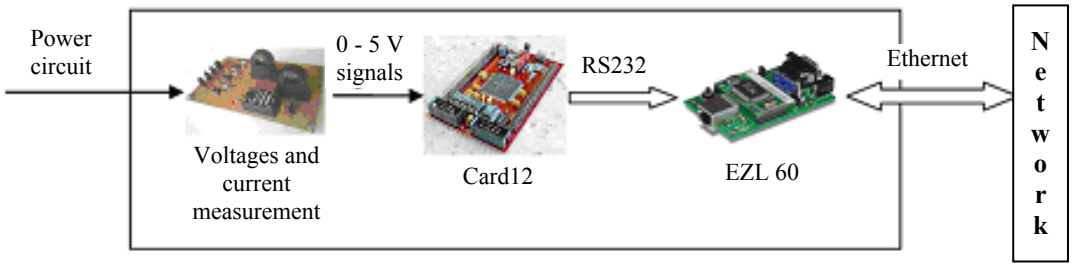

Fig. 7. *Acquisition, data processing and communication*

- A voltage and current measurement card
- A microcontroller card (Card12 with the MC912DG128 microcontroller).
- A RS232 to Ethernet adapter (EZL 60

Voltage and current measurement module

This module consists of current sensors and voltage dividers followed by filtering circuits. This makes possible to obtain appropriate voltage values that are the image of the values of current and tension produced by the PV panels in the case of the first building and by the HPS in the case of the second building. These voltages are lead to the analog input of the microcontroller, so the values must fit in 0 V to 5 V interval.

Microcontroller card

Card12 is a credit card sized controller module with a MC912DG128 microcontroller. It was programmed to compute and send periodically a character string containing the information of the value of the energy produced by the renewable sources. This value is calculated from the signals provided by the measurement module.

One of the principal objectives is to have a sufficient quantity of data to be able to determine for on one day, one month or one year, the quantity of energy produced by the renewable sources. These statistics could be used thereafter as a basis for enterprises or associations which wish work in the field of renewable energies. Using almost the same structure of the acquisition system it is possible to obtain helpful information on the electrical power consumption allowing private persons to be able to find an interest to invest in this type of systems.

The microcontroller converts the analog signals into numeric values, compute the produced energy, create and send the message to the server using the RS232 interface. All these tasks are implemented in a C language program which contains instructions and variables specific to the HC12 microcontroller. A compiler especially designed for the development of this type of programs generates the object code which is transferred in the MC68HC912DG128A microcontroller memory.

RS232 to Ethernet adapter

The routing of the information towards the server is made using a series Ethernet adapter which makes possible to connect the RS232 port of the Card12 to the local area network.

EZL 60 is part of the ezTCP family. These products relates to the Ethernet series interfaces offer a material and a software solution to the manufacturers who wish add very simply and quickly possibilities of network connectivity to their applications.

The use of the EZL 60 module in partnership with Card12 allows connecting it to the network without limitation of distance, making it accessible to a multitude of PC (including via Internet by distant PC).

The RS232 to Ethernet adapter has its own IP address. It reads the information provided by the microcontroller and sends it to the server. If the server is down, this module can store the information during one day.

Other initiatives

Other initiatives have been adopted in ESTIA in the frame of this project. Their objective is to reduce the energetic consumption in ESTIA. These initiatives have been carried out or supervised by the ORLI department of ESTIA. The following actions can be highlighted:

- All the PCs and the associated screens of ESTIA have been configured to shut down automatically themselves if they are not used during half an hour.
- For each new computer which is bought, a flat screen is also bought and it replaces a cathode ray tube display. Thus, the electrical energy consumption is reduced for each workstation.
- The air-conditioning system of ESTIA 1 building has been replaced by a new one which is much efficient and thus spends less energy.
- All new bulbs installed in the two buildings of ESTIA are of low consumption.
- The video projector installed in different rooms of ESTIA are automatically shut down if there are not used during ten minutes.

Conclusions

ESTIA engineering school has carried out a specific approach during these last years in order to fight the global warming. The core of this approach has been the design, manufacturing and installation of a public awareness Kit of renewable energies. Important measures have also been taken to reduce the electric consumption of ESTIA.

There are few months the Kit was installed and it is still difficult to say if its awareness impact is good or not. However, some signs let us to think that the ESTIA's approach in the whole has been a success. Actually, the ESTIA’s electric consumption has decreased this last year, comparing it with the consumption of precedent years. Moreover, some surveys carried out among the student shows that they have more knowledge on renewable energies and on the importance of reducing energy consumption since the Kit has been installed. A questionnaire with simple questions about renewable energies and global warming was sent to the student of the first year of ESTIA in September 2006. Similar questions have been sent to the same students this year to do a comparison. The analysis of the answers shows that these students have more knowledge on these topics and that they are more aware of the need to act against global warming.

The Kit presented in this paper has been designed to be easily installed in others sites. Thus, ESTIA will try to spread this public awareness solution.

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VALORIZATION OF THE SAWDUST FOR THE IMPROVEMENT OF THE MECHANICAL-PHYSICAL PROPERTIES AND OBTAINING A LIGHT CERAMIC PRODUCT

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Nowadays terra cotta industry is interested in the manufacture of a new reduced produced whose design deviates from the traditional models. The recycling of chips of wood such as the sawdust seems to be the best insulator which offers the properties of required ceramic products. Two types sawdusts were considered in this study, pertaining to two wood (pine of Alep) family of coniferous timber and the other (the eucalyptus) family of timber broad leaved and which differ by their origin, structure, their physical properties, chemical etc. These sawdusts were introduced into various argillaceous mixtures made up of yellow clay, of grey clay more of the tuff. The work was concerned moistures of shaping varying from 22, 24 and 26 % with contents of sawdust of 3, 6 and 9 % and diameter dimensions of particles of 0.5; 1 and 1.6. Cooking was carried out at temperatures of 850 and 950 °C. The characterization of the ceramic products obtained during drying and of cooking made it possible to raise the considerable differences with regard to the physical and mechanical properties. A comparative study and of optimization enters the various products obtained made it possible to fix the choice on the products having been worked with a moisture of 22 %, a content of sawdust resulting from wood eucalyptus of 9 %, with a diameter of particles ϕ =1.6 mm corresponding to a density of 1.48 g/cm^3 and a mechanical resistance of 138.60 kgf/cm^2.

Keywords: valorization, sawdusts pine of Alep, eucalyptus, development of alveolar bricks, light, insulating

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Publications: Ceramic Industry and glass, No. 990 September-October 2003.

Introduction

The increasing obligation to manage and develop the industrial and domestic waste leads to the development of new recycled products [1]. To develop waste is a choice which meets at the same time the economic and environmental requirements [2]. Each material must contribute to the total objectives of recycling while fitting in a range of 55 to 80 % and to await a minimum of 60 % of valorization. The principal innovation consists of the fixing of targets differentiated by materials (Glass: Sciences, Technology, Industry, Produced, Art, History) [3]. Wood is a material which seems to be very appreciated for these mechanical

properties, its calorific value and other. It has many uses in the building and industry as a fuel [4]. Constituted mainly of organic matter (1.0-1.5 %) of biogenic salts, it also contains a variable share of moisture: Cellulose (40 to 50 %), lignin (20 to 30 %), hemicellulose (15 to 25 %) and other organic substances (polysaccharides, resins, waxes etc) [5, 6]. Nowadays, it is extremely interesting to fix its vision towards new insulating materials because the insulation plays the part of barrier for the thermal transfer by means of this type of material having the capacity to transmit the lowest possible heat. In the Seventies the need for heat insulation to save energy became an obsession. The industrialists then rushed on very powerful and not very expensive insulators often resulting from polystyrenes and polyurethans. Alas these materials are not safe for health and require a great quantity of energy of manufacture. Thirty years later an increased sensitivity appeared coming from the countries of Europe and spreading little by little towards the south concerning the elaborate ecological insulating products starting from vegetable and animal fibres, of mineral insulators as well as other renewable materials such as cellulose, cork, sawdust etc [7]. To achieve these goals our principal efforts in this study were dedicated on the use of the sawdust in a ceramic mixture of mass which at the same time plays the part of grease-remover and amongst other things gives the possibility of obtaining terra cotta bricks having an alveolar aspect, of low density and higher mechanical resistance in comparison with traditional bricks.

Experimentation

The analyses were carried out on raw materials local grey clay, the yellow clay of the tuff and sawdust coming from two types of wood "pine of Alep and eucalyptus". The results of analyses are based on the preparation of sawdusts to various granulometry obtained in sieves (0.5 – 1 – 1.6 mm). The drying of the sawdust is carried out in a drying oven of laboratory at the temperature 105 °C of the type Memmert UL50. Maximum temperature 220 °C with ventilation the granulometric analysis was determined by wet process by using a series of sieve of various diameters (5 –2 – 1 – 0.63 and 0.20 mm), and by "pipette of Robinson". The optimization of ceramic pastes is related to: preparation of briquettes starting from 03 types of mixtures made up of clays grey, yellow, tuff and sawdust. These mixtures are named M_1, M_2, M_3, M_4 of which the proportions are respectively: (65 – 30 – 2 – 3 %), (65 – 27 – 2 – 6 %), (65 – 24 – 2 – 9 %). The water contents of shaping are 22, 24 and 26 %. The contents of sawdusts are 3, 6 and 9 %. For some moisture we considered the 3 types of contents of sawdusts and for each content one considered the 3 types of granulometry. The drying of briquettes proceeded in two stages: with the free air during 24 hours then in a drier with room lasting 24 hours. Cooking was carried out in a tunnel kiln with temperatures of 850 and 950 °C. The characterization of the physical and mechanical properties was related to the drying and firing shrinkage, absorption, porosity, the bulk density and the specific mass. The mechanical resistance is given in an apparatus of inflection of the type 401 NEZSCH EN100. The chemical analysis was determined by the sequential spectrometer of X-ray of the type SRS 303 Siemens. Water supply: 3V min. Supply air: 2V min.; Pressure water: 4 to 8 Bars; Pressure air: 4.5 to 10 Bars. The principal minerals combined with clays and natures of phases are determined by diffractometer X-ray de type Siemens "500D" 20 my – 40 kV with X-ray Cu tube.

Results and discussions

The results of chemical analysis are carried in Tables 1, 2.

Table1

Chemical analysis of two clays

Principal elements	Contents (%)	
	Grey clay	Yellow clay
SiO_2	48.02	51.28
Al_2O_3	10.63	12.34
Fe_2O_3	4.68	4.76
CaO	13.49	11.39
MgO	1.67	1.48
SO_3	1.23	0.95
K_2O	1.51	1.67
Na_2O	0.61	0.57
Loss in ignition PF	17.34	14.72

Table 2

Chemical analysis of the tuff

Tuff	
Element	(%)
SiO_2	33.66
Al_2O_3	15.78
Fe_2O_3	4.42
CaO	2.27
MgO	2.42
P_2O_5	0.08
K_2O	4.34
Na_2O	3.40
TiO_2	0.40
MnO	0.08
PF	2.92

According to Table 1 one notes that the two types of clays have one propriety in common on the one hand: the rate of Al_2O_3 which in both cases is < 14 % which makes it possible to classify them in the group of acid clays [8], in addition the limestone rate ranging between 6-20 % makes it possible to classify them in the group of marly clays. The products cooks yellow [9].

The elements playing the part of energy fluxes (K_2O, Na_2O) have a rate slightly more raised concerning yellow clay, which confers better properties of cooking to him. The principal elements which make distinguish these two clays are first of all the rate of SiO_2 which is higher in yellow clay this makes it possible to say that this type of clay is sandier and plays consequently the part of grease-remover. It is also noticed that the rate of CaO, SO_3 and Loss in ignition PF is higher in the case of grey clay what exact correlation is with the rate raised in loss on the ignition.

One notes according to Table 2 that the prevalent elements in the tuff are silica the iron alumina and oxide. This last element colours the tuff in red. The tuff presents an aspect of perfectly consolidated ash what makes it possible to classify it in the group of pumice tuff [10, 11, 12]. In addition it is noticed that the rate of the alkaline elements is considerably important and makes it possible to conclude that the tuff plays the part of flux in the ceramic mass.

According to the results of the mineralogical analysis (Table 3), yellow clay is of type illite/ montmorillonite and grey clay is of type Illite/ Kaolinite/chlorite.

Table 3

Mineralogical analysis of clays

Principal minerals	Contents (%)	
	Grey clay	Yellow clay
Quartz	32	27.5
Calcite	21	18
Dolomite	3	2
Feldspar: potassic	1	1
Feldspar: sodic, calcic	2.5	2.5
Semi gypsum hydrate	2	2
Ferriguneux minerals	4.5	4.5
Illite	13.5	15
Kaolinite / chlorite	12	13.5
Montmorillonite	8.5	14

According to Table 4 one notes that grey clay contains much more argillaceous particles than yellow clay this is in correlation with the data of the Table 1.

The grain size analysis of the two types of clays are illustrated in Tables 4 and 5.

Table 4

Granulometric analysis of clays "Pipette of Robinson"

Type of clay contents (%)	Dimensions of the particles (mm)				
	1 to 0.063	0.063 to 0.01	0.01 to 0.005	0.005 to 0.001	< 0.001
Grey clay	14.65	30.99	13.20	11.00	30.16
Yellow clay	12.40	25.28	13.28	22.72	26.32

Table 5

Granulometric analysis of clays "Wet process"

Type of clay Contents (%)	Mesh sizes of sieve (mm)				
	5.00	2.00	1.00	0.63	0.20
Grey clay	0.00	0.00	0.03	0.03	0.10
Yellow clay	0.00	0.00	0.00	0.1	0.03

According to Table 4 one observes that the rate of refusal of yellow clay is weaker than that of grey clay. In addition yellow clay is made up much more small particles probably with the mineral montmorillonite which is associated clay and which is in correlation with the results of Table 3.

Among the principal studied physical mechanical properties, one notices that the drying shrinkage the products manufactured containing sawdust of the pine of Alep is higher than that of those manufactured containing eucalyptus. This last A tendency to decrease according to the increase in granulometry and the content of sawdust but the values become definitely high when the moisture of shaping of the ceramic paste passes from 22 to 26 %. This variation remains identical in the case of adding the two types of sawdusts. This is with the structure of the wood of origin [5]. The sawdust of the pine of Alep belongs to the family of coniferous timber tender with structure made up of large channels which have the capacity to absorb much water and to give a great shrinkage compared to the family of leafy trees "eucalyptus" which them consist of vessels [13]. The absorption of water is done by the hydrogen bonds of the hydroxyls groups accessible from hemicelluloses, lignin and cellulose. Water, occupying a space in polymers, inflates the cellular walls and wood dilates as water is absorbed until the cellular walls are saturated. Wood east defines as a hygroscopic material which inflates by absorbing moisture and contracts by losing moisture below the point of saturation of the fibres [14]. For firing shrinkage, one notes the same case of variations of values. On the other hand clay containing sawdust of the pine of Alep varies proportionally with the temperature of cooking, and preserves values always higher than those of the eucalyptus. The highest shrinkage is recorded for moisture of shaping of 26 %, a content of sawdust 3 % with a diameter (Φ) of particles 0.5 mm. The values of the firing shrinkage temperatures of cooking of 850 and

950 °C are respectively 2.44 and 2.79 %. The high values shrinkage of result in a rearrangement of the particles which leads to a texture consolidation compared to the initial state followed by contraction [15, 16]. The sawdust plays the part of grease-remover of paste in a believed state and porogene agent. During cooking the specific values of mass obtained with the pine of Alep remain in their turn higher than those of the eucalyptus. The specific mass is inversely proportional to the content of sawdust to size of the particles and moisture the paste, but varies proportionally with the temperature cooking. The values of bulk density as for them are inversely proportional to the content of sawdust, with the size of the particles, the moisture of the paste and the temperature cooking. These values remain always higher than those of the sawdust of the eucalyptus. The rise in the temperature leads to a swelling and a reduction in volume of material obtained. There is a direct correlation between the values of absorption and apparent porosity. To low values of absorption corresponding to low apparent porosities and on the contrary. These values are proportional to the content of sawdust, with its size but are inversely proportional to the temperature. Because during the cooking of the ceramic product there is appearance of liquid phase which takes part in the elimination of the vacuums and the pores allowing the bringing together of the particles following a formation of zones of contact inter granular [17]. The products leading to the bulk density lowest are those obtained with the sawdust mixture of the eucalyptus with the moisture of shaping of 22 and 24 %, diameter (Φ) of particles 1.6 mm, of content of sawdust of 9 %, temperature of cooking 950 °C. The values corresponding to these two types of moistures of shapings are respectively 1.52 and 1.43 g/cm^3. Table 6 gathers the values the physical and mechanical properties of the cooked eucalyptus with 950 °C.

Table 6

Physical and mechanical properties of light bricks containing sawdust eucalyptus (Temperatures 950 °C)

H_f (%)	Φ (mm)	Content of sawdust (%)	Drying shrinkage (%)	Firing shrinkage (%)	Abs (%)	Apparent porosity (%)	Sealed porosity (%)	M_v g/cm^3	M_s g/cm^3	R_{Flex} kf/cm^2	R_{Comp} kf/cm^2
22	3	0.5	13.93	1.83	2.37	4.42	23.83	1.84	2.61	165.20	660.80
		1	12.65	1.75	3.30	4.70	24.03	1.82	2.56	158.00	632.00
		1.6	10.89	1.68	5.28	5.69	24.18	1.75	2.51	150.80	603.20
	6	0.5	13.51	1.67	5.19	4.46	24.49	1.82	2.59	162.80	651.20
		1	11.98	1.64	8.35	4.91	24.62	1.80	2.54	154.40	617.60
		1.6	9.28	1.59	10.66	5.74	25.26	1.71	2.45	147.20	588.80
	9	0.5	12.99	1.60	7.36	5.46	24.78	1.79	2.53	154.42	617.68
		1	11.66	1.56	11.18	6.31	24.81	1.72	2.49	148.40	593.60
		1.6	8.66	1.49	12.86	6.39	26.15	1.68	2.43	144.80	579.20
24	3	0.5	15.91	2.35	4.07	4.68	24.34	1.81	2.55	162.80	651.20
		1	14.58	2.04	5.27	5.44	24.37	1.76	2.51	153.21	612.80
		1.6	12.67	1.85	6.80	6.74	24.98	1.70	2.49	148.41	593.64
	6	0.5	14.94	1.98	5.46	4.77	24.67	1.78	2.53	158.02	632.08
		1	12.98	1.81	8.99	5.56	24.77	1.74	2.48	149.60	598.40
		1.6	11.42	1.73	10.97	6.87	25.40	1.67	2.43	146.00	584.00
	9	0.5	14.23	1.82	8.06	5.67	25.15	1.75	2.51	152.02	608.08
		1	12.53	1.67	11.63	6.71	25.30	1.69	2.46	147.22	588.88
		1.6	10.86	1.61	13.45	7.05	26.89	1.65	2.41	143.60	574.40

***Legend**: H_f – Moisture, **Abs** – Absorption, M_s – Specific mass, R_{Flex} – Bending strength, **Φ** – Diameter, M_v – Bulk density, R_{Comp} – Compressive strength.*

By considering the results carried in Table 7 one notes that the pine of Alep provides the same mechanical resistance as that of the eucalyptus mentioned in table 6 for a value of moisture of shaping of argillaceous paste of 24 %, to which corresponds a bulk density of 1.65 %. As for that of the eucalyptus the values of bulk densities and mechanical resistances are lower to 26 % of moisture of shaping. To avoid the problem of sensitivity

of drying it would be thus necessary to remain in an interval limited enough by humidifying the argillaceous mixtures and to fix our assumption on moisture 24 %.
The rates of shrinkage of the pine of Alep are considerable as the moisture of the argillaceous paste increases which could make drying rather slow and delicate It is advisable to consider that the characteristics of the sawdust of the eucalyptus for a water content of paste of 24 % as it was underlined in fat in Table 5 remains the best recycling wood product.
The latter enabled us to acquire the required properties of light brick.

Table 7

Physical and mechanical properties of light bricks containing sawdust of pine of Alep – sawdust of eucalyptus with 26 % of moisture of argillaceous paste

Parameters of manufacture		Physical and mechanical characteristics	Sawdust of pine of Alep	Sawdust eucalyptus
Sawdust Φ	1.6 mm	M_v (Bulk density)	1.48 %	1.43 %
Content	9 %	Abs (Absorption)	13.85 %	15.70 %
Moisture of the paste	26 %	$R_{flexion}$ (Bending strength)	134.00 kf/cm^2	126.80 kf/cm^2

Fig. 1 shows well a considerable difference between the two sawdusts in comparison with the values obtained in a former study and where addition was of the organic type such “coal”.

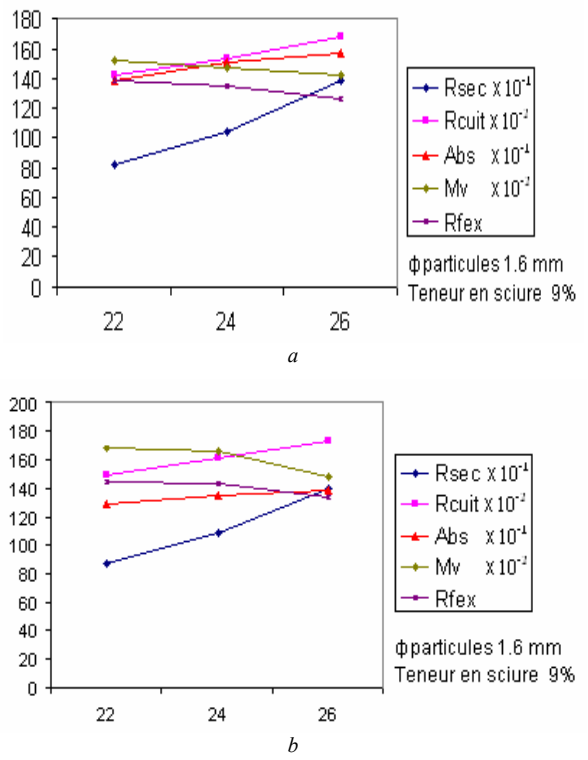

Fig. 1. *Physical mechanical characteristics of the sawdust of the eucalyptus (a) and that of the pine of Alep (b) for a content of 9 % and one diameter of particles of 1.6 mm*

Conclusion

Before developing a waste it would be advisable to know its origin, to analyze it, characterize its current state, its behavior like addition in the mass or mixes to analyze and evaluate its traitability.
Thus the global solution of waste will make it possible to define some its to become with knowing which type of valorization choose.

The sawdust as a matter of recycling introduced into various mixtures of clays plays at the same time the part of grease-remover in the raw paste and porogene agent (insulators) during cooking.
The sawdusts considered and pertaining to two wood different pines of Alep and eucalyptus give products which show definitely different characteristics.
This difference comes owing to the fact that the cells constituting the structure of wood form an assembly according to a true architecture whose plan differs from one wood turpentine to other what confers no identical properties to us.
The sawdust addition resulting from the pine of Alep in the argillaceous mass gives values of definitely high shrinkage becoming increasingly large with the rise in the moisture of the paste. This remains related to the structure of the pine of Alep which is porous compared to that of the eucalyptus. The properties which characterize the quality of required insulating materials are obtained starting from the mixtures made up of 24 % of moisture of shaping, sawdust 9 % of eucalyptus and having a diameter of particles of 1.6 mm.
The value of recorded bulk density is of the order about 1.48 g/cm^3 corresponding to a mechanical resistance of about 134.60 kf/cm^2. The latter is definitely high in comparison with that of a traditional terra cotta brick which is of the order about 100 kf/cm^2.

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FLOODS IN SEMI-ARID ZONE: EXAMPLE OF THE OURIKA (HIGH ATLAS OF MARRAKECH, MOROCCO)

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In the High Atlas of Marrakech, the watershed areas are submitted to important and frequent floods, associated with landslide and rockslide. Morphological and lithological characteristics of the basins watershed have a clear influence on the rising waters strength and the hydrogram's shape. The products of erosion accumulated in the upstream part as gravity accumulation and fans are remobilised during high floods when the discharges increase. This situation make flows muddy and torrential. The consequences of these natural risks can be grave in term of damage and cost. In the Ourika valleys, we are confronted to the amplification and repetition of this process owing to its deepness and narrowness. Furthermore, the degradation of environment speeds up because of the development of tourist activities. All these conclusions suggest the management of these suddenly beating of flows.

Keywords: floods, high atlas, landslide, erosion.

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Introduction

In arid environments rising waters accompanied by landslides, the consequences of which can be very serious in terms of damage and cost, are quite frequent. In the Ourika basin (High Atlas of Marrakech, Morocco), the rising waters rapidly turn the roads dangerous and consequently out of use, especially as the valley is linked to the outside world by a unique fragile and vulnerable road.

On August 17th, 1995, the High Atlas of Marrakech, and most particularly the Ourika valley witnessed floods of enormous strength which occurred in an unexpected brutal way [1, 2]. In an unprecedented short time, the

floods caused human casualties (more than 200 death and unaccounted for) and huge material damage. The torrential rain and the mudslides whish followed swept away road infrastructures, agricultural lands, houses, hospitals and schools as well as a great part of the irrigation infrastructures [3]. On the whole, the material damage (vegetable and animal production, hydro-agricultural network and properties) are estimated at 155 million dirhams (about 15 millions US dollars) [4]. This catastrophe caused a great imbalance as far as the production system and the ecological environments is concerned.

This paper is a study of the hydrological, lithological and geomorphological aspects of the Ourika basin. The primordial purpose of this study is: 1 – to understand the dynamics of this natural fragile environments, 2 – to provide indications allowing for a characterization of its hydrological behaviour.

Characterisation of the Ourika basin watershed

The hydrological behaviour of a basin watershed depends mainly on its climatic and geomorphological characteristics. In fact, just like the weather, the physical environment can provide appropriate grounds for brutal pulsations of rising waters. A heavy rain, whish falls on a sloppy basin with deep watershed and with little permeable substratum, can cause flows on the surface with a very short time response of water concentration.

Geographic and climatic situation

The Ourika basin at Aghbalou, about forty kilometers south of Marrakech (Fig. 1), is situated between 31° and 31°20′ North and between 7°30′ and 8° West. Several aridity indexes place the sector in a semi-arid zone with a sub humid tendency where oceanic (west perturbations), continental and mountainous influences interfere. The average annual temperature is 17.6 °C at Aghbalou, but the difference in temperatures between the hottest mounts (July) and the coldest (January) can reach 15 °C. The region is characterized by precipitations of a spatio-temporal variability and by relative irregularity in superficial flows. The average annual rainfall is 584 mm per year at the Aghbalou station with a 34 % variation rate. The monthly and seasonal variability is even more marked respectively by 50 and 55 % variation rate. According to the Marrakech hydraulic regional office, the average annual discharge at the basin vary from 0.59 m^3/s to 29.6 m^3/s. However, the marked trace of the Ourika flows corresponds to the highly occasional flow discharge which can reach several hundred of cubic meters per second.

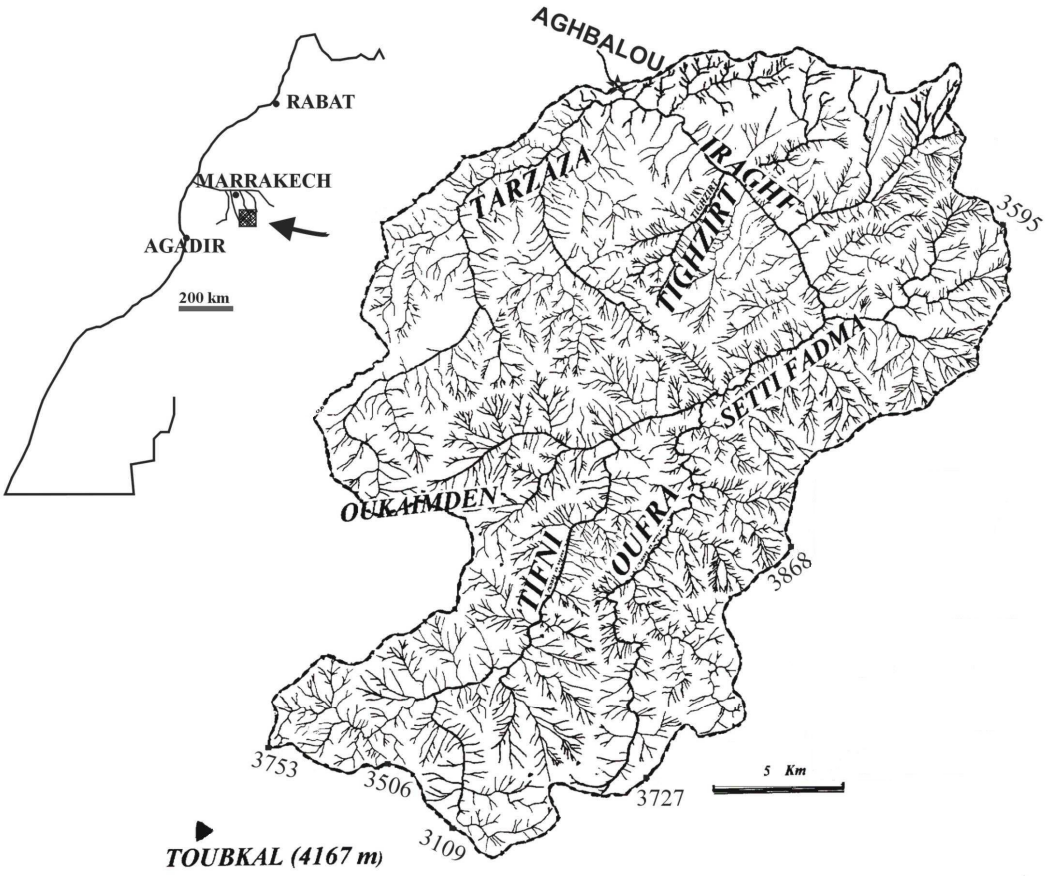

Fig. 1. *Ourika basin watershed: location map and hydrographic network*

Morphological characteristics

The basin watershed shape can have important hydrological consequences, mainly the rain-discharge relationship and the evolution of the flows in periods of rising waters. In other words, and besides the nature of the rainfall, it is basin's morphological characteristics that condition the shape of hydrograms observed downstream the basin. Several formulae and indexes illustrate these characteristics (Table 1).

The Gravelius compactness index ($Kc = 0.28\ P/\sqrt{S}$); where P is the perimeter and S the surface) offers and idea of the basin's geometrical shape; it is the range of 1.3. This relatively mediocre compactness grants the basin with an elongated shape. The main flow forms a linear valley, fed on the two banks, by a succession of tributary ravines (Fig. 1). This situation allows for the waves of rising waters to swell downstream while being fed by the tributaries.

The analysis of the distribution of the altitude parts is made of the basis of a topographical map at 1/100 000 m Oukaimeden-Toubkal. The altimetric distribution at the Ourika basins shows the predominance of sites situated between 1600 and 3200 m (75 %); the average altitude reaching 2500 m, Fig. 2.

Table 1

Morphological characteristics of the Ourika basin watershed

Perimeter (km)	104
Surface (km²)	503
Compactness index	1.3
Length of the main (km)	45.5
Length of the equivalent rectangle (km)	39.2
Width of the equivalent rectangle (km)	12.8
Maximum altitude (m)	4001
Minimum altitude (m)	1070
Average altitude (m)	2500
Average slope of the main flow (%)	2.15
Average slope of the main tributaries (%)	9.35
Average slope of the basin watershed (%)	35

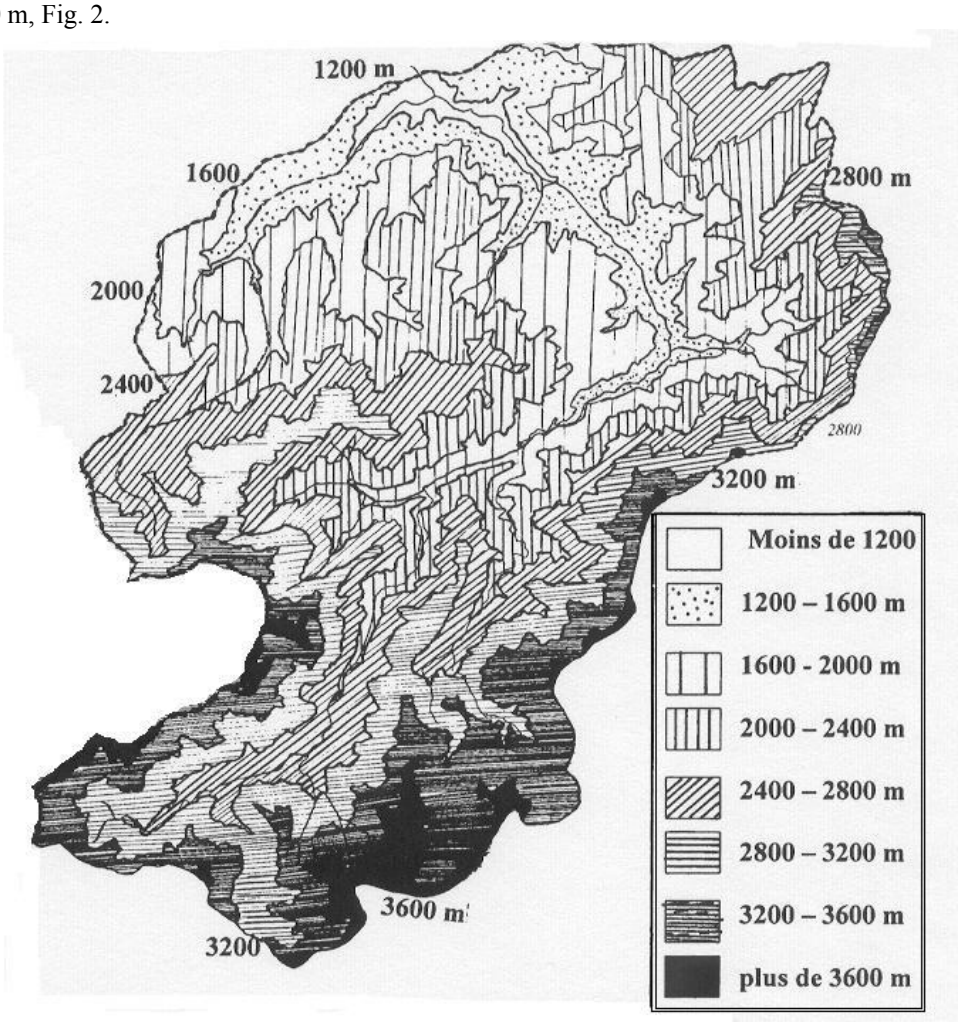

Fig. 2. *Hypsometry of Ourika basin*

The calculation of the Ourika slopes shows that the main flow slopes are not particularly high (0 to 5 %). However, the speed and the violence of the flows are mainly governed by the most important slopes of the tributaries. All the tributaries feed the main flow with very important slopes. The Tarzaza that drains the Oukaimeden massif follows an average slope of 11 %, but the most sloppy little valleys are situated upstream the basin with slopes reaching, in some places 30 to 40 %, Fig. 1 and 2.

Geological context of the basin

On the geological side, the basin slope offers two types of facies (Fig. 3):

– The upstream part, situated at heights superior to 2000 m, is composed of igneous and metamorphic rocks wish form the Atlas chain platform. We found especially plutonic, mainly granite and granodiorite rocks, volcanic (andesites, rhyolites, …) rocks and metamorphic rocks (such as gneiss and migmatites).

This crystalline mosaic is appropriate for a rapid flow of the rain waters.

– The septentrional part, situated at heights inferior to 2000 m, is composed of permo-triasic and softer quaternary deposits. These facies are formed by conglomerates, sandstones, siltites and clays [5].

The lithological observations deduced from the geological map at 1/500 000 m and from land prospections show that soft to averagely soft rock represent an outstretch inferior to 40 % while the hard substract represents about 65 % of the basin outstretch. Thus, the source of the blocks and the drifting pebbles carried by Ourika came essentially from the platform which constitutes the axial part of the Atlas chain. As for lateral softer materials coming from the watersheds, their entrances into the main drains are very varied: alluvial materials (contact with the cones of dejection and the tributary confluences) and non alluvial materials (debris cones and landslides). Nevertheless, the geomorphological environments is marked by two major groups of forms of deposits: the dejection cones and fluvio-torrential terraces. These two units are intimately linked in time and space.

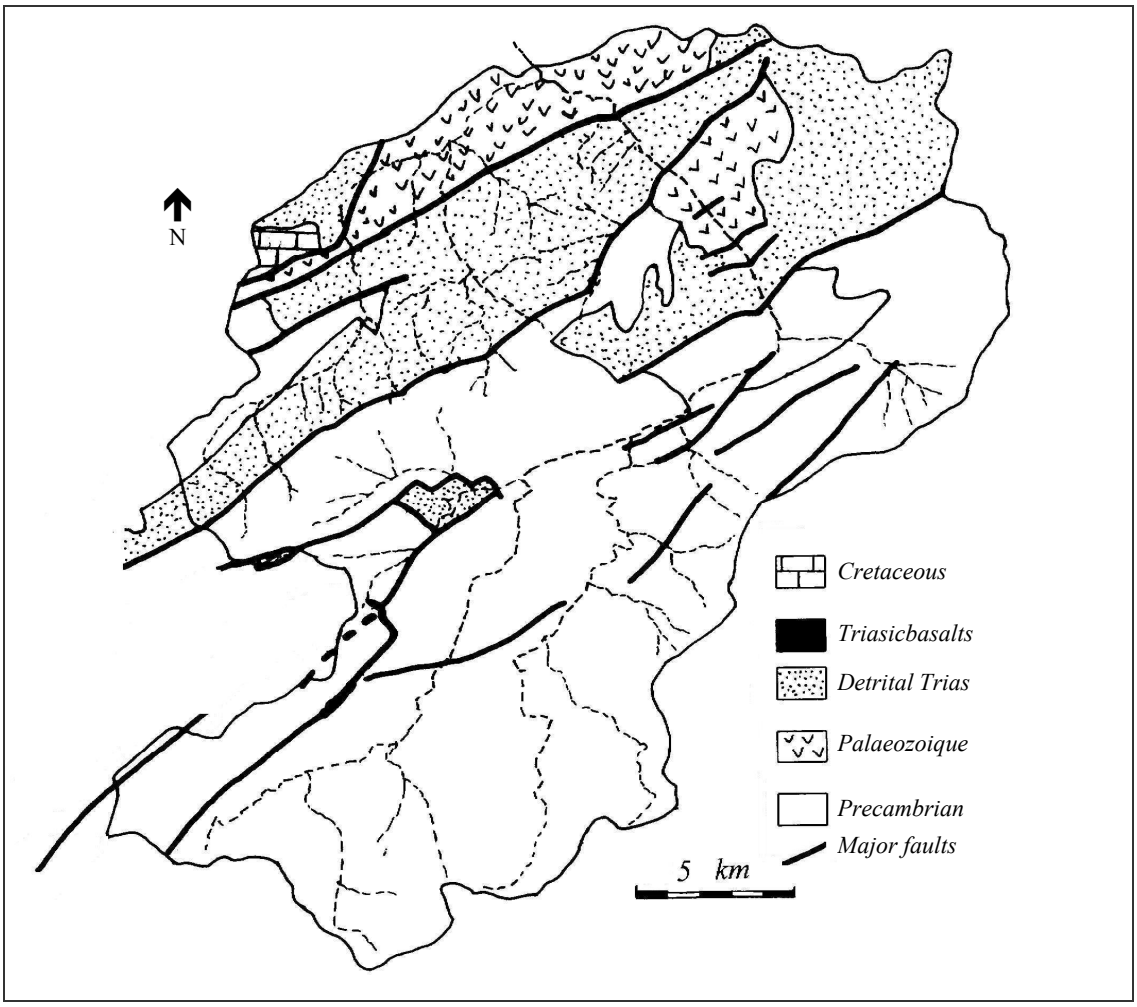

Fig. 3. *Geology of Ourika basin*

Consequence over the flowings and the solid discharge

Flowings

All the analysed morphological and lithological characteristics have a clear influence on the rising waters strength and the hydrogram's shape. The rising waters of Ourika are generally violent and of short duration [1, 2, 6]. The observed hydrograms downstream (Fig. 4) are often marked by quite brief mounting waters (generally about 10 minutes) and by subsiding waters that lasts several hours. The concentration time, relatively short, is estimated at 5 hours, calling, thus, for the necessity of installing warning system stations upstream. As a response of this worry a network of measurement stations have actually been put in place in four spots upstream the Ourika basin. These instantaneous informations will be of paramount interest in the prevention of floods downstream where it is highly frequented by tourists. One of the most deadliest and devastating floods was that of August 17th, 1995 [1, 2]. It was a consequence of a meteorological situation favouring the development of thunders according to the national meteorology. In fact, in altitude, a south flux carried humid, cold and convectively instable air over the High Atlas region from the Canary islands. On the surface, the hot air of continental origin followed a cyclonic curvature and produced upon the High Atlas chain from the North getting humidified in its way in contact with maritime air coming from the Atlantic. This air arrived in the afternoon with a temperature exceeding 40 °C producing a sudden outbreak of instability caused partly by the thermic convection and partly by the orographic effect. A local formation of thick thundery clouds was the result. The cloudy cell over the Haouz takes a remarkable dimension at about 19.00 h and begins to dissipate while moving towards the east at about 21.37 h. The thunderstorm hit the mountains in a restricted zone between 2000 and 3000 m of altitude. The intensity of precipitations is estimated at 100 mm/h, over a 228 km^2 surface [4].

The floods only lasted for three hours, but the rising duration was particularly short (hardly a quarter of an hour). The highest delivery rate at Aghbalou reached 1030 m^3/s with a volume of 3.3 million m^3. The hydrogram (Fig. 4) illustrates the characteristics of a simple monogenic flood with very strong rising level.

According to the instantaneous annual maxima rate of the delivery established by the Marrakech regional hydraulic office, and with the help of a statistical computerised data we have managed to adjust a certain number of statistical laws with a sample of the Ourika flood. The result obtained shows that the most adequate laws of these floods are the log Gamma, log Pearson and normal log laws; they allowed us to estimate the heights of certain rising waters as follows.

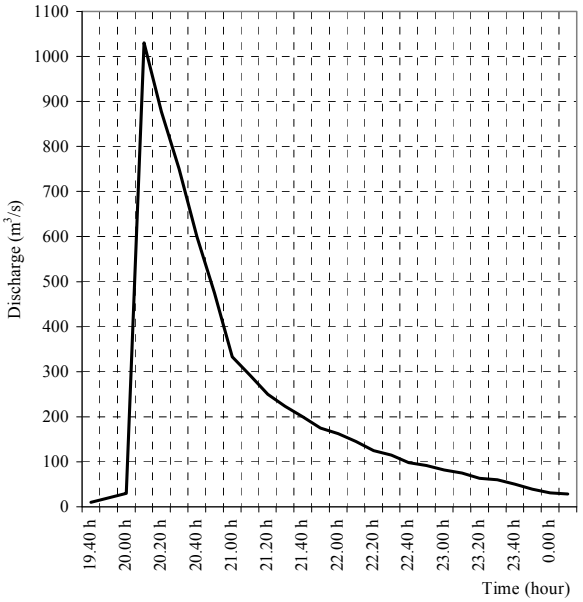

Fig. 4. *Hydrogram of the 17th August 95 floods of Ourika*

Rising median	Period rising, year			
	5	10	50	100
103 m^3/s	280 m^3/s	485 m^3/s	1320 m^3/s	1700 m^3/s

Erosion and solid load

Up to now, the studies devoted to the erosion and to the fluvial transport estmation in Morocco have all focused on the quantitative importance of the exported loads through the basin watersheds in semi-arid climate [7, 8]. Nevertheless, the global approach often used for the result estimation of the transported materials in semi-arid zones is confronted to the big hydrological irregularities of Moroccan rivers [8, 9].

In normal flow period, the solid load constitution of the water flows, carried in suspension, is mainly the result of contributing surfaces rather than the entire basin watershed [10]. This load comes generally from sectors submitted to intense erosion. At the level of watersheds formed by furniture, the erosion is particularly accelerated by the reduction of the vegetal layout, for reasons of natural fragility and anthropic over exploitation. The fine sediments can have three origines:

− Permo-triasic argillaceous-siltic dominated lands favourable for erosions and landslides despite their weak argillaceous swollen proportions [11];
− Argillaceous-muddy lands corresponding to soils;
− Terrace alluvia and dejection cones.

On what concerns the massive rocks of the platform and of the rigid layout temporarily covered by snow, the erosion can be equally important in places. In this region, where the peri-glacier and the arid (two extreme climatic models) coexist side by side, the alternation of the cold and the hot favours the thermoclastic and cryoclastic process whish facilitates the desegregation of the granitic and schistic rocks. Therefore, the abundance

of inverse faults in the platform and their Triassic bites favours the swelling of plastic rocks, whish fragilises even further the rigid rocks and which paves the way for the development of massive movements. The size of the materials produced in these sectors varies from sands to pebbles and blocks reaching several meters in diameter. These materials of varied crystalline nature (Palaeozoic and Precambrian rocks) are generally stocked upstream scattered in form of debris and dejection cones, in the slopes ruptures at the bottom of watersheds or confluences.

In flood period, the accelerated erosion consumes progressively a mass of furniture sediments corresponding to big dejection cones. Thus, we observe an hyperconcentrated flow which 10 to 35 % of alluvionary particles concentration [12]. A few kilometres downstream Setti Fatma, the Ourika valley has opened a deep button whole in the complex structures of the north side of the High Atlas of Marrakech. These button wholes, present a slope reaching 10 % in some places. The strong slope, the narrowing as well as the increase of the depth of the flow that follows create a drilling effect for blocks reaching 50 cm of diameter, which need a transport speed of 4 to 5 m/s and a system of supercritical turbulent flow with a shooting effect as commonly known in mountain torrents [3]. Examining the profiles length (Fig. 1), the Ourika valley presents the junction of several tributaries, mainly the Tifri, the Oufra, the Tighzirt and the Tarzaza. These different junctions are distinguished downstream by a relative loading, the slope declining more than 12 to 5 %, so the great part of the gross load coming from the watersheds is stocked on torrential cones consumed in rising periods.

Socio-economic consequences and preventive measures

Since August 17th, 1995 catastrophe, the interventions concerned all the sinistered sectors. The various researches undertaken on the sites during these last years, and in comparison with the existing data and situations before this date, show a significant improvement on the socio-economic side of the sinistered zone [4]. These interventions concerned mainly the hydrographic and road networks. However, in the protective function of the works realized in effective concerning the average and even strong rising waters, it is, on the contrary, not so concerning very strong rising waters of rare occurrence. At the level of certain tributaries of the Ourika river, certain works have been recently realized to intercept the solid discharge carried by the river. The observations made following the recent strong rising flows show that these work are insufficient and are along way from guaranteeing a full interceptive function of the discharge correctly during strong intense rising flows.

Therefore, despite the protective actions, the valley suffers from a lack of reforestation, a lack of means fighting against erosion, and a lack of adequate hydro-meteorological equipment. The erosion is always continuing, which imposes the choice of great works such as:

− the construction and the reinforcement of works of discharge breakers, of protective walls, to limit the damage and to enhance the downstream soil;
− the installation of warning systems upstream;
− the fixation of dykes set up to stop erosion;
− the reforestation of watershed slopes and the addition of fruit-bearing trees likely to preserve the soil and to prevent it from sliding;
− the installation of well-equipped meteorological stations at key sites allowing for the constitution of a data bank that is liable both for studying the rising flows and for being used for agricultural purposes.

Conclusion

The morpho-climatic environment and the litho-structural context of the Ourika watershed basin, mainly the deep slopes and the impermeable lands of varied lithological nature, grant the flowings a torrential muddy character, and offers an environment favourable for sudden pulsations for water flows.

The damaging impacts, either on the environment in general, or on the road network, the agricultural lands and on the housing sites are visible in the valley wherein we are confronted to the amplification and repetition of the phenomenon because of the collecting nature of the valley and its ability to concentration the flowing. Therefore, the degradation of the site is accelerated by the housing and tourist activities.

All these conclusions call, then, for a better management of the sudden pulsations of the rivers by improving the hydro-meteorological equipment, by taking preventive hydraulic measures in form of dykes and appropriate works and by sensitising the population about the dangers of this natural risk in order to avoid human losses.

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EVALUATION OF THE SIDI BEL ABBÈS ATMOSPHERIC POLLUTION GRADE AND ITS RISKS OVER HEALTH

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This study has been realized on the agglomeration of Sidi Bel Abbès, north western Algeria in North Africa. Its main goal is the determination of the atmosphere pollution intensity and the noxious probability risk (at short term) over the exposed populations.
Nevertheless, this very huge 200,000 inhabitants city is deprived from any air quality surveying organ or structure.
The atmospheric pollutants metrology achieved in this paper, from 2005 to 2006 showed very elevated episodic concentrations of principals' urban pollutants.
Comparing with international guide values, these concentrations are susceptible to cause respiratory alterations on the exposed populations.
This study aims to sensitize decision makers, researchers as well as the civil society on the real existence of a noxious risk upon the city, and the necessity of taking in account the atmospheric pollution question in quality of public health problem.

Keywords: atmospheric pollution, metrology, risk evaluation, respiratory illnesses

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Introduction

Former several scientific papers have shown the intimate relation between atmospheric pollution and public health [1]. Since this, pollution researches and studies have been diversified, and the question becomes a multidisciplinary problem [2].

Currently it is well-known and proven that with determined contents, the pollutants in the air, water and the food, human health can be seriously deteriorated and these can even lead to death. This report is very confirmed by all the publications, which gives, with precision, thresholds and amounts presenting health risks, in particular those published by the specialized agencies (NCEA, the EPA-US and the ATSRD) [3].

Our work is based on the method validated by these organizations, and is interested by the evaluation of the risks of the air pollution of Sidi Bel Abbès which is an agglomeration of average density, located in a forest area and of agricultural vocation with a weak industrial activity.

The problems is that several years later, the area were recommended to the suffering people of respiratory insufficiencies, because of the purity of its air, but currently there appears a prevalence of the asthmatic cases close to the national average which is about 9 %, and the frequency to hospitalization due to respiratory deficiencies has grown increasingly.

More, the area is deprived of structures of air-quality monitoring, from where follow the ignorance and the absence of data to evaluate the exposure of the population to the air pollution.

The study was carried out over a period of two years, from January 1, 2005 to December 31, 2006 and comprises two aspects; the metrology of the atmospheric pollutants, and in parallel analysis of the frequency of the hospital admissions for respiratory causes.

The expected objectives of the study are multiple, where the most important would be:

− The metrology of the pollutants present in the atmosphere of Sidi Bel Abbès.

− The impact risk evaluation of the air pollution by comparison between the variation of the concentration of the pollutants and the frequency of hospitalization for a respiratory cause.

− To exhort the decision makers to set up measurements centres and monitoring for the forecast and the risk managing.

− The responsibility assumption of this public health problem by the constitution of a data base on the exposure of the population and the impact risks.

Description of the studied zone and the factors acting on the pollutants

For the evaluation of the medical risk the study of the zone is very important for the estimation of the exposure. In our case, one considers that the population concerned is residential, then with an occupation of time of 100 % in urban environment. In an arbitrary way, one estimates that the urban air pollution is identical inside, and then the exposure of the population can be regarded as homogeneous and suitably estimated.

A very brief study of the zone is necessary, because the environmental factors influence the pollutants, the latter are not stationary and undergo variations of the climate factors (humidity, precipitations, temperatures and winds) [4, 5].

In addition an outline on the population, its characteristics and distribution makes it possible to determine the most exposed populations.

The department of Sidi Bel Abbès located at the North-West of Algeria, is distant approximately fifty kilometres of the Mediterranean. It extends on 15 % of the north western Algeria, being stretched in the plain of Mekerra and remaining under the screen of the Tessala mounts in the north and Dhaya in the south. Its geographical site makes it a crossroads, crossed by the principal road axes of the west Algerian, thus constituting a transit centre of the western area with the south of the country.

The climatic factors are important for the study of the air pollution, because they interact with the it to act on human health. They have an action on the transport and the dispersion of the pollutants [5].

Our studied zone belongs to the semi-arid bioclimatic stage characterized by the rain concentration in autumn and winter and of dryness during the summer. The seasonal mode is of the HAPE type (see Fig. 1 and 2). These last show the maximum of the rains in winter followed by the autumn, spring and finally the summer. However the number of days of rain per period remains weak.

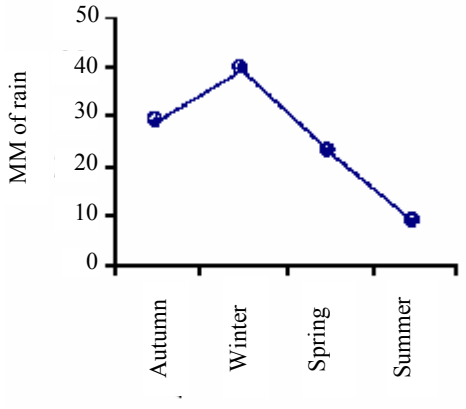


Fig. 1. *Importance of rain/season*

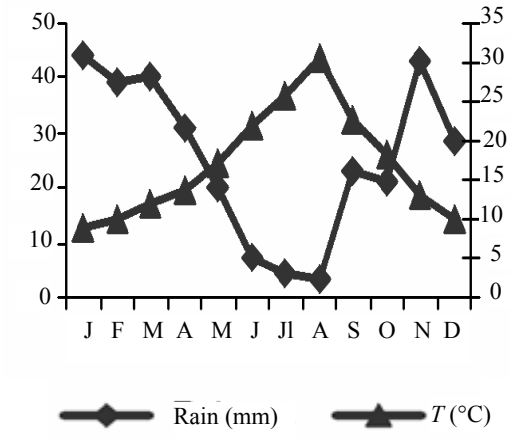


Fig. 2. *Ombrometric curve of Sidi Bel Abbès*

The wind is a dominating factor in the transport and the space concentration of the pollutants. It acts on the dispersion of the pollutants, such as more the wind is strong; more the levels of pollution are lowered. On the other hand, a low speed wind favours the accumulation of the pollutants [4]. In the Sidi Bel Abbès district, the winds are of the North-West or North-East, weak to

moderated during the day and calm during the night (National office of Meteorology, 2005). The weakness of precipitations and winds permit pollutants to accumulate and persist in the atmosphere of the city.

The topography of Sidi Bel Abbès district is appreciably plane allowing a certain liberty of air movement. The only obstacles are the buildings, where which the average height is about 15 to 20 meters. Ground surface is at the origin of atmospheric turbulences on the level of the rough underlayer. These turbulences can be due to the thermal instability of air masses, or have mechanical origin, due to the surface obstacles [4]. It is the size, the form, the density of the obstacle and its environment which condition the air flow on the surface of the ground, the time of residence and the exchanges with the bordering layer; thus, in an insulated and ventilated street, the time of residence of an air mass is, perhaps, of a few seconds only [5]. The short outline on the characteristics of the city enables us to draw three conclusions:

1. From its geographical situation, the city is a crossroads crossed by a dense road traffic, composed mainly of heavy vehicles of the diesel functioning type functioning.
2. The weakness and the absence of precipitations and humidity during the dry season allow the persistence and the concentration of the pollutants in the atmosphere of the agglomeration.
3. Despite of the flatness of the city, the weakness of the winds make that the pollutants circulate more slowly and are thus maintained longer in the urban atmosphere.

Finally, according to the National Office of Statistics data, the district population is estimated of 537,276 inhabitants, where 187,042 are living in the town, with a rate of 34.81 % of town resident, representing the urban atmospheric pollution most exposed population.

Materials and methods

The evaluation methodology of the medical risk followed is that validated by the US-EPA (United States Environmental Protection Agency) [3], which follows four standardized stages:

1. Identification of the danger (metrology of the pollutants in the atmosphere). The pollutants are measured uninterruptedly and in real time, directly by fixed sensors analysers installed in precise points of the agglomeration. The measured substances, are the nitrogen dioxides (NO_2), ozone (O_3), carbon dioxide CO_2 and the sulphur dioxide (SO_2) [6]. The levels of NO_2, CO_2 and SO_2 are evaluated by an average concentration during 24 h and expressed in mg/m^3. The level of O_3 is evaluated by 8 consecutive hours averages per day and expressed in µg/m^3. The identification of the dangerous potential of these substances and the determination of the risk probability are done according to the method validated by the National Institute of Research and Safety (NIRS), the Agency for Toxic Substances and Diseases Registry (ATSDR), the US-EPA, and the WHO international agencies [7, 8, 9].
2. Toxicological characterization which is a comparison between the concentrations measured and the guides' values. The characterization of the danger is established by comparison between the concentrations measured (estimated like values of exposure) and the recommendations or guides' values based on observations on human or by extrapolation of the animal experiments [8]. The estimation of the exposure on the populations is rated with the amount Daily Estimated Ratio (DER).
3. Determination of the exposed populations. It is estimated that the population exposed to the pollutants is equal to the total population of the town of Sidi Bel Abbès and its periphery. In the same way, this exposure is supposed to be homogeneous for the whole of the population. Since the lung is the air pollution directly exposed organ, the medical impact selected is the individuals' hospitalized total number for a non-infectious respiratory pathology during the period of the study [4]. We recorded the frequency of the respiratory due hospitalizations, during the period going of January 1, 2005 to December 31, 2006 to the pneumological service of the Sidi Bel Abbès University Hospital Centre.
4. Estimation of the risk. For a defined geographical area, the populations are subjected to the same level of exposure [10]. Evaluation of the air pollution impact risk on health in the area have been done by the study of the connection between the variations of the measured pollutants and the frequency of hospitalization for a respiratory cause [11, 12].

The measurement of the air pollution was carried out by sensors fixed on four selected stations according to well-defined criteria, in order to cover various spaces of the city [7]. The sensors are connected by Intranet network to a measuring apparatus connected to a computer, and the unit is managed by software allowing the recording of gases concentrations in the atmosphere, hour per hour continuously.

The measuring apparatus used is an IMR 1400-Compact type combustion gas analyser, able to measure and analyse, uninterruptedly, the following atmospheric parameters: temperature of the air and concentration of gases such as oxygen, carbon oxides, nitrogen oxides, and the sulphur dioxide. It displays, simultaneously, eight measured variables on LCD in the set of units: ppm, mg, µg/k., and a minimal resolution of 1 ppm. It is provided with a memory for 220 measurements, and appropriate for connection with a computer.

Four stations were selected according to two criteria: the pollutants zone exposure and the importance of the population circulating there. A third requirement of a sedentary and technical nature (connection by Intranet of the equipment) was taken into account in the choice of the site of the sensors. The sensors were installed on

university buildings with heights of 3 and 4 meters over the ground, covering great sectors of the city:
1. Station 1 in downtown, to measure the importance of pollution resulting from the road traffic and the density of the exposed population which circulates there the day long.
2. Station 2 on the periphery of the city (by-pass) to measure the road traffic pollution risk which crosses the area.
3. Station 3 close to the industrial area to measure possible risks of industrial pollution.
4. Station 4 in a zone apparently with a weak risk, since located in a residential environment, around the UHC, where there remain gardens and agricultural farms.
The study have regarded exclusively four urban pollution indicator gases, like ozone O_3, the nitrogen dioxide NO_2, the sulphur dioxide SO_2 and carbon dioxide CO_2.

Results and discussion

The Sidi Bel Abbès department is of an agricultural vocation. The industrial activities present in the periphery of the city are very low polluting the atmosphere; put aside a complex of electronic instruments manufacture and a factory of farm equipment assembly. The remainder is composed by small and average agro-alimentary units, cosmetic, and clothing.
The most important sources of urban pollution would be the solid wastes incinerators in open air and the road traffic.
An analysis of the cars park reveals that this latter doubled in the last 10 years. Currently, it is estimated to 90571 vehicles, whereas the road infrastructures only evolved very little. This situation is worsened by a degraded state of the roads and strewn with speed reducers. It results from this frequent congestions and obstructions which slow down circulation, while remembering that the idling engines produce more pollution.

In addition the analysis of the components of the automobile set of the area shows that:
a) 84.55 % of the vehicles are of 11 years old and more (see Fig. 3), in consequence that this amount of vehicles is aged. The old vehicles are generally badly regulated and consume up to 10 % additional fuel, leading to a significant increase in the pollutants emissions in the air.
b) 51 % of the vehicles of the district function are diesel type, while knowing that this kind of engine strongly emits nitrogen oxide, sulphur oxides and fine particles (from 30 to 100 times more emitted particles than those running on the gasoline) [13, 14, 15].

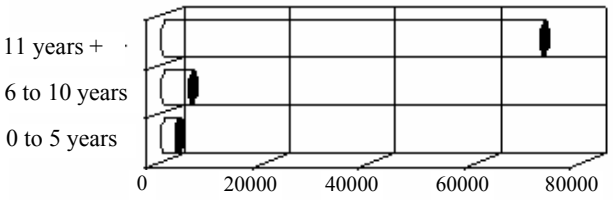


Fig. 3. *Cars' repartition by age*

To these factors is added all the west Algerian road traffic which crosses Sidi Bel Abbès, while waiting for the finalization of the by-pass of the town avoidance.
By what precedes we estimate that automobile transport constitutes the principal source of air pollution.
The studied zone measurements homogeneity and the good agreement of measuring sites provided data were controlled by the calculation of the correlation coefficients for each pollutant.
Thus, one notes for the two years that the measurements of the stations are very well correlated. The correlation coefficients of the stations vary from 0.68 to 0.99 for Ozone and from 0.83 to 0.99 for other pollutants (Table 1). The monthly averages measured of gases are variable with peaks in January, March, June and September of the principal atmospheric pollutants NO_2, SO_2 and O_3 (Fig. 4).

Table 1

Correlation coefficients between gases measuring stations

	Station 1				**Station 2**				**Station 3**				**Station 4**			
	NO_2	**SO_2**	**CO_2**	**O_3**	**NO_2**	**SO_2**	**CO_2**	**O_3**	**NO_2**	**SO_2**	**CO_2**	**O_3**	**NO_2**	**SO_2**	**CO_2**	**O_3**
Station 1	1.00	1.00	1.00	1.00	0.96	0.96	0.83	0.99	0.83	0.83	0.99	0.88	0.97	0.97	0.81	0.79
Station 2	0.96	0.96	0.83	0.99	1.00	1.00	1.00	1.00	0.86	0.86	0.83	0.87	0.97	0.97	0.99	0.80
Station 3	0.83	0.83	0.99	0.88	0.86	0.86	0.83	0.87	1.00	1.00	1.00	1.00	0.81	0.81	0.82	0.68
Station 4	0.97	0.97	0.81	0.79	0.97	0.97	0.99	0.80	0.81	0.81	0.82	0.68	1.00	1.00	1.00	1.00

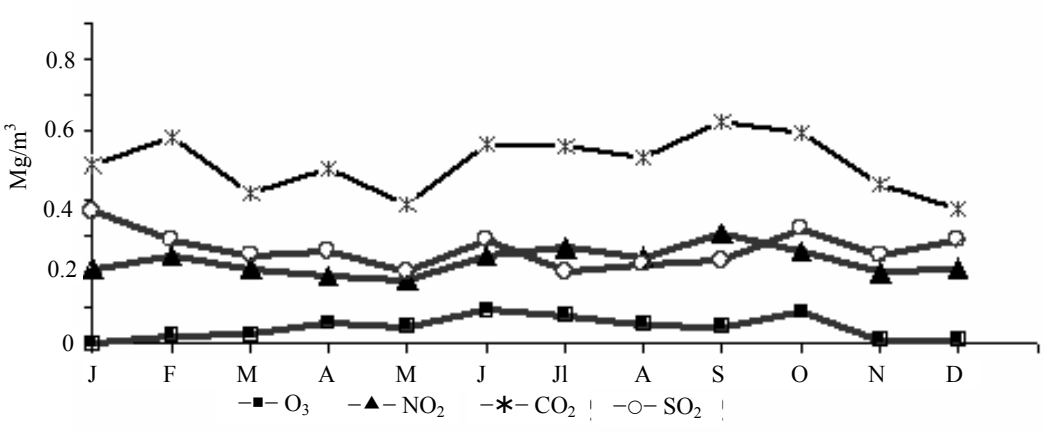


Fig. 4. *Pollutants monthly average variation in 2006*

The amplitude of the variations of the gas concentrations versus time is very important (see Table 2). One notes important peaks, as SO_2 varies from 0.16 mg/m^3 in April to 0.29 mg/m^3 in September (see Fig. 4 also). Ozone oscillates from 00 µg/m^3 in January to 0.96 µg/m^3 in June. The high level of the latter at this period is justified by the fact that it is secondary photochemical pollutant.

The recorded variations can be explained by the action of the climatic factors. One observes, thus, that the pollutant averages remain high during the dry season, without precipitations and with strong heats (Fig. 4 and Table 2).

The quantitative differences between the measuring sites are negligible, cause of the flatness of the city and the weakness and even the absence of winds. Pollution disperses more slowly and in a homogeneous way in all the urban area.

SO_2 is always present in the atmosphere and with important concentrations. This is explained by the concentration of the heavy road traffic all the year.

The quantities of CO_2 and NO_2 vary from 0.30 mg/m^3 to 0.62 mg/m^3 and 0.19 mg/m^3 to 0.37 mg/m^3, respectively (see Table 2).

It is noted that the annual average is in progression in 2006 compared to that of 2005 (see Table 2 always).

Table 2

Monthly averages of the pollutants measured in the four stations (unit: µg/m^3 for Ozone and mg/m^3 for other gases)

Month average	O_3		NO_2		SO_2		CO_2	
	2004	2005	2004	2005	2004	2005	2004	2005
January	0.02	0.00	0.205	0.210	0.290	0.376	0.40	0.50
February	0.17	0.22	0.208	0.251	0.220	0.295	0.50	0.58
March	0.25	0.25	0.225	0.212	0.570	0.251	0.32	0.42
April	0.60	0.60	0.160	0.194	0.220	0.263	0.47	0.49
May	0.52	0.45	0.167	0.187	0.200	0.203	0.43	0.39
June	0.84	0.96	0.232	0.251	0.370	0.297	0.60	0.56
July	0.76	0.80	0.252	0.272	0.220	0.209	0.45	0.55
August	0.45	0.55	0.228	0.241	0.250	0.223	0.62	0.52
September	0.32	0.42	0.290	0.310	0.100	0.237	0.60	0.62
October	0.10	0.09	0.222	0.267	0.100	0.320	0.62	0.59
November	0.10	0.10	0.185	0.198	0.120	0.256	0.35	0.45
December	0.12	0.02	0.209	0.214	0.350	0.294	0.30	0.38
Annual average	0.35	0.37	0.215	0.233	0.250	0.268	0.471	0.504

The characterization of the danger is highlighted by the identification of the dangerous potential of the measured substances in the atmosphere of Sidi Bel Abbots using the bibliography which recognizes the referenced toxicological values (see Table 3). The guides' values used in this study are those validated by the US-EPA, and the WHO recommendations.

Table 3

Guides' values for current pollutants. Source: WHO (2003)

Pollutant	Guide's value ($\mu g/m^3$)	Concentration where effects on the health could be observed in $\mu g/m^3$	Exposure duration
CO_2	10,000 60,000 30,000 10,000	No object	15 min 30 min 1 hour 8 hours
O_3	160 110	No object	1 hour 8 hours
SO_2	500 350 125 50	1000 700 250 100	10 min 1 hour 24 hours 1 year
NO_2	200 40	400 80	1 hour 1 year

The determination of the danger occurrence probability has been established by the relation between the exposure for a certain amount of pollutant and an effect or the occurrence probability of an effect. The risk is calculated by the relationship between the measured values and the referred guides' values

A proportion, equal or higher than 1, of a contaminant present in the environment indicates the probability of a noxious effect on health [16].

Concerning the exposure, one considers that the total air pollutant exposure index is the same one for the whole of the population (inside and outside) dwelling in the urban environment [17, 11].

It should be noticed that for this type of study it is very difficult to measure duration that the population in an environment passes, which represents the exposure time [18].

Moreover, one took into account the fact that the urban environmental exposures, other than all other exposures of professional nature (pollen, pesticides and solvents used by industry), can probably have an action on public health or a synergistic effect.

The atmospheric pollutants emissions measured inside the town of Sidi Bel Abbès approach strong values. Average concentrations of measured gases, exceed in, all cases, amounts recognized by the various specialized organizations as presenting a toxic health risk [19, 20, 21]. All hospitalized for a respiratory cause in the UHC pneumological service are listed in Table 4.

Table 4

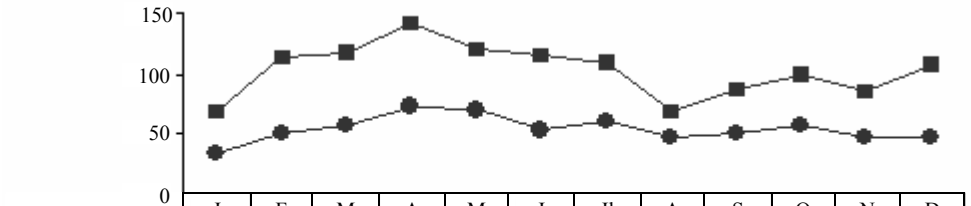
Monthly distribution of the hospitalizations for a respiratory cause (2005-2006)

Hospitalisation for a respiratory cause	J	F	M	A	M	J	Jl	A	S	O	N	D
2005 year	33	51	58	73	65	57	60	27	46	51	43	57
2006 year	36	62	60	69	51	62	49	21	37	42	38	61

One notes that there are small monthly variations, except for February, May and July when an important variation is distinguished. However the respective fluctuations vary in the same direction (see Fig. 5).

The patients distribution by residence zone, shows that the frequency of hospitalization among the urban population, resident with Sidi Bel Abbots and its periphery, presents a rate of 74,78 % of the total population of the department. The quality of the air have, probably, a part of responsibility in this important variation.

The morbidity nature analysis shows that the asthma and asthma crisis are the most frequent hospitalizations with a rate of 45.76 %. Various pathologies such dry coughs, pleurisies, bronchitises, laryngitides account for 28.24 %. Infectious diseases (tuberculosis, infectious pneumopathies,..) 7.90 %, and finally cancers 3.95 %.



	J	F	M	A	M	J	Jl	A	S	O	N	D
−■−Morbidities	36	62	60	69	51	62	49	21	37	42	38	61
−●−Morbidity	33	51	58	73	70	53	60	47	50	57	48	47

Fig. 5. *Hospitalization variations for respiratory cause in 2006*

Analysis of the asthma distribution (Fig. 6) indicates that the peaks appear during the winter and spring seasons.
The pollution level varies according to seasons and climatic hazards, such as scrubbing by precipitations in the winter and a strong concentration in dry period. Ozone, him, increases from April to September, period of strong luminosity.
The Sidi Bel Abbès atmosphere pollutants metrology and the hospitalizations frequency for a respiratory cause for the risk situation evaluation, led to study the intensity of the existing connection between their variations in the year.
This relation is measured by the population exposures to the atmospheric pollutants and the hospitalization (medical impact).
Thus, graphs (in Fig. 7) illustrate the existence of a correlation between the curves variations, while this statistical relation between pollutants and morbidities does not, inevitably, mean the existence of direct causality bond, since other factors could influence each of both first and explain the correlation observed.

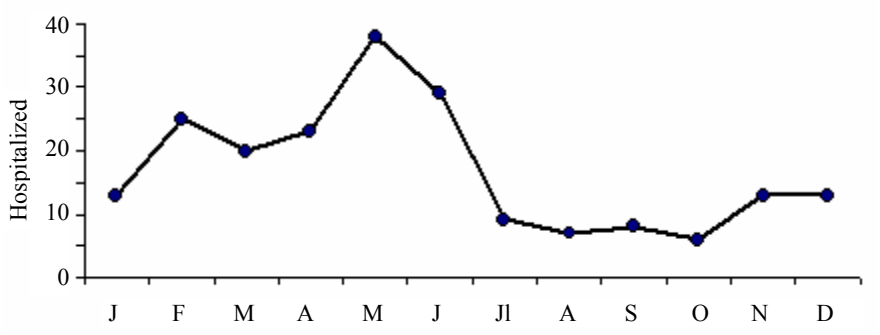


Fig. 6. *Asthma variation in 2006*

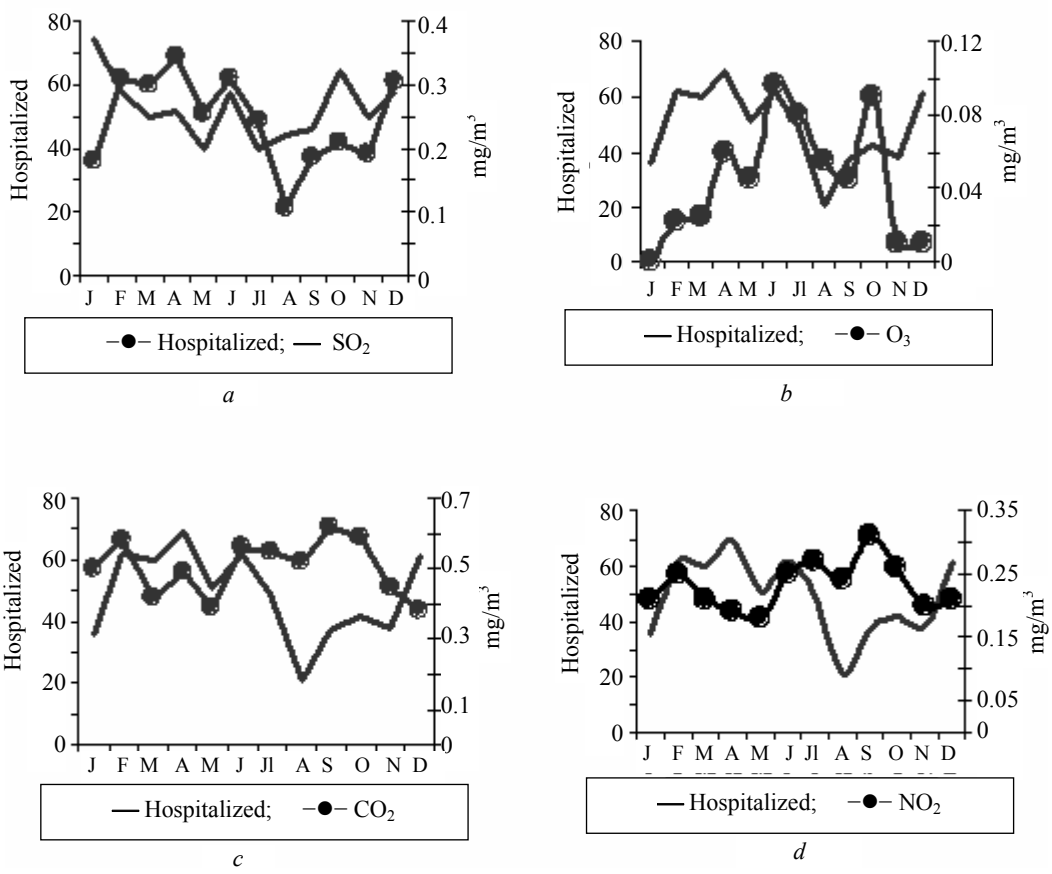


Fig. 7. *Hospitalization variations for respiratory cause versus pollutants:*
a − SO_2, b − O_3, c − CO_2 and d −NO_2

As we can see on the graph (Fig. 4), the pollutants variations are, themselves, well correlated, which makes difficult the understanding of their respective influences.
However, and being based on the literature, their convergences indicate an influence of the air pollution on the breathing apparatus.
One can, therefore, admit that there is an effective impact even if the epidemiologic analysis does not make possible to identify with precision which components of pollution is the true determinant of this impact [22, 23, 24, 25, 26].
Moreover, to certain asthmatics, the air pollution is over added to other factors such as nervous tiredness, anguish, efforts, passive nicotinism, allergy, climate, etc. [26]. Let us notice that certain irritants are natural, like the cold, moisture or pollen.
The results obtained show that there are strong increases in the hospitalizations for respiratory causes during the cold winter period and of pollen in spring (Fig. 5 and 6).
According to the expertise organizations published recommendations which are founded on human observations or by extrapolation of animals experiments, the relationship between the pollutants concentrations found in the atmosphere of Sidi Bel Abbès and the guides' values, show the probability of possible impact on resident public health who is permanently exposed [10, 19, 20, 22, 23].
It is noted that the pollutants concentrations (SO_2 and O_3) reach raised levels in comparison with the noxious found thresholds, being able to cause or worsen respiratory morbidities.
In addition recent results in epidemiologic research led to think that even on levels of concentrations usually observed, there is a measurable impact of pollution on human health [23].
Thus, it has been demonstrated, by many research and scientific studies, in particular in the industrialized countries that at the asthmatic or respiratory deficient people, the air pollution can have consequences, sometimes tough, at certain periods (heat wave, anticyclone, stormy heat), hence a certain pathology indicating the presence of an allergen factor which could be polluting [9, 10, 24].
The phenomenon of these pathologies is in a constant rise for few years in Algeria and in the area of Sidi Bel Abbès, particularly. By this fact, it has been deduced that the factor pollution is not foreign with this increase in the prevalence of asthmatics in the region.

Conclusion

The noxious effects on health of the air pollution are currently well-known and the epidemiologic and experimental studies highlighted the role of the air pollution in the appearance or the aggravation of respiratory and cardiovascular pathologies. Because of the absence of threshold, the medical effects of the air pollution can be observed for levels of exposure lower than the legal guides' values.
The question is a problem of public health, and currently, many research tasks are carried out in order to better understand dispersion and the become of pollutants in the urban environments and to establish with precision the existing correlation between the presence of these substances in the air and health for better risks preventing, health preserving and the environment.
To be unaware of the level of pollution of our atmosphere is not equivalent to the absence of risks for the population. Our evaluation of the air pollution in Sidi Bel Abbès has given concentrations, often, higher than the recommended guides' values as limiting thresholds for health protection of health. Thus the risk probability of short-term public health harmfulness exists, particularly the exposure of the people presenting a cardiovascular and/or a respiratory insufficiency.
In conclusion, our risk evaluation is of an interest at the decisional plan to deal with this problem of public health by:
1. The creation of inspection networks of the quality of the air, determining element for better apprehending the importance of the problem.
2. To better know the quality of the air than we breathe and thus the possibility of intervening by reducing the rejections and the pollutants emissions in the atmosphere within non-noxious recognized limits for health.
3. The approach can be developed and generalized to envisage medical and environmental impacts on the urban environments before setting up new projects and activities.

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ANALYSES FAILURE REASONS OF THE DEVELOPMENT SCHEMES OF THE STEPPE AND ROLE OF TETRACLINIS ARTICULATA VAHL MASTER IN ITS ECO-DEVELOPMENT

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The steppe in Algeria is a strategic space that opposes the desert extension; it covers more 20 millions of hectares and is actually exposed to an important deterioration. The different programs aimed at the protection and rehabilitation of this space that have been implemented have failed, further more they generated an aggravation of this deterioration. An analysis of the reasons of this failure allowed us to propose a new approach centred on the introduction of a very rustic plant and whose ecological impact could save the steppe.

Keywords: steppe, deterioration, strategy, impact

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Introduction

The economical and social development of a region depends upon a rational management of its physical, biological and socio-economic environment. Enormous potentialities in terms of natural resources risk to be irreversibly compromised by the climate evolution and the socio-economic mutations in the steppe which remains the ultimate natural barrier against the desert extension. This space is seriously threatened by the desertification process [1].

Many specialists have insisted on the necessity of adopting urgent and adequate solutions to remedy to this situation.

Numerous works done in the last four decades reveal progressive degradation of the steppe vegetal cover and the soil. The aim of this work is the evaluation of the phyto-ecological impact of the implementation of a rustic vegetal specie; the *Tetraclinis articulata* which presents interesting characteristics such as the adaptation to the climate conditions, the soil and the social context of the area.

Theoretical analysis

Socio-economic and ecological generalities of the steppe

a. Geographical delimitation of the steppe

The Algerian Steppe constitutes a vast region that spreads from the South of the Atlas of the Sahara, (Fig. 1) forming a band of 1000 km length and 300 km large, and is reduced to less than 150 km in the East. It occupies a surface of 36 millions of hectares but counts 20 millions of hectares of course [2]. The Annual average rain precipitations in the northern limits are 400 mm while those of the south are 100 mm [3].

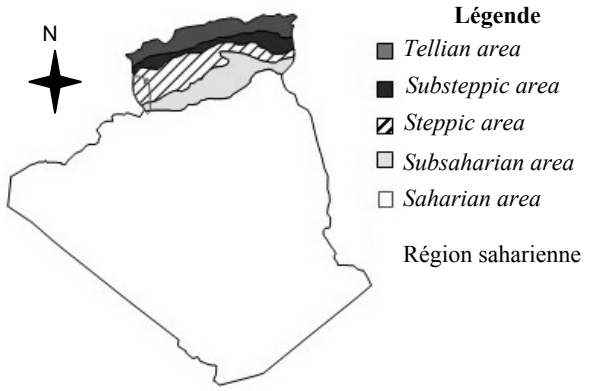

Fig. 1. *The card of situation of the steppe area [4], saharian area, subsaharian area, steppic area, tellian area*

b. Climate, vegetation and soil

The steppe is characterized by a semi-arid climate in the northern regions and an arid climate in the South. The average rain precipitations are comprised between 400 mm and 100 mm, which is not enough for an intensive agricultural usage. In dry years, the whole steppe receives less than 250 mm of rain; these isohyets spread up until the Tell.

The vegetation of the steppe is short and discontinuous, composed of herbaceous plants, generally in tufts. This vegetation varies by its floristic composition and its density and constitutes the fundamental stake of the pastor's life. It determines human displacements and his parking areas with his herds [5].

There are four zones in the Algerian steppe [6].

Zone 1: 700,000 to 1000,000 hectares; with an annual average of 400 mm of rain, it is mainly the domain of scrubs, the garrigues and the forests of the Saharian Atlas.

Zone 2: 3.5 to 4 thousands hectares, it receives 300 to 400 mm of rain. It is t the most favoured zone, situated on the South fringe of the tellian Atlas. It is the zone of the big tracts which is exposed to an important pastoral load (2 to 4 sheep in the hectare). It is occupied however by the profitable culture of cereals in rainy season.

Zone 3: 5 to 6 thousands hectares with an annual average of 200 to 300 mm of rain. It is la region of the high central and southern plains and the South side of the Atlas of the Sahara. The courses are of unequal quality and the pastoral load is there weaker (2 sheep to the maximum ha).

Zone 4: 10 thousands hectares, with an annual average rain fall of 100 mm to 200 mm. It is situated in the south of the Hodna and South of the Atlas. The pastoral load is very low (20 to 60 times less than that of zone 2).

The real potentialities of these regions represent, actually, half of their surface, because of the immense abandoned areas, due to a lack of points of water.

The Steppe is essentially composed of a varied herbaceous stratum of vivacious and ephemeral species. Generally there are thee dominant flora species: the esparto (*Stipa tenacissima L.*), the Artemisia (*Artemisia herba Alba L*) and the false esparto (*Lygeum spartum*), (Fig. 2 and 3) [7].

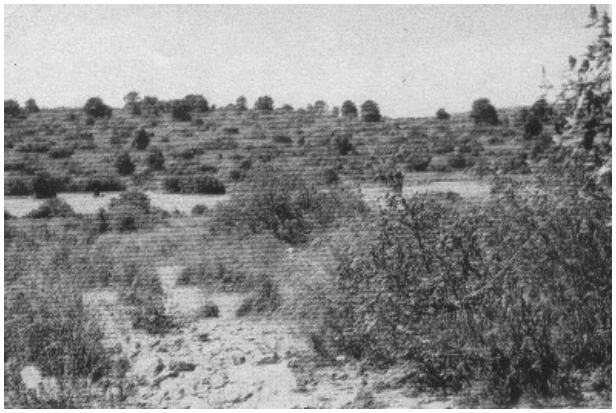

Fig. 2. *The forest deteriorate with the under wood of the Stipa*

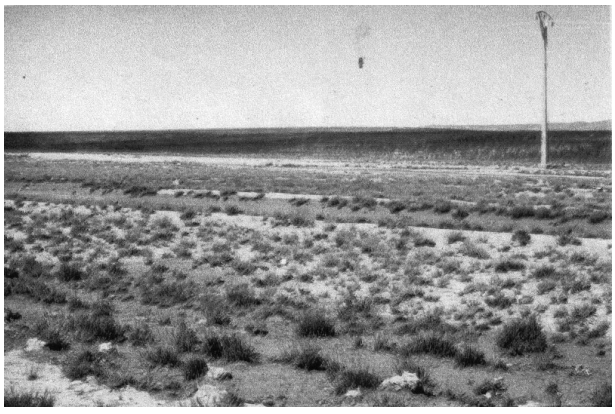

Fig. 3. *The ground of the Stipa deteriorate and association with the Artemisia*

More than thirty other species vegetate at different periods of the year. The esparto and the Artemisia occupy for their part almost 7,000,000 hectares while the *Lygeum* occupies 3,000,000 hectares. Generally, numerous halophytes species occupy the salty soils in the vicinity of the chotts [5].

The pastoral surfaces offer substantial food diversity considering the species diversity [8].

c. Entropic factors

The national ovine livestock is the first supplier of red meat, with 68,000 tons in 1983. It provided 75 % of the 2,996,000 produced quintals. Its contribution to national economy is important insofar as it represents a capital of more than 1000000000 dinars.

In 1985, on a national 15,500,000 heads, some 11,500,000 heads remained confined in the steppe. In 1996 the number of the ovine livestock rose to 17,301,000 heads of which 75 % concentrated in the steppe zone [9].

The steppe and its difficulties

An arid steppe is an environment which, by definition, offers extreme conditions for the establishment and the survival of perennial vegetation which plays a fundamental role in the structure and the functioning of the ecosystem. Despite all the national programs applied to it the steppe zone remains subjected to the degradations and very low rate of successful plantations. The consequences which ensue are alarming, and are characterised by the alteration of soils, the intense erosion and a diminution of its biological potential [10].

The natural vegetal cover is continuously subjected to a double impact: that of the soil and the climate on one side and the anthropogenic on the other side [11].

a. Chronicle of the applied strategies

The steppe has been the object of many development projects since 1962.

This period is characterised by too significant steps:

***** The First period 1962 to 1980: the state attempted to organize the pastoral populations by grouping them in cooperatives on much delimited territories, the objective was to organize these populations to allow a rational use of the courses. The number of created cooperatives was very low in relation to the autochthonous population, the delimited zones were not in adequacy with the habits of the breeders and the way of life of these inhabitants has been disturbed. It resulted in an abandonment of this politics and a pure and simple disappearance of these cooperatives.

This period is also characterised by the enactment of the charter carrying agrarian revolution notably the pastoral code. Its objective was the planning integration of the space and the radical transformation of the social behaviour and the system of production without a real knowledge their social system. This period distinguishes itself by three important facts but without positive effects on the steppe.

– The agrarian revolution: with a strategy based on the organization of the agro-pastors in cooperatives those impact on the behaviour of the breeders was negative. This phase did only concern 3 % of the breeders of the whole region and solely 5 % of the livestock of the steppe. The state also sustained the food of the ovine by importing barley those consequences were negative upon the traditional systems of breeding.

– The green dam: the primary objective of this project was to oppose the desertification by the timbering and reforestation on more of 3 millions hectares with the introduction of the rustic arboriculture and fodder species. All launched operations have been made beforehand without studies and the obtained results were not satisfactory. Among the main reasons of this failure it is necessary to note the bad choice of the plant specie and the techniques of plantation, the transformation of a space of course in forest zone, the absence of integration of the population in the project and the unsuitability of the vocation of the lands and the projected planning.

– The creation of the state Secretariat to the forests and to the reforestation in 1980 allowed some corrections by stopping reforestations which were most often improvised. A policy of lands classification and the elaboration of planed development in pilot zones, as well as the reconstitution of the degraded forest massifs were the principal action undertaken. Other actions were undertaken: the pastoral plantations, the fixing of the dunes, track initializations. These actions remained modest with regard to the importance of the steppe surface (20 millions hectares).

*****The second period: 1980-1996, it corresponds to a new orientation of the agricultural politics of the country with the enactment of four laws: the one carrying accession to the agricultural real property by an enhancement in 1983, the law carrying exploitation modes of the agricultural lands in 1987, the law carrying fundamental orientation in 1990 and the law carrying integration in the privet state domains of the pastoral lands in a special protective regulation, management and exploitation in accordance with the pastoral code. The creation of an organism in charge of the management of the steppe in 1985 constitutes another fact of this period; this institution had to control the environment was in charge of planning the steppe zone [10].

b. Analysis of the successive strategies failures

The traditional system of breeding and management of the steppe zone guaranteed a biologic balance with control of the size of the livestock which avoided over grazing.

The reproduction of the livestock remained traditional and the transhumance allowed the hope to regenerate, in doing so the biological equilibrium was respected with regard to the phenological cycle. The rule was to never remain too long in one place. The pressure on the environment was distributed therefore in the time and in the space, according to the rhythm of the seasons respecting precise rules adopted by all breeders.

The extent of the sedendarisation which resulted from the new villages implantations caused the end of the seasonal mobility of the herds. The mechanisation is one of the principal reasons of the sedentarisation with all the negative consequences on the steppe ecosystem: the surface clearing for cereals cultures, overgrazing, and the use of ligneous species for domestic purposes. The introduction of bovines and last but not the least the absence of regulations aimed at the protection of the esperato.

Experimental methods

Introduction impact of the Tetraclinis articulata Masters vahl

In order to evaluate the state of degradation and the impact of the introduction of *Tetraclinis articulata*, twenty observation stations were installed all over the steppe. The measures were performed in situ, the data collected by local technical services and the results of multiple analyses in laboratories allowed to appreciate the impact of *Tetraclinis articulata* on steppe.

At the level of the 20 stations measures of the total biomass and the number of species were undertaken in order to appreciate the induced dynamic by the *Tetraclinis articulata* (Table 1).

The *Stipa tenacissima* presents the most elevated indications. The mineral indication for the Sparta decreases 0.43 to most elevated mineral 0.35. L'indice corresponds to the station 2 that is a setting in defense and 0.35 correspond to the station 12 that is an abandoned fodder plantation.

The graph which follows gives an outline on the evolution, calculates it covering of the first dominant species, makes it possible to note that Lygeum spartum, is the species with a stronger covering (12 %), followed by Thymelia microphylla (6 %). it is about species which develops, on sandy, and sablo-muddy ground (Fig. 4, 5).

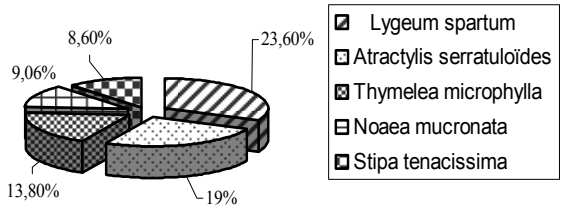

Fig. 4. *Specific contribution of the main cash [12]*

Five main species showed the strongest contribution, they represent to them only 74 % of the total of the specific contributions of the cash of the plant carpet. It is about *Lygeum spartum* with 23.6 %, *Atractylis serratuloïdes* with 19 % and *Thymelea microphylla* and *Noaea mucronata* respectively 13.8 and 9.06 %.

Table 1

Measures of phyto-mass and number of species the 20 stations [1]

Stations	Cash	Phyto-mass (Kg of M·S/ha)	
		initial	final
1	Stipa tenacissima	1254	1578
2	Lygeum spartum	1972	1895
3	Noaea mucronata	96	1002
4	Lygeum spartum	1048	4.29
5	Stipa tenacissima	471	2.11
6	Atractylis serratuloïdes	144	0.40
7	Salsola vermiculata	109	0.22
8	Lygeum spartum	581	2.15
9	Lygeum spartum	288	1.10
10	Thymelea microphylla	280	0.71
12	Lygeum spartum	1283	4.48
14	Atractylis serratuloïdes	164	0.42
15	Thymelea microphylla	86	0.25
16	Salsola vermiculata	195	0.53
17	Noaea mucronata	124	0.28
18	Lygeum spartum	69	0.30
19	Thymelea microphylla	91	0.29
20	Thymelea microphylla	222	0.76

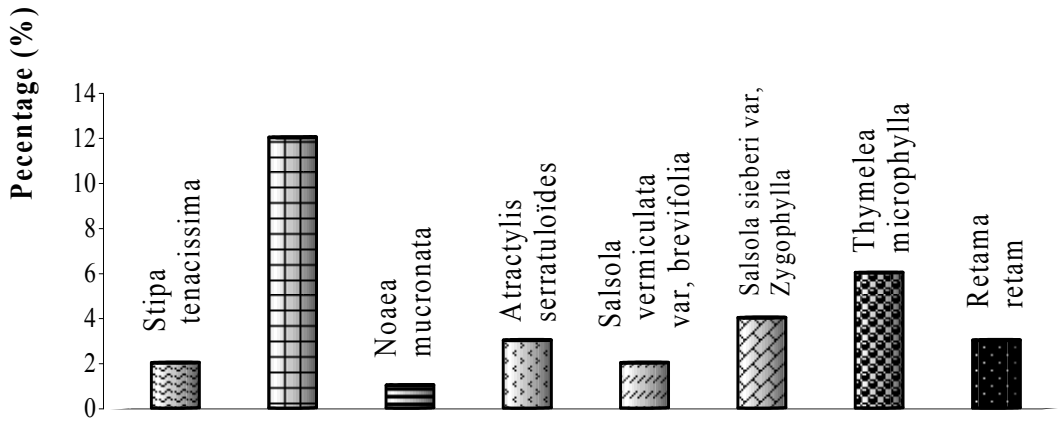

Fig. 5. *Recovery of the first dominant cash [12]*

Generalities of Tetraclinis articulata

All authors having studied this specie agree to say that *Tetraclinis articulata* has small exigencies with respect to the environment because of its faculty to adapt to different types of soils and bioclimatic (sub humid, semi arid and arid). The dry soils are more appropriate for its growth that the humid soils. It grows well on the fixed dunes which allow the fixing of the sand.

Tetraclinis articulata is a specie that showed a large capacity of adaptation and resistance and resists to the most difficult environmental conditions; it has an exceptional seeds r or suckers regeneration faculty, it grows under all bioclimatic lands of Algeria (from sub-humid to the arid) and on all types of the soils with the exception of the saline [13].

The Tetraclinis articulata resists to the drought and the heat as well as the cold weather. Well adapted to extreme conditions, it develops within a range of 250 to 30 mm yearly average rain, a yearly average temperature of 11.2 °C, an average temperature of the coldest month of 1 °C and the average temperature of the hottest month of 33.5 °C [14].

It is utilised in polishing white woods that is used for making furniture, its fibers could be used in the paper industry [15].

Methodology adopt

A test of assessment of the potentialities of this specie to grew in this expanse, through the evaluation of the it's germination rate and growth will allow us to estimate the ecological impact of this specie on the steppe.

The plant's seeds were harvested on 10 to 15 years aged trees of *Tetraclinis articulata* situated in Tessala area (Wilaya of Sidi Bel Abbès Fig. 6) and which is situated in the cold semi-arid level. All seeds were washed with distilled water, then planted and watered every week in order to help the germination and the raise.

A 20 weeks period of time was necessary before performing the first observations and measures. The quantified parameters are:

– The speed of germination.

– The germinative capacity [16].

Results and discussion

According to the results of the development test, we can state that *Tetraclinis articulata* found a favourable biotope in the steppe zones, with a rate of maximal germination of 80 % and a 10 weeks rate of germination which is remarkable compared to the results obtained in the Tell zone with the same seeds. (Tables 2-4).

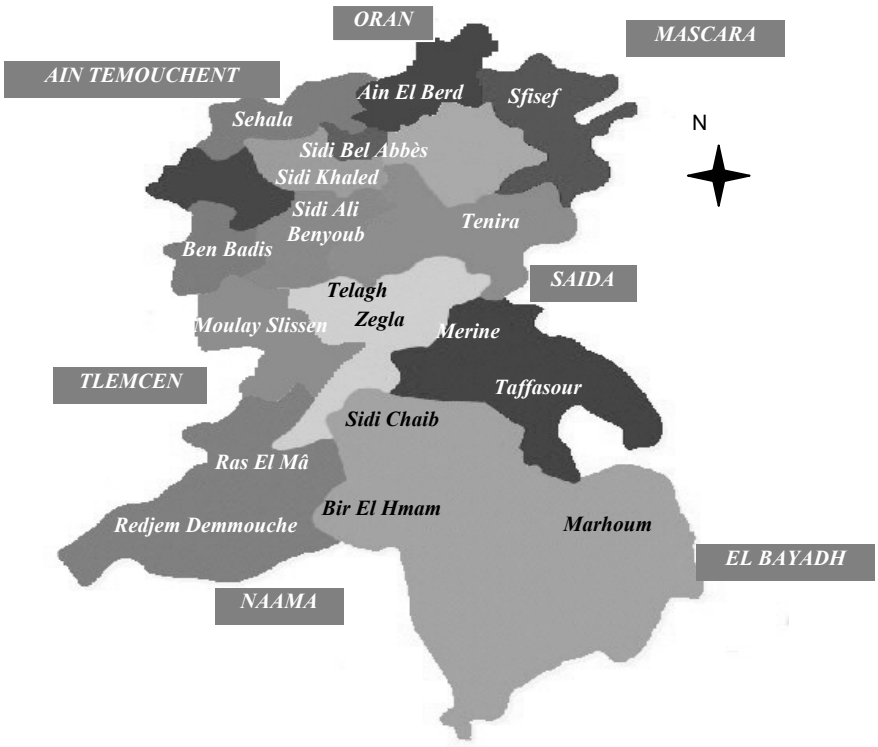

Fig. 6. *Localisation of the Wilaya of Sidi Bel Abbès*

Table 2

Number of the seed sprout according to the time

Num of week	4th	6th	8th	10th	12th	14th	16th	18th	20th
*NSS	08	20	30	40	50	55	60	70	80

**N: Number, *S: the seed, *S: Sprout.*

Table 3

The test of germination gives the results

Capacity of germination	80 %
Speed of germination	60 days
The forwardness	8 %
The latency time	35 days

Table 4

The average growth in cm

Number of the weeks	20	30	40	50	60
The average of the growing in height in cm	06	09	12.50	15.50	18.70

Tetraclinis articulata recorded a growth of 18.70 cm in height in a 60 weeks period. The average height growth is of 1.2 cm per month, which results in a 15 cm yearly growth. This is quite important for these areas.

Conclusion

This study showed the importance of the *Tetraclinis articulata* in the preservation of secluded areas through its generation in the damaged areas. It constitutes a prime factor in the struggle against the extension of the desert.

It is necessary to note also that the species has a power suckering very important and therefore even though the conditions of culture are un favorable provoking the drying up of the plant mother, the Thuya of Maghreb will give some dismissals quickly.

The desertification of the steppe zone is a reality. It has been measured scientifically on the basis of an ecological diagnosis. In the dynamics of deterioration of the plant table setting in some years, one passed on state 3 graminean steppe in *Stipa tenacissima*, stage 4 chamaephytic steppe to *Artemisia herba alba* (on slimy soils) or to *Artemisia campestris* (on sandy soils) to the stage 5 steppe to *Peganum harmala* and *Noaea mucronata,* it is unfortunately the ultimate stage of deterioration.

The climatic conditions constitute a factor of this regressive evolution. However, the factor anthropique is multilevel determinant:

To the level of the breeders, operators of the zone who have privileged the profit to the protective imperative of place. The mechanization and the motorization gave to these operators the means to attack the courses more and more greatly and on extents more and bigger.

To the level of the decision-makers that had resort to strategies that gave the proof of their limits extensively.

The main mistakes concern:

- The absence of integral global economic vision for the regional development.
- The predominance of the sartorial approach.
- The brutal change of operating system that provoked the disequilibrium

Procures/chapter.

The problems are known, however the identification of the problems constitutes a stage important of the analytic phase that could clear on a correct scheduling and the formulation of applicable projects.

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TETRACLINIS ARTICULATA REGENERATION (THE THUYA OF THE MAGHREB) AND ITS RESISTANCE TO HUMAN CAUSED DETERIORATIONS: CASE OF FIRE

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Tetraclinis Articulata (The Thuya of the Maghreb) is one of the threatened species, in its ecological area where it is endemic, not only under pressure of animal and human effects, but especially fire, currently, this formation knows an alarming regression although it has the ability to regenerate very often quickly, so it plays an important role preserving the vegetable covertures in the semi-arid areas.
The purpose of this work is to check the regeneration of Thuya through dendrometric characteristics: annual increase of height and diameter, this will allow us to know more about this vegetable formation bringing to light all its potentialities in the eco-development of spaces and to emphasize the degraded and marginalized zones.
The results obtained in the three facies will prove the resistant aspect of Thuya against alternations such as fire meanwhile it's imperatively advised to fight against all risks of regression of this vegetable formation.

Keywords: increase, dendrometry, phyto-ecology, facies, forest of Tenira (west of Algeria)

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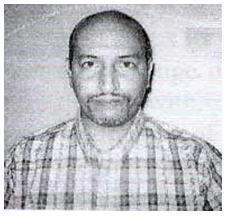

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Introduction

Thuya covers about 143,000 hectare [1], this is one of the rare species in Algeria, and it is going to disappear because this useful rustic forest which needs to be given more care is permanently harmed, (cutting – degradation, fire) [2], its resistant aspect makes it one of the most important and dense species which needs more effective studies.
A wide field of Thuya still dominates the national forest of Tenira which is situated in the mountains of Dhaya. Its superficies counted about 16630 hectare [3] while it

is now only 8800 hectares. The degradation of forest ecosystems is a problem that worries all searchers in general and ecologists in particular.

The main cause of this degradation is the antropozoogene pressure: many searchers such as [4-6], [7-9] were interested in studying the causes of the forest ecosystem degradation, both [10] and [11] studies were established in western Algeria.

Fire keeps its dominating pressure with a destructive impact on the Tetraclinaie, which is the only vestige of the Thuya species, it's a warning diminution in which Thuya formations are dealing with.

The danger of fire is a notion resulting of the combined action of many factors; we can mention the most important factors responsible of the wide sensitivity of Algerian forests:

− The length of the dry season of summer.
− Structure and nature of the vegetation.
− Frequency of the stormy dry winds
− Uneven relieves.
− Eroded ground which is often over-passing.
− Terrorism taking the forests as a refuge in the1990, especially in Tenira.

Fire is an important factor that affects the vegetation because of its high frequency; many authors agreed that the successive regression of vegetation is due to it, however, it is necessary to follow the evolution of this vegetation for a period of time either controlling it with an experimental devices or in nature where the vegetation came under fire but in both cases, the exact date of when fire happened must be known [12].

According to him – [12] – the evolution may be done within four ways:

− Checking the different steps of the previous vegetation remaining to a long time.
− The gaps that became more overt than they was before the fire, associated to decreased proportion of ligneous vegetables.
− Instant checking the previous vegetation with no transition.
− Progressive evolution to different vegetations

Presentation of the studied area

Climate and soil

The forest of Tenira is 16 km south of Sidi Bel Abbes, 12 km from Teghalimet and 9 km from Boukhanifis; it is crossed by the national road No. 13 linking Sidi Bel Abbès to Telagh.

The forest lies on the secondary Jurassic, relieves are bad enough and formed of porous calcareous layers giving the ground a superficial aspect, the forest lies on superficial enclaved soil between emerged rocks. The superior horizons are constituted of a mixture of sand and calcareous pebbles. The local climate has been realized through two meteorological stations; of Sidi Bel Abbès and of Teghalimet (Table 1).

According to [13] the forest of Tenira has a superior semi-arid bio-climate [14].

Table 1

Climatic data of the studied area

Station	Altitude, m	Rainfall, mm	M – m, °C	Q_2
Sidi Bel Abbès	476	395	33.2 – 1.9	43.2
Teghalimet	650	334	34 – 1	34.8
Tenira				
PH	840	468	30.6 – 2.8	57.7
PB	628	393	32.1 – 3.6	47.2

PH: It's the most high point of area.
PB: It's the most low point of area.
M: The avearge of maximals temperature of the hot month.
m: The avearge of minimals temperature of the cold month.

Vegetation

The forest consisted on a populating of young and old timber-trees of *Pinus halepentis* Mill and *Tetraclinis* A*rticulata* Wahl before the fire took place, in under-stages with an average covering of 20 % as a dense high copse. Thuya formed in the particular stationary conditions, pure formations with some vestiges of forest. *Quercus Rotundifolia L.*, it was third in position with a rate of covering of 10 %. The secondary species were especially dominated by *Quercus Coccifere L.*, *Phillyrea media L.* and *Pistacia Lentiscus L.*

Tetraclinis articulata reached in this forest the treelike stage with an under-wood characteristic of this formation with three different facies:

The first one to *Rosmarinus tourneforti L.*
The second to *Ampelodesma mauritanica L.*
The third to *Stipa tenacissima L.*

In spite of a quasi-permanent animal and human pressure, the Thuya formed a plant grouping and dominated the pine of Alep relegating it to secondary specie.

Tetraclinis articulata is present essentially in the form of copse in under-wood of *Pinus Halepensis* in such conditions the Thuya vegetates and this is what explains its strong density [15].

Tetraclinis articulata presents three facies:

* Ampelodesma when the ground is deep, slightly muddy, in the north and in depressions.
* Rosmarinus when the ground is of type rendzine, strong presence of limestone in the south.
* Stipa in the most extreme conditions [16].

Identification of Tetraclinis articulata

Monographic quality of Tetraclinis articulata

The Thuya of North Africa (*Tetraclinis articulata Vahl.*) has been defined by (Vahl, 1979) under the name of Thuya articulata, it is one of the spermaphyte gymnosperme branches, belonging to coniferous family [17].

The botanic characters as given by [3] are: the Thuya of Maghreb (North Africa) is resinous with a light foliage,

(see Fig. 1) when it's still young plant, its port is pyramidal, leaves are reduced to two opposed scales, fruits are like a cubic cone, can be opened by four valves in hot conditions, giving away six seeds, the longevity of Thuya can exceed 400 years, it's reproduction is generally done with rejects or sowing [18].

The Thuya of North Africa is an endemic essence of the southern occidental Mediterranean sea [17, 19], in particular in the Maghreb countries where its density floats from the east to the west [2].

However [20] consider that Thuya in North Africa covers a surface of million hectares, all the searches that studied this specie: [1, 2, 3, 16, 19, 21-26], and others have agreed that Thuya does not require edaphic factors, it is indifferent to the chemical nature of the substratum, can be found in poorest and dries soils, meanwhile it seems that it prefers more calcareous and deep soils.

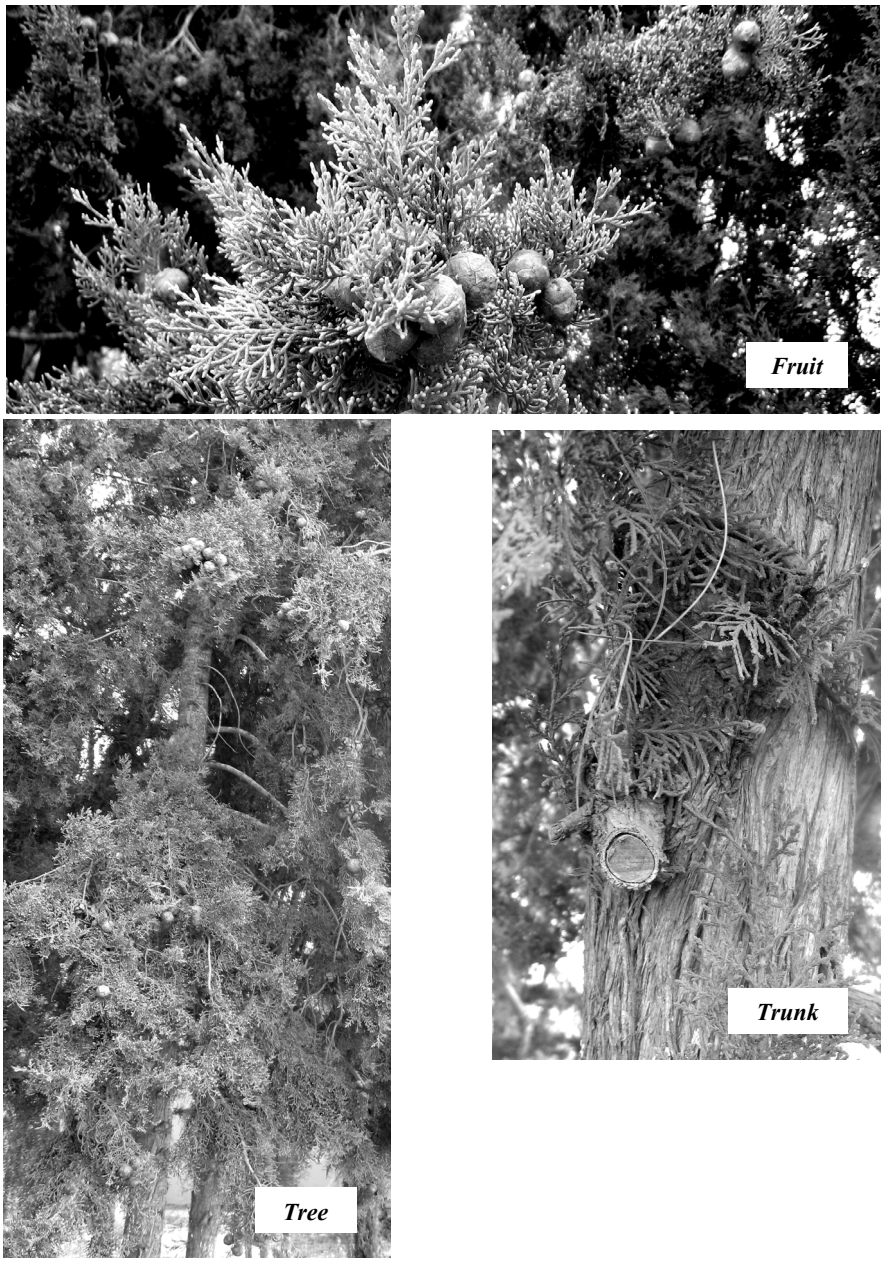

Fig. 1. *Picture of different parts of Thuya three (Tetraclinis articulata)*

It is doted with a faculty of adaptation to different types of bio-climates, hot semi-arid in particular, temperate or sub-humid and cool [24], it supports the drought and hot weather conditions but not cool humid weather. Adapted to extreme conditions, the Thuya of the Maghreb can develop on an annual pluviometric slice of 300 mm, an annual average temperature of 15.2 °C and a minimal temperature of 2 °C, average of the temperatures of the warmest month (M) is 32.5 °C [15], [25-27].

Dendrometric characteristics

Thuya is present, as underlined previously, whether in the form of copse or of timber-tree. Exceptionally, the following dendrometric parameters (density averages, height, diameter and volume) for every type of formation and for every facies give an outline onto these populating. Small squares m^2 among 3 types of formation informing about the dendrometric characteristics of the formations of vegetable as showed in Table 2 [23].

Table 2

Dendrometric characteristic of the Thuya formations

Evaluated parameters	Copse				Timber-tree			
	F1	F2	F3	Average	F1	F2	F3	Average
Density	1680	1120	510	1100	320	210	130	220
Height in cm	2.60	2.10	1.60	2.10	3.70	2.90	2.30	2.90
Diameter in cm	10	8	6	8	21	16	11	16
Volume in cm	34.20	11.80	2.30	16.10	12.20	2.80	18.60	17.30

F1: Facies of Ampelodesma; F2: Facies of Rosmarinus; F3: Facies of Stipa.

These averages of dendrometric data constitute ecological indicators and inform about the dynamism, the potentialities and the development of this plant grouping threatened in its three facies before the fire destroys them. The obtained results constitute a reference in western Algeria where no work is carried on.

Phyto-ecologic Statements

The floral characterizations of these three facies were recapitulated through three representative average statements of the floral composition of this grouping. The phyto-ecologic description of the forest of Tenira confirms these statements of vegetations for the same period [24] (Table 3).

Table 3

Phyto-ecologic average of facies

Facies	Ampelodesma			Rosmarinus			Stipa		
Constant species	1	2	3	1	2	3	1	2	3
Quercus coccifera	2.1	1.1	2.1	1.1	+	+			
Phillyrea angustifolia	2.2	2.1	2.1	2.1	1.1	1.1	+		
Pistacia lentiscus	+	1.1	1.1	1.1	2.1	2.2	1.1	2.2	2.2
Cytusus triflorus	+	+	+						
Cistus villosus	1.1	+	1.1	1.1	1.1	2.2	2.1	2.1	2.2
Vhamaerops humi	+		+	+	1.1	+	2.1	1.1	1.1
Juniperus osycedrus				+	1.1	+	+	1.1	1.1
Differential species									
Stipa tenacissima	+	1.1	+	+	2.1	1.1	2.1	3.2	2.2
Arbutus unedo	1.1	+	1. 1						
Genista quadriflora					+	1.1			
Ampelodesma	2.2	2.1	2. 2	1.1	1.1	+			
Mauritanicum	+			+	1.1	+	+	2.1	1.1
Globularia alypum	+		+	1.12.2	2.1	2.2	1.1	+	2.1
Rosmarinus tournefortii									
Campaign species									
Astragalus lusitanicus									+
Asphodelus		+					1.1	+	2.1
Microcarpus				+	+		1.1	1.1	
Elichrysum stoechas	1.1	+	1.1						
Helanthemum	+	1.1	+						
Halimifoliums									

Materials and methods

The objective of this work is follow the dynamism of *Tetraclinis atriculata* after the 1991 fire that affected most of our forests (the case of Tenira forest in this study), this dynamism needs a long period of time to obtain satisfactory results, concerning the regeneration, development and their comparison with other neighbourhood species.

As we have seen previously, the Tetraclinetum is affected with human and animal alterations, it became more fragile after being affected by fire in 1991, due to terrorism who took the forest as a refuge.

This vital plant grouping for a perpetuity of the vegetable cover in semi-arid conditions, its capacities of rejecting and to colonize space every time it is destroyed needs to be protected.

The work will be methodologically based on observing Thuya in the forests of Tenira (western Algeria) after it was destroyed by fire and to know its behaviour, these observations will be taken in a period of 15 years along, with a periodicity of 5 years in which we will determine the number of stalks, as well as the height and diameter of two formations which are (timber-tree and copse) and then of three identified facies: F1, F2, F3, then we will determine the annual increase of height and diameter taking into account their age.

The observations of 15 years from 1991 to 2006 took place some months after the fire of 1991, with a periodicity of 5 years, which means three measures concerning:

– The number of copses by hectare.
– The number of stalks by copse by hectare.
– The average diameter of stalks.
– The height averages stalks.

Obtained results

Three years after fire took place, Thuya started rejecting and colonizing destroyed spaces, after some floral sorts of its procession The dendrometric parameters measured after five years on small squares of 100 m^2 and those measured after ten years and fifteen years began to give refusals and to colonize the space as shown in Table 4, 5 and 6 respectively. Table 7 constitutes the global result of our study, and then we have to underline annual growth average in height, and in diameter of this specie.

Table 4

Dendrometric parameter 5 years after fire on small squares of 100 m^2

Evaluated parameters	Copse				Timber-tree			
	F1	F2	F3	Average	F1	F2	F3	Average
Number of copse	530	460	290	426	310	260	160	243
Number of stalks of copse	2120	1380	870	1456	1550	1300	960	1270
Height average of stalks in cm	55	48	37	46. 6	83	76	65	74.6
Diameter average of stalks in cm	2.8	2.1	1.8	2.2	4.3	3.5	2.2	3.3
Annual growth average in height	11.0	9.6	7.0	9.3	16.6	15.2	13.0	14.9
Annual growth average in diameter	0.5	0.4	0.30	0.4	0.8	0.7	0.4	0.6

F1: Facies of Ampelodesma; F2: Facies of Rosmarinus; F3: Facies of Stipa.

Table 5

Measure of dendrometric parameters ten years after fire done on the same small squares of 100 m^2

Evaluated parameters	Copse				Timber-tree			
	F1	F2	F3	Average	F1	F2	F3	Average
Number of copse	510	430	270	403	290	230	140	220
Number of stalks of copse	2550	1290	1620	1820	1740	1150	840	1343
Height average of stalks in cm	112	103	81	98.6	178	157	137	157.3
Diameter average of stalks in cm	4.9	4.6	4.1	4.5	5.1	4.9	4.3	4.7
Annual growth average in height	11.2	10.3	0.8	9.8	17.8	15.7	13.7	15.7
Annual growth average in diameter	0.49	0.46	0.41	0.45	0.51	0.49	0.43	0.4

Table 6

Dendrometric parameter 15 years after fire

Evaluated parameters	Copse				Timber-tree			
	F1	F2	F3	Average	F1	F2	F3	Average
Number of copse	510	420	250	393	280	230	120	210
Number of stalks of copse	2040	1260	1000	1433	840	920	480	746
Height average of stalks in cm	162	145	98	135	251	237	214	234
Diameter average of stalks in cm	6.7	6.2	5.8	6.2	7.3	6.8	6.1	6.7
Annual growth average in height	10.8	9.6	6.5	9.0	16.7	15.8	14.3	15.0
Annual growth average in diameter	0.4	0.4	0.3	0.45	0.4	0.4	0.4	0.4

Table 7

Annual growth average in height and in diameter

Growth average in cm	Under copse			Under timber-tree		
Age, years	5	10	15	5	10	15
Height	9.3	9.8	9.0	14.9	15.7	15.0
Diameter	0.4	0.45	0.45	0.6	0.4	0.4

The obtained results over a relatively short period are interesting and allow appreciating the evolution of Thuya after fire destroyed the formation of copse and forest. The data obtained by stuffed and by type of formation help to better understand the dynamics of this plant grouping.

Synthesis and interpretation of the results

Five years after fire, the regeneration is strongly present but the dominant sort is not *Tetraclinis articulata*, because its increase in height is weak compared with the other sorts affected by the fire as Phillyrea, Pistacia, Cistus.

The annual average increase both in height and in diameter remains considerable compared with other species often used in reforestations.

The forest where Thuya was destroyed by fire presents a lower regeneration than that of the copse which is 15 %.

Ten years after fire, the registered differences are constant and the average increases both in height and in diameter remain rather stable. The same observations would be made on the results obtained 15 years after fire.

15 years after fire of the copse of Thuya, stalks stemming from refusal among 1433 present an average height of 135 cm and an average diameter of 6.2 cm while in forest, the averages are sharply superior, the height is 234 cm while the diameter is 6.7 cm and the number of stalks is 746. The growth in height and in diameter remains superior to 30 % in the results obtained in the destroyed copse.

The annual average growth in height and in diameter of all Thuya facies is recapitulated in the Table 7.

The growth in height remains sharply superior for the developing forest after fire. They are 9 cm for the copse and 15 cm for the young forest. The density or the number of stalk by hectare constitutes a determining parameter in the growth average especially in height.

The growth remains relatively stable for the diameter no matter what conditions of the destroyed vegetable formation are.

The increases both in height and in diameter and under three fancies and type of formation (copse or timber-tree) affected by fire remain slightly lower than those of other species considered as fast growing in semi-arid floor and which remain widely used in Algeria. In this range we can mention *Pinus Halepensis* Mill. *Quercus ilex L, Pinus pinaster L*.

Comparison with other species

After fire, growth in height and in diameter are respectively estimated at 9.3 cm and 0.4 cm: for the pine of Alep (the most used specie in reforestation and afforestation and repopulation) under bioclimatic semi-arid conditions, the floor the average increases in height and in diameter and is estimated for the first one between 14 and 18 cm and for the second between 1 and 2 cm.

Analyzing the development in height and in diameter of the *Pinus halepinsis* of 13-year-old in the green dam [28], advance an annual average growth of 0.2 cm in diameter and 17 cm in height.

Conclusion

The fire does not seem to modify in any important way the floral composition the vegetable training formations of *Tetraclinis articulata*. It is competed by species with strong power of covering as *Pistacia lentiscus*, *Quercus coccifera*, *Phillyrea angustifolia*, *Rosmarinus tourneforti*, Thuya, with its small domination of space starts again slowly but certainly its colonizing area. Thuya, after fire develops and to reconstitute its plant grouping in all climatic, edaphic, and antropozoogene pressure conditions.

The results of growth in height and in diameter obtained under three facies of Thuya confirm the resistance of this specie to changes in general and fires in particular. Annual growth average in height and in diameter oscillates respectively between 9.3 and 15.7 cm for the first parameter and between 0.4 and 0.6 cm for the second.

The hasty condemnation of which Thuya was the subject, imputed to its very slow growth, seems to be wondering by comparing the results obtained after fire to other species. The difference is not important, the faculty of refusal and resistance of Thuya often militates in favour of this relegated specie giving a second plan in all repopulations and reforestations.

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THE DIFFERENTIATION OF HOSPITAL WASTE INCINERATION ASHES AN ACADEMIC CASE: THE MARRAKECH HOSPITAL

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The composition of "health care waste" or "hospital waste" does not differ significantly way from urban waste. An analysis of selected hospital waste made it possible to differentiate two sorts and furthermore two different sorts in the second case.
The following results deal with:
− the differentiation of ashes resulting from the incineration of radiological plates by the presence of silver halides.
− the difference in the nature of medical gloves according to their formulation (sterile or not sterile) by the more or less significant quantity of calcium.

Keywords*:* problems of factory and domestic waste utilization

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Khadija Boulaajoul is a 4th year Ph.D. student at Marrakech Cadi Ayyad University (Morocco). Two laboratories are involved in her research work: The Chemistry laboratory of mineral solid, Department of Chemistry (Pr. M. Mesnaoui) and the Laboratory of Cleansing, hydrology, ecotoxicology and environment (Pr. A. Sedki). In 2001 she obtained a "licence" in analytical chemistry (applied to the analysis and control of water), followed in 2003 by a "diplome d'études supérieures avancées" in management, protection and valorization of water resources.
The physicochemical studies were carried out throughout several missions at L2MP laboratory in Toulon, France (Dr. J.A. Musso). The former Laboratory is associated with the French National Centre of Research CNRS.
The results obtained were the subject of several presentions at several international congresses (Mohammedia, 2004, Marrakech, 2004, Marrakech, 2005, El-Jadida, 2005, Meknes, Morocco, 2005, Albi, France, 2007, Oujda, Morocco, 2007), and national (Rabat, Morocco, 2004).

Introduction

The management of urban waste, in general, and of hospital waste, in particular, is an economic and environmental problem becoming more and more extensive everywhere in the world. Incineration currently appears to be one of the solutions. However, the problem is delayed because it is necessary to manage the residues from a double point of view of storage and pollution: the matter is not destroyed – it simply changes form. Waste incineration residues are often complex physico-chemical systems. Their heterogeneity mainly results from the type of incinerated refuse and the operating mode of the incinerator.
This work aims at trying to bring an answer, at least partial, to the characterization and differentiation of "health care waste" incineration ashes, of the city of Marrakech. We initially carried out a total characterization of the residues resulting from the incineration of this waste. Several techniques of analysis of the solid were used (differential scanning calorimetry DSC and thermogravimetry TG, X-ray diffraction DRX, scanning electron microscopy SEM and transmission electron microscopy TEM, impedance electric spectroscopy IES, inductive coupled plasma ICP ...).
The first results of the analyses of ashes of non-sorted incinerated waste show that the composition of those different ashes do not differ significantly from ashes resulting from the incineration of urban waste [1]. It then appeared necessary to seek one or more characters which would make it possible to differentiate the nature or the origin of the waste. The analyses were carried out after a selective sorting (radiological plates and medical gloves of two different origins) although this sorting is not currently carried out in hospitals. The following results deal with:
− *the differentiation of ashes resulting from the incineration of radiological plates by the presence of silver halides.* The negatives in Transmission Electron Microscopy and the diffraction image show an amorphous

phase which corresponds to a glass and another one to the cubic centered faces structure of the atom of silver.

− *the differentiation of the nature of the medical gloves according to whether they are sterile or not sterile*. Sterile gloves are made of natural latex Nonsterile gloves are made up from synthetic polymers containing ligno-sulphonate of calcium [2]. Calcium is also used to increase the kinetics and the regularity of polymerization. That results in the abundant presence of calcium and sulphur in spectra EDAX of ashes resulting from the incineration of these synthetic gloves.

Characterization of "rough" ashes

General observations

The Table 1 below gathers the results of the analyses carried out by analysis by the atomic emission spectroscopy with inductively coupled plasma (ICP). The incineration was carried out at a temperature of 500 °C for 30 minutes. These conditions are very close to the two recommendations of the World Health Organization WHO [3] and the European Union EU [4].

This waste contains non negligible proportions of Nb and Y. Their presence, although unusual, is explained by their medical origin: yttrium is in the form of silicate in two medicines used in radiotherapy; niobium is present in alloys used in orthopedics.

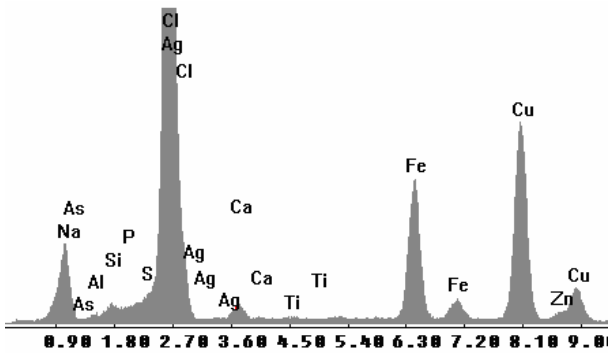
Analysis by scanning electron microscopy SEM and transmission electron microscopy TEM

The two analyses (Fig. 1) confirm the starting assumptions: the significant presence of silver coming from radiological plates and an atomic fraction of calcium higher than that usually observed in waste.

Table 1

Analysis by ICP

SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	K_2O (%)	MnO (%)	TiO_2 (%)	P_2O_5 (%)		
17.57	12.45	2.05	22.36	2.64	1.13	0.04	2.44	0.94		
B (g/t)	**Ba (g/t)**	**Be (g/t)**	**Bi (g/t)**	**Cd (g/t)**	**Co (g/t)**	**Cr (g/t)**	**Cu (g/t)**	**Ge (g/t)**	**As (g/t)**	**Ag (g/t)**
201	860	< 0.2	< 20	15	< 7	135	319	< 10	41.39	71
Mo (g/t)	**Nb (g/t)**	**Ni (g/t)**	**Pb (g/t)**	**Sb (g/t)**	**Se (g/t)**	**Sn (g/t)**	**Sr (g/t)**	**Y (g/t)**	**Li (g/t)**	**Zn (g/t)**
< 8	63	202	246	145	57	393	286	2	34	8 062



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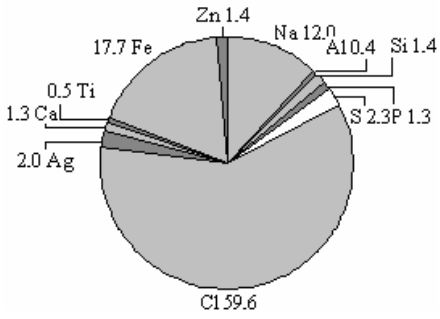

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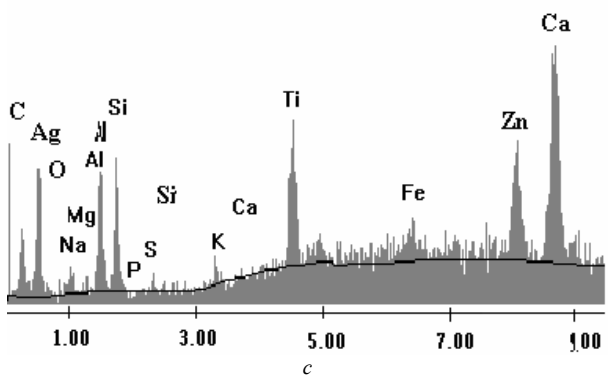

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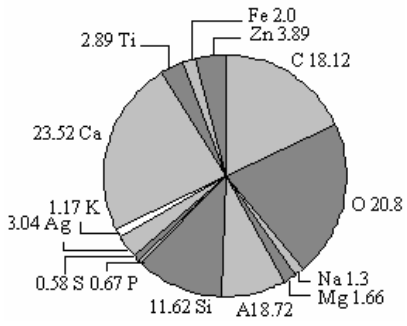


d

Fig. 1. *Analysis by SEM and TEM: a – EDAX analysis; b – atomic composition; c – SEM spectrum; d – atomic composition*

Comparison with urban waste

The reference [1] summarizes the average composition of the residues of four treatments of urban waste (it should be specified that hospital waste is not incinerated with domestic waste in accordance with the European directives).

The Table 2 below gathers this average composition in mass fraction:

Table 2

Compared compositions of urban waste and hospital ones

	Urban waste	Hospital waste
SiO_2	28	11.35
Al_2O_3	5	5.65
P_2O_5	2	1.67
CaO	6	15.77
TiO_2	1	1.26
Fe_2O_3	2	1.45
MgO	1	1.23
K_2O	1	0.91

The comparison of the results in this table shows that, the residues, although of different origin (urban or hospital) usually have rather close compositions. The greatest composition in SiO_2 in domestic waste can be explained by a more significant presence of natural silicates in this waste. The greatest composition in CaO in hospital waste is explained by a significant presence of polymers.

The thorough analysis of the composition of ashes resulting from the incineration of hospital waste reveals two characteristics:

– silver as a new element resulting from the incineration of radiological plates.

– a very different proportion of calcium according to the use of gloves (sterile or nonsterile).

Ashes resulting from the incineration of X-ray photography

Composition of the photographic plates

The whole photographic process is based on the sensitivity of silver halide crystals to luminous radiations or to the action of X-rays. A black and white photographic film consists of a flexible matter sheet, usually out of acetate or transparent polyester, covered with a sensitive layer of silver halide in suspension in a gelatine emulsion. When this film is exposed to light or X-rays, the silver halide undergoes an electrochemical reduction forming a latent image on the film. The "revelation" of the image results from an electrochemical oxidation of both hydroquinone/quinone. Metal silver particles are formed then in the zones exposed to the light. This silver metal deposit might be used as an indicator of the origin of ashes.

Characterization of the radiological plates

The plates were collected in the radiological department and were incinerated at the laboratory in a tubular furnace matching as closely as possible the running parameters of the hospital incinerator.

The different methods of analysis in solid chemistry science were used: scanning electron microscopy SEM and transmission one TEM at high resolution HREM, the diffraction of X-rays XRD, the analysis by inductive coupled plasma ICP and the electric impedance spectroscopy EIS compared with the differential scanning calorimetry coupled with thermogravimetry DSC-TG (Table 3).

Table 3

Mass composition of ashes resulting from the incineration of radiological plates

SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	MnO %	P_2O_5 %	K_2O %	CaO %	TiO_2 %		Ag ppm
1.07	0.18	< 0.1	1.85	< 0.01	0.12	< 0.1	0.15	< 0.001		71
Cr ppm	**Cu ppm**	**B ppm**	**Cd ppm**	**Li ppm**	**Ba ppm**	**Be ppm**	**Mo ppm**	**Nb ppm**	**Ni ppm**	**Zn ppm**
42	46	< 5	4	< 15	13	< 0.02	< 8	9	46	< 2
Bi ppm	**Pb ppm**	**Ge ppm**	**Sb ppm**	**Se ppm**	**As ppm**	**Sn ppm**	**Sr ppm**	**Y ppm**	**Co ppm**	**W ppm**
< 20	90	42	440	< 40	< 8	78	6	14	< 7	< 23

Analysis by inductive coupled plasma ICP

The interest of the method is a relative dosing of in the form slight traces of free elements or oxide: about one or two percents mass and a few grams per ton, i.e. about the mass part per million.

X-ray diffraction analysis

The spectrum of ash X-ray diffraction of was compared with the spectrum of silver metal spectrum of the ASTM library. The result is consolidated by the TEM-HREM observations (Fig. 2).

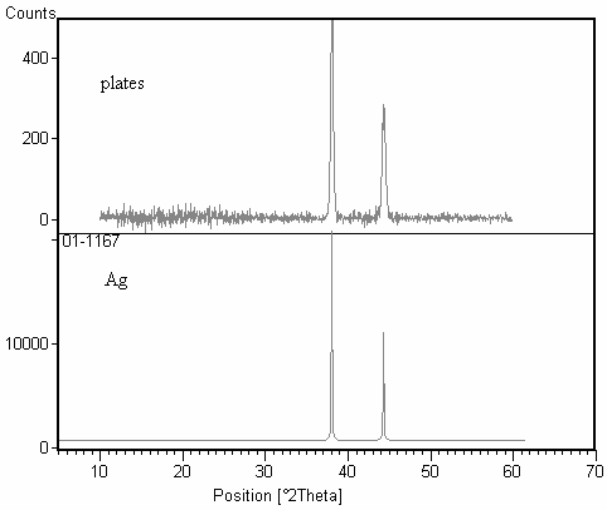


Fig. 2. *Spectra of DRX of ashes resulting from the incineration of radiological plates and ASTM library*

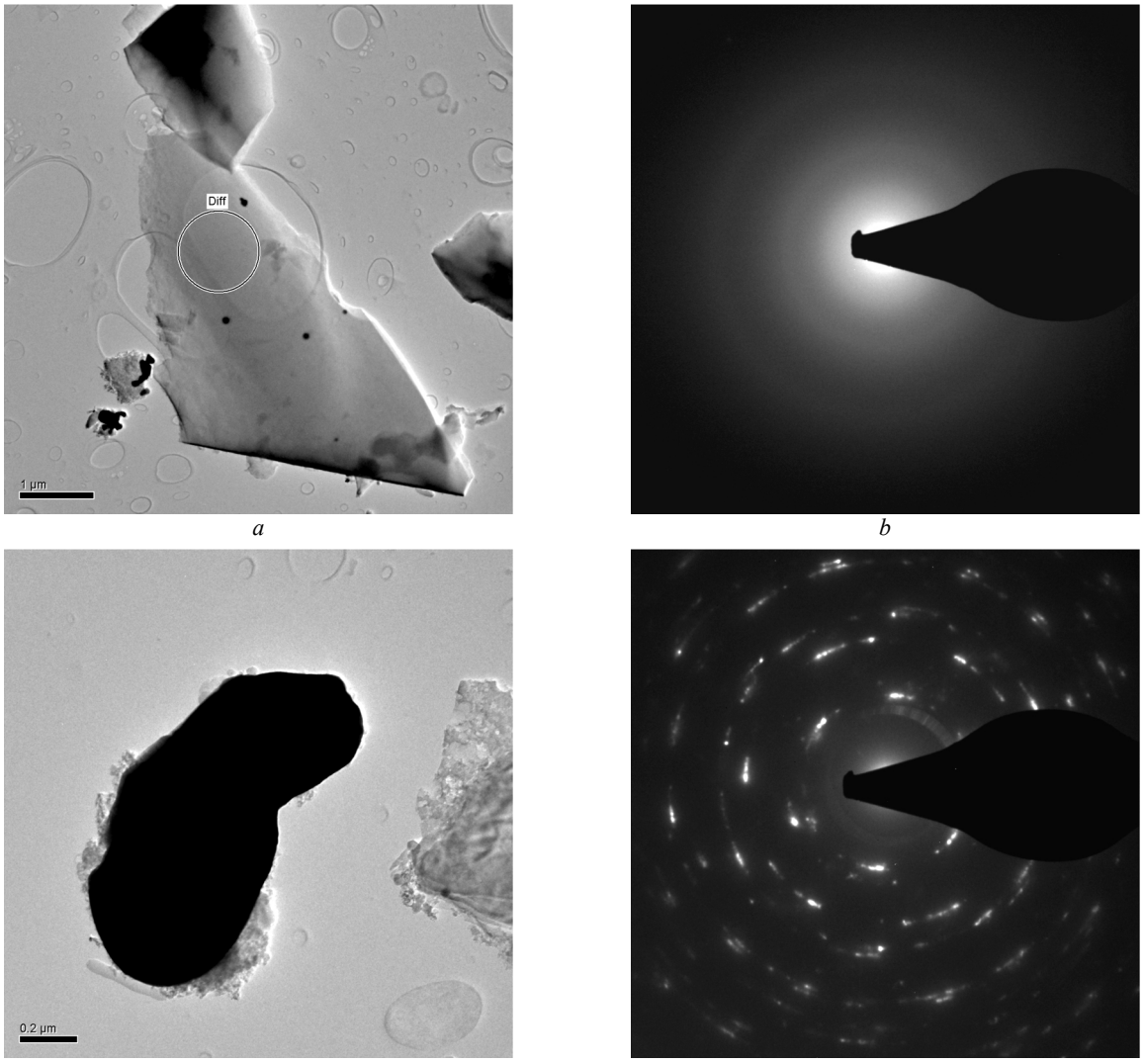
Analysis by transmission electronic microscopy TEM-HREM

Within the microscopic scale, two shapes of grain can be observed: grains of dark colour and silver plated grains (Fig. 3) The images of electron microscopy transmission show that:

– the dark grains are composed of aluminosilicates (Fig. 3, *a*). The absence of diffraction (Fig. 3, *b*) shows that these grains are in an amorphous or vitreous state

– the grains, of silver plated appearance (Fig. 3, *c*), are made up mainly of silver. The image of diffraction (Fig. 3, *d*) shows that these grains are crystallized (cubic centered faces system of the silver atom).

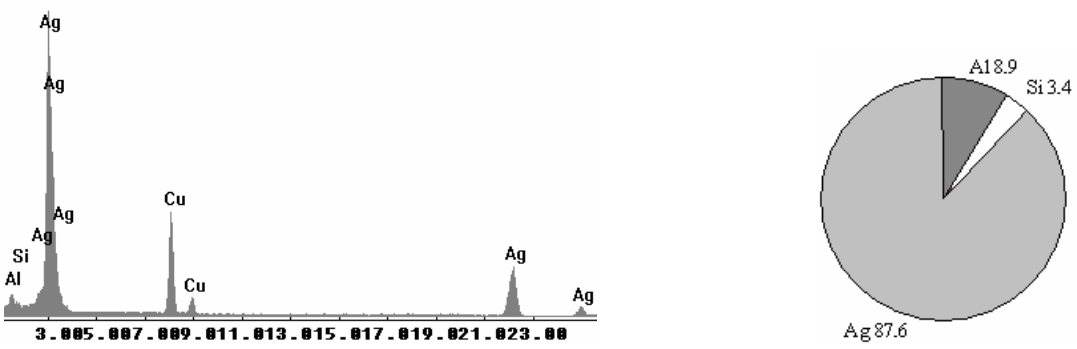
These results show, as one can expect, that silver metal is dominant. The atomic fraction is very high: it is only an impression. In fact, a radiographic plate is made up, of silver halide and the traces of developer containing sulphur. In addition, it contains organic substances mainly including "light" atoms (carbon, oxygen, nitrogen, hydrogen) which are not highlighted by TEM (Fig. 4).



a *b*

c *d*

Fig. 3. *Grains of dark colour and silver plated grains: a – dark grains composed of aluminosilicates; b – absence of diffraction; c – silver plated grains; d – image of diffraction*



a *b*

Note: Copper is not taken into account in the calculation of the atomic composition because the sample-carrier contains copper.

Fig. 4. *HREM spectrum analysis of ashes resulting from the incineration of radiological plates: a – EDAX analysis; b – atomic composition*

Electric impedance spectrometry and differential scanning calorimetry-thermogravimetry

1. Electric impedance spectroscopy EIS: ashes are compacted under 10 kbar and placed between two nonreactive plane electrodes, an alternate field of variable frequency is applied to the electrodes; the analysis of the associated current is then carried out. The analyzer measures an impedance, function of the frequency from which conductivity or conductance can be deduced. Conductimetric measurements are carried out in cells under controlled atmosphere and at variable temperatures (Fig. 5).

2. Differential scanning calorimetry and thermogravimetry DSC-TG: the reactivity according to the temperature is studied by the usual method of differential scanning calorimetry coupled to thermogravimetry. This method makes it possible to follow the thermal effects (dehydration, decomposition...) and the possible losses of mass associated to these effects according to the temperature (Fig. 6).

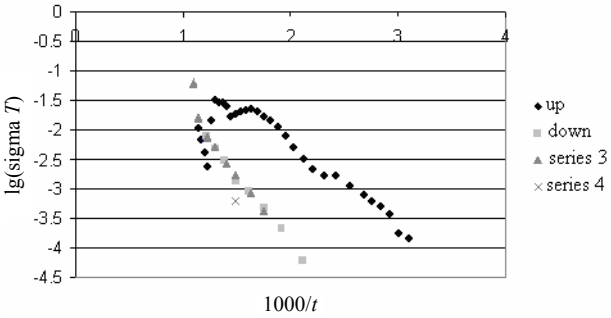


Fig. 5. *lg(conductivity) vs 1/t of ashes resulting from the incineration of radiological plates*

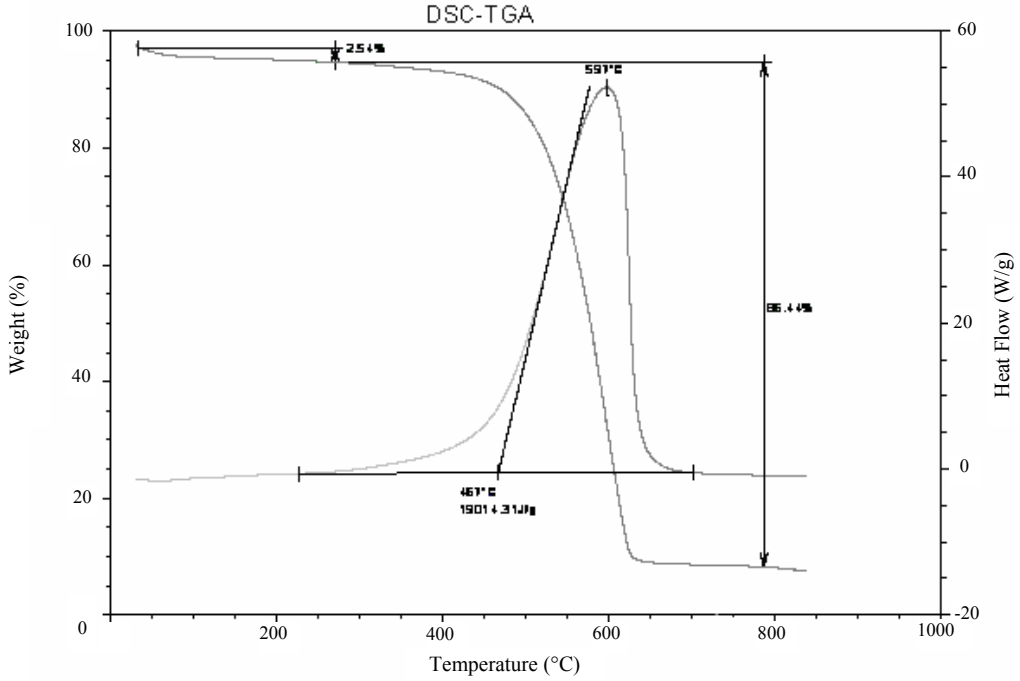


Fig. 6. *Differential scanning calorimetry and thermogravimetry vs temperature of ashes resulting from the incineration of radiological plates*

Discussion

Two thermal accidents have been identified:

− An accident at a temperature close to 140 °C with a loss of mass of 2.54 % corresponding to the surface water loss. The small quantity of this loss means that water was primarily brought by hydration in free atmosphere.

− A significant loss of mass (86.44 %) is observed between 300 °C and 700 °C. The DSC-TG is carried out under air; this loss of mass can correspond to the degradation of the photographic support made up mainly of light atoms.

A very strong evolution of the characteristics (thickness and diameter) of the pellet was observed. This degradation of the pellet makes it difficult to interpret the sharp increase in the electric conductivity of the sample beyond 700 °C: an increase which may come from the remainder of the pellet (11 % in mass) made up of silver or silver salt or a unwanted contact between the electrodes.

Ashes resulting from the incineration of medical gloves

Composition

The properties and the different compositions of medical gloves are stated in national and international standards, for example the ISO 11 193 standard. These gloves are, most of the time manufactured either from rubber (natural or synthetic), or from thermoplastic polymers. New materials are currently being studied for the manufacture of these gloves; Particularly copolymers of ethylene and methyl or butyl methacrylate. These materials give the gloves particular characteristics of flexibility, solidity and extensibility [5]. Various additives are included in the polymeric matrix: a vulcanization agent containing sulphur and zinc salt, an antioxydant, titanium oxide and zinc oxide used as dyes, a stabilizer, dispersants, ions such as Ca^{2+} [6]. The inside of each glove is coated with talc to make it easier to use. The theoretical formula of talc is $Mg_3[Si_2O_5]_2(OH)_2$. As in any natural mineral, a few cations replace other cations in the lattice by respecting the neutrality of the crystal and its structure: for example two ions Al^{3+} permute with three ions Mg^{2+} and reciprocally. The same substitution can be observed, but to a lesser extent, with an Fe^{3+} ion or a Cu^{2+} ion.

Characterization of medical gloves

The gloves were collected at the civil hospital and at the blood transfusion center (City of Marrakech), both these places correspond to a specific formulation of the material (sterile and nonsterile gloves). It is interesting to know if these two formulations can be distinguished by means of the usual methods solid physicochemistry.

The gloves were incinerated separately in the laboratory under conditions which reproduce real incineration (Table 3).

Table 3

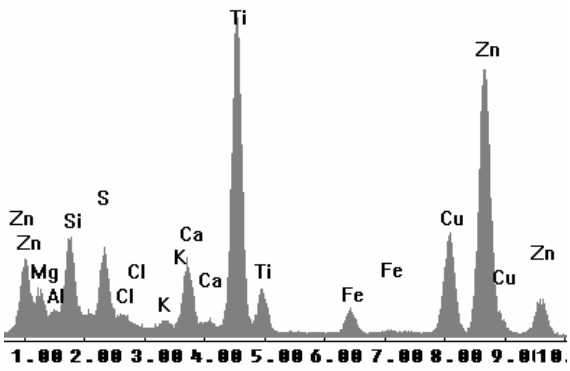
Mass composition of ashes resulting from the incineration of sterile gloves

SiO_2	Al_2O_3	Fe_2O_3	MgO	MnO	P_2O_5	K_2O	CaO	TiO_2	ZnO
(%)									
35.11	29.01	0.90	2.78	< 0.01	0.19	2.25	0.52	3.93	3.8
Cr	**Cu**	**B**	**Cd**	**Li**	**Ba**	**Be**	**Mo**	**Nb**	**Ni**	**Co**
(ppm)										
21.00	26.00	185.00	5.00	208.00	175.00	< 0.02	< 8	45.00	44.00	< 7
Bi	**Pb**	**Ge**	**Sb**	**Se**	**As**	**Sn**	**Sr**	**Y**	**W**	
(ppm)										
< 20	161.0	39	< 32	< 40	30.0	92.00	68.00	19.00	< 23	

Sterile gloves

1. Analysis by ICP: Analysis by ICP showed two unexpected elements in these formulations: yttrium and lead. Yttrium can come from crucible ceramics in the form of Y_2O_3 which is not usually found, or only in negligible quantity in the measurements carried out in an Al_2O_3 crucible. Lead is used as protection against ionizing radiations and the radioactive contamination

2. Analysis by HREM: The quantitative analysis of the transmission electron microscopy TEM and of scanning electron microscopy SEM allowed us to highlight the presence of zinc (32.1 % at.) and of titanium (32.6 % at.) in great quantity which comes from dyes, in the form of oxides (Fig. 7).



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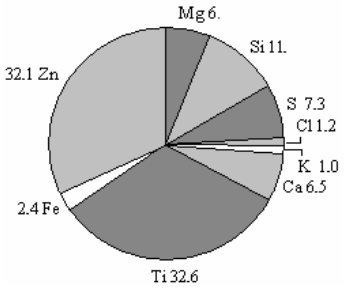
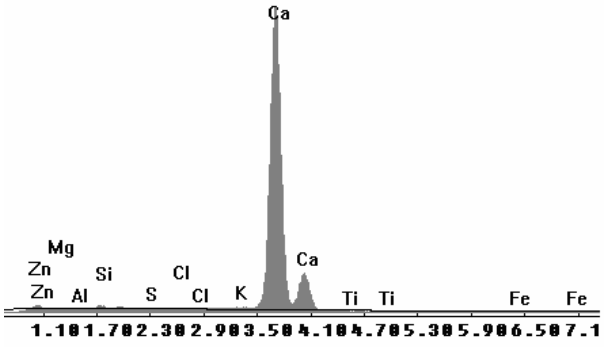


b

***Fig. 7**. HREM ashes analysis resulting from the incineration of sterile gloves: a – EDAX analysis; b – atomic composition*

Nonsterile gloves

The nonsterile gloves correspond to a different formulation. An HREM analysis followed by an EDAX analysis makes it possible to highlight the characteristics of this formulation (Fig. 8).



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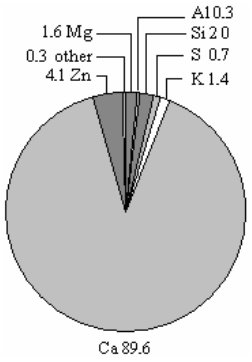

b

***Fig. 8**. HREM ashes analysis resulting from the incineration of nonsterile gloves: a – EDAX analysis; b – atomic composition*

Discussion

Gloves of different origin were studied. Nonsterile gloves feature a significant quantity of Ca. A possible explanation lies in the specific use of the gloves. Surgical gloves are manufactured from natural latex and are free of contamination; the other nonsterile gloves are made of synthetic polymer; an organic compound of calcium, calcium ligno-sulphonate, is used as an agent of polymerization by increasing speed and regularity. This explanation is backed by the change of one of its physical properties: Gloves sticking to each-other: sterile gloves contain anti-sticking agent inserted in natural latex [6].

Conclusion

Practically, "Health care waste" is separated from urban or domestic waste and incinerated separately but without any other sorting process. An analysis of the ashes resulting from "Health care waste" showed that their composition is rather close to those of urban waste. It then appeared necessary for us to seek which elements were specific to hospital waste. We concluded from it that silver enhances the presence of radiological plates. The change in the physical property of glove sticking made us seek the origin of this change. The more or less significant quantity of calcium allowed us to sort out sterile gloves (made of natural matter) from nonsterile gloves (made of synthesis polymer).

Waste storage, even incinerated is very costly. The current tendency is valorization (road surface, building materials...); the word "incineration" is replaced moreover by the word "energetic valorization" in international recommendations. The recovery of the silver metal from radiological plates is an industrial process usually performed by electrolysis without incineration of the plates, but these plates need to be sorted by the staff hospital. The quantity of recoverable silver in an hospital is not economically profitable.

Experimental part

Physical measurements are carried out jointly on the spectrometers of the University Cadi Ayyad of Marrakech and those of the Sud-Toulon-Var University.

a) ICP: inducted coupled plasma.
The light elements are proportioned with an apparatus ULTIMA.
The heavy elements are proportioned with an apparatus PANORAMA.

b) XRD: X-ray diffraction.
The apparatus used is a diffractometer BRUCKER-SIEMENS D5000 with radiations $K_{\alpha 1}$ and $K_{\alpha 2}$ of a copper anticathode bombarded by electrons accelerated under a tension of 35 kV. The source of electrons is a filament of tungsten. A nickel filter makes it possible to mainly eliminate radiations K_{β} from copper.

Wavelengths used are $\lambda K_{\alpha 1}$ = 154.0 pm and are $\lambda K_{\alpha 2}$ = = 154.5 pm the identification of the samples is carried out by comparing the experimental diagrams and the diagrams of reference of JCPDS file or ASTM file.

c) IES: impedance electric spectroscopy.
The apparatus used is composed of a potentiostat-galvanostat of model EGG 273A coupled to an analyzer of model frequency SOLARTRON IF 1260. The ceramics pastilles are placed between two electrodes of gold maintained by a light pressure ensuring a stable and reproducible contact. Measurements are taken in AC current in a broad field of frequency of 10^{-1} Hz to 10^{7} Hz. The conductivity of the samples is measured under air in the temperature range of 40 to 700 °C.

d) DSC-TG: differential scanning calorimetry and thermogravimetry.
The apparatus used standard DSC TG- 92 SETARAM is equipped with a microbalance and a graphite furnace (maximum temperature 1600 °C). The unit, controlled by a computer, allows the simultaneous layout of the curve of the variation of the masses of the sample and the curve of differential thermal analysis. The temperature is measured with a thermocouple (rhodium Pt-Pt with 10 %).

e) SEM: scanning electron microscopy.
Images are performed with a JEOL, JSM-5500.
The ultimate analysis is done by EDAX-Falcon.

f) TEM-HREM: transmission electron microscopy.
The apparatus used is an electron microscope with high resolution TECNAI G^2 having an accelerating tension of 200 kV, that is to say a wavelength associated 2.51 pm and an objective with the super-twin type. The electron beam is emitted under a vacuum of about $30 \cdot 10^{-6}$ Pa by the heating, towards 1550 °C, of a crystal of hexaborure of lanthanum (LaB_6). The images are carried out with a growth going up to 1,000,000. One can point by point reach resolutions of 0.248 nm what makes it possible to colour reticular distances. This aircraft is equipped with a system of analysis by X-ray spectrometry in dispersion of energy EDAX making it possible to obtain qualitative and quantitative information on the chemical elements present in the samples.

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ENVIRONMENTAL IMPACTS ASSOCIATED WITH OCEAN THERMAL ENERGY CONVERSION

Research Proposal

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More than one century ago French physicist Jacques Arsene d'Arsonval was the first to propose tapping the thermal energy of the ocean for producing useful energy. The relevant process was named Ocean Thermal Energy Conversion − OTEC. Surface and deep water of the ocean, which have different temperatures, can be used as a heat source and a heat sink in a thermal engine ruled by the Carnot principle. The first plant, that demonstrated the process feasibility and permitted assessing the engineering problems and financial risks stemming from its implementation, was constructed in 1930. The background of setting up diverse facilities on the basis of OTEC in different countries is provided. It is emphasized that in recent decade many countries abandoned their activities aimed at OTEC development. The USA and Japan can be mentioned as the exception, as both countries continued research in OTEC, their efforts being aimed at expansion of possible applications for deep ocean water, besides improving the OTEC processes and studying their potential impacts on the environment. OTEC impact will essentially consist of massive seawater intakes and effluent discharge, the latter having a temperature and composition a priori different from ambient values. The magnitude of this impact will mostly depend on the scale of OTEC operations (overall power generation capacity), on the spatial distribution of power plants and on the effluent discharge strategy.

This paper is linked to the first contribution of the Club des Argonautes to the International Scientific Journal for Alternative Energy and Ecology 2007: OTEC – STATE OF THE ART AND PRESENT STATUS.

Keywords: solar energy, OTEC, ETM, environmental impact, hydrogen economy

The "Club des Argonautes" is a small group of retired scientists and engineers who happened to work with French public institutions such as IRD, IFREMER, Météo France, CNES, CNRS, and MNHN

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Introduction

Ocean Thermal Energy Conversion (OTEC) has recently received renewed attention as the search for renewable, clean energies capable of replacing costlier fossil fuels has intensified. The most accessible reserves of oil, coal and natural gas have actually started to decline. Stored as heat in the surface layer of tropical oceans, solar energy can be partially converted into mechanical and electrical power by utilizing the existing thermal stratification between warm surface water and cold deep water.

The conversion process, conceived by the end of the 19th Century and tested in the 1930s, uses warm surface water and cold deep water to respectively feed an evaporator and a condenser on either side of a turbomachine operating on a so-called Rankine cycle. Operational parameters are well adapted to the small vertical temperature differences, of the order of 20 ºC, that are available in the warmest regions of the tropical oceans. Small temperature differences, however, lead to low process efficiency. Consequently, large seawater flow rates are required, of the order of several cubic meters per second per net megawatt generated. Typically, this seawater intensity would be 5 $m^3s^{-1}MW^{-1}$ and 2.5 $m^3s^{-1}MW^{-1}$ for warm and cold water, respectively (Nihous [1], 2005).

It follows that the impact of OTEC on the ocean environment will essentially consist of massive seawater intakes and effluent discharge, the latter having a temperature and composition a priori different from ambient values. The magnitude of this impact will mostly depend on the scale of OTEC operations (overall power generation capacity), on the spatial distribution of power plants and on the effluent discharge strategy. In the latter case, multiple choices are available and environmental responses will vary according to the depth at which effluents (from evaporator and condenser) are released, mixed or not. It is therefore critical to carefully evaluate impacts from OTEC seawater intakes and effluent discharge under various scenarios in order to simultaneously optimize OTEC power production and minimize its potential disruption of the ocean environment.

Such studies concern the global impact of future intensive OTEC exploitation. They are different from those necessary to evaluate the local impact of any OTEC plant construction.

Optimization itself could be based on different metrics according to possibly different objectives: e.g. to maximize power production, or to promote biological production from the artificial upwellings generated by the discharge of nutrient-rich OTEC effluents into the photic layer.

The importance of upwellings on the marine ecosystem

Natural upwellings are produced by wind stress over the ocean under certain conditions that favor a divergence of surface waters (proximity of a coastline or of the Equator). This locally induces the upward motion of deeper, colder nutrient-rich waters toward the surface.

Upwellings play an important role in the global energy balance of the ocean and of the Earth. In tropical regions, they allow an accumulation of heat that is later transferred to higher latitudes by major currents (Gulf Stream in the Atlantic and Kuro Shiyo in the Pacific). They also strongly mediate interactions between the ocean and the atmosphere by inducing meteo-oceanic oscillations that affect climate across the entire tropical belt, such as the phenomenon known for centuries as El Niño (ENSO).

Wherever they occur, upwellings boost biological productivity as well. The high nutrient concentrations generally found in deeper waters are advected upward into the photic layer where photosynthesis is promoted. This increase in primary productivity benefits the entire food chain. In certain cases (cf. below), artificial upwellings related to OTEC operations could contribute to a local increase in primary production. While seemingly positive, the consequences of such biological effects should be assessed from a long-term perspective involving multiple trophic levels.

In view of the foregoing, potential impacts of artificial anthropogenic perturbations of the thermal and chemical structures of the ocean upon ocean dynamics itself, atmospheric dynamics and marine biological processes must be evaluated carefully in the context of an ultimate and massive deployment of OTEC plants within tropical regions. Thresholds could exist beyond which such perturbations could permanently alter oceanic circulation and, possibly, atmospheric circulation as well. This could substantially constrain the acceptable scale of OTEC-related perturbations upon the environment. Such thresholds should be assessed as precisely as possible.

Problem fundamentals: energy needs and OTEC potential

World annual electric consumption in 2001 reached 15500 TW·h. It could rise to 36000 TW·h by 2040 (EREC scenario [2] to 2040). This future demand typically would be met with a total power-plant installed capacity of 5 TW (assuming a capacity factor of 80 %).

What is the theoretical amount of ocean energy that could be converted toward such a target?

Solar radiation absorbed by the oceans corresponds to an overall mean flux of 52 PW (Huang [3], 2004). References from the technical literature suggest that it should be possible to extract 10 TW of OTEC resources in a 60 million km^2 region where temperature differences between the ocean surface and a water depth of 1000 m exceed 22 ºC (Avery [4], 1994). These estimates are obviously theoretical and most likely beyond practical limits.

Beyond a strictly thermal consideration of the problem, another important limiting factor in the deployment of OTEC technologies consists of the magnitude of the process flow rates. All natural upwellings, for the most part located in the intertropical region, amount to about 30 Sverdrups (Sv). This is a flow rate equivalent to the downwelling of deep and bottom waters in the Arctic and Antarctic convective zones, so that a meridional thermohaline circulation is maintained to keep the overall system's balance as we know it today. Any perturbation of the mechanisms related to this ocean circulation, for example from artificially upwelled deep water, intuitively should remain much smaller than this background flow rate, lest the overall ocean circulation change substantially. One should keep in mind (Nihous, 2005) that the net production of 1 GW by OTEC plants would require the pumping of 2500 m^3/s of deep water (that is 25 Sv for 10 TW, a theoretical value of the same order as the magnitude of natural upwellings). In truth, even with a rapid expansion of OTEC operations, for example with 5000 plants rated at 100 MW generating 10 % of the predicted electrical power demand in 2040, the corresponding deep water flow rate would not exceed 1.25 Sv. The primary goal of this study would be the definition of optimized scenarios and the identification of potential thresholds.

Potential OTEC resource limits

At face value, a theoretical OTEC potential of 10 TW would represent an electrical power generation capacity twice as large as that predictably needed by mankind in 2040 (5 TW). This amounts to a significantly large value, but it does not take into account a number of limiting factors arising from technical difficulties, physical and geographic constraints, and environmental concerns which undoubtedly would reduce the exploitable OTEC resource. Political issues, such as a nation's sovereignty over its EEZ, are susceptible of imposing further constraints.

The exploitation of OTEC resources will therefore necessitate hard choices based on technical, economic and political parameters. Such choices will in turn influence the nature and magnitude of the environmental impacts which represent the object of this research proposal. For example, OTEC plants and their artificial upwellings located in the warm western most margins of the inter-tropical zone, where OTEC temperature differences are the most favorable, will not cause the same effects on ocean dynamics and climate as OTEC plants sited in the easternmost regions where natural upwellings occur.

Environmental impact also will depend on the selected method of effluent discharge: should effluents be mixed or not before being released into the ambient water column? at what depth(s) should the discharge take place? What are the time scales of the perturbations of the oceanic thermal structure induced by OTEC itself?
Some of these questions recently were tackled with very simplified simulations (Nihous, 2005; Nihous, 2006) that show the likely existence of a limit for exploitable OTEC resources beyond which a degradation of the oceanic thermal structure may take place. In order to sustain OTEC operations, it is necessary to preserve a sufficient vertical thermal gradient. The upper bound of sustainable OTEC power generation may be as low as 3 TW.
Beside such theoretical limits, the effects of OTEC seawater streams on the coupled dynamic behavior of the ocean, the lower atmosphere and marine biota clearly must be assessed in order to be able to quantify OTEC impacts and to determine thresholds beyond which these impacts would become unacceptable. This is the object of this research project**.**

Research project objectives

Many environmental issues arise from a prospective deployment of OTEC technologies, the more so as effluent discharge options may vary with different targeted outputs.
For a given design configuration, the following questions should be addressed:
a) How will ocean dynamics adapt to a perturbation of the oceanic thermal structure?
b) What effects perturbations of the ocean surface temperature and the onset of an artificial heat sink may have on the atmosphere and its dynamics?
c) How can marine biota respond to nutrient enrichment and different temperatures?
These questions give rise to research priorities which can be articulated along three axes, with a definite dependence on the selected effluent discharge option:
1. Study of the perturbations of the thermal structure of the ocean and of the dynamic response of the ocean as a result of OTEC operations.
2. Study of the coupling of thermal and dynamic oceanic perturbations with atmospheric behavior.
3. Study of the impact of artificial nutrient enrichment in the photic zone on the marine ecosystem.
These three research areas involve modeling as a necessary simulation tool for scenarios that cannot be tested in the field.

Boundary conditions for the proposed studies

OTEC operations rely on the existence of sustained vertical temperature differences through the water column, and therefore on elevated surface temperatures generally found in inter-tropical areas, but more precisely toward western boundaries.
A priori, one will only consider regions where temperature differences between surface and deep waters exceed 20 ºC, i.e. approximately between latitudes 20º N and 20º S. Among possible strategies to better define this OTEC zone, one could fix the deep-seawater withdrawal depth at 1000 m; this choice reflects a realistic evaluation of current and short-term technological capabilities in ocean engineering. Generally speaking, one will strive to select parameters consistently in order to facilitate the comparison of results among peers involved in this research field.

Possible tools

A) Computer simulations of the thermal and dynamic perturbations of the ocean will be performed with Ocean General Circulation Models (OGCMs) run in a predictive mode. At first, it won't be necessary to resort to high-resolution versions of these models. A horizontal mesh size of 1 to 2 degrees will help trim down the problem by allowing multiple cost-effective simulations for a few standard scenarios corresponding to an increasing overall OTEC production as a function of time. The number of power plants, their positions and rated capacity would all be input parameters.
B) The coupled effects of oceanic perturbations on the atmosphere could be studied with models currently used for seasonal forecasts. Coupled OGCM/AGCM models which deal with ENSO predictions would be a tool of choice to test the impact of artificial upwellings on ENSO dynamics along the Pacific tropical belt (regions dotted with islands where preliminary tests of OTEC plants have been performed or are under consideration).
C) The coupling between biological models and ocean-atmosphere physical models has been a strong developmental focus for many research teams. Experimental models already exist, soon to be replaced by operational models. The study of the ocean's capacity to increase its biological productivity in response to nutrient-rich upwellings is a topic of current interest that recently prompted international panel of experts to draft a specific resolution (Bergen Declaration [5]).

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OCEAN THERMAL ENERGY CONVERSION (OTEC) – STATE OF THE ART AND PRESENT STATUS

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More than one century ago, French physicist Jacques Arsene d'Arsonval was the first to propose tapping the thermal energy of the ocean for producing useful energy. The relevant process was named Ocean Thermal Energy Conversion − OTEC. Surface and deep water of the ocean, which have different temperatures, can be used as a heat source and a heat sink in a thermal engine ruled by the Carnot principle. The first plant, that demonstrated the process feasibility and permitted assessing the engineering problems and financial risks stemming from its implementation, was constructed in 1930 (see http://www.clubdesargonautes.org/histoirestem/etmclaude.htm, in french). The background of setting up diverse facilities on the basis of OTEC in different countries is provided. It is emphasized that in recent decade many countries abandoned their activities aimed at OTEC development. The USA and Japan can be mentioned as the only exception, as the countries continued research in OTEC, their efforts being aimed at expansion of possible applications for deep ocean water, besides improving the OTEC processes and studying their potential impacts on the environment. At present there is no OTEC power plant of large enough power (several megawatts), which impedes a better estimation of economic opportunities offered by this renewable energy source.

See also another contribution of the Club des Argonautes to this issue of the International Scientific Journal for Alternative Energy and Ecology 2007: ENVIRONMENTAL IMPACTS ASSOCIATED WITH OCEAN THERMAL ENERGY CONVERSION. *Research Proposal*.

Keywords: solar energy, OTEC, ETM, hydrogen economy

The "Club des Argonautes" is a small group of retired scientists and engineers who happened to work with French public institutions such as IRD, IFREMER, Météo France, CNES, CNRS, and MNHN

Introduction

Ocean Thermal Energy Conversion – OTEC – is the process that uses warm water from the surface and cold water from the depth of the tropical ocean to produce useful energy. For more than one century OTEC has been addressed a possible alternative for traditional sources of energy supply. During the 1930s, OTEC demonstrated its feasibility and an OTEC commercial plant was developed that allowed assessing the technical difficulties and financial risk inherent in the use of the OTEC resource. After World War II, several projects for building OTEC electric plants were studied with the idea of supplying some French overseas territories with electricity. Nevertheless, these projects were abandoned in the mid 1950s, as they did not appear competitive with local hydroelectric resource. Then, OTEC has been "forgotten" for almost 20 years until the 1973 oil crisis.

A continuing rise in oil prices through the late 70s highlighted the defects of oil market, vulnerability of oil supply, and ineluctable limits of the oil resource itself. The crisis reactivated public interest in renewable energy including OTEC, therefore 1975-1985 became a golden period for OTEC. Strong political support encouraged important funding from both public and private sectors. In the USA, under the Carter Administration, this support was expected to lead to a vivid demonstration of commercial-sized OTEC plants by 1990 [1]. However, the drastic drop of oil market price in 1986 killed this ambitious prospect and OTEC activities were shut down in many countries, except in the USA and Japan. These two countries got adapted to the situation and focused their attention on the development of technology helping reduce construction and operation costs of future OTEC plants as well as study other commercial applications of deep cold water.

OTEC process and components

On a large area of the tropical ocean, the temperature difference between the surface water and the water at the depth of 800 to 1000 m is in the range of 20-25 °C. This

thermal gradient between the surface water and the deep water results from the wind driven global circulation of the ocean. The surface water and the deep water can be used respectively as a heat source and a heat sink of a thermal engine ruled by the Carnot principle. A very simplified scheme of OTEC system is shown in Fig. 1.

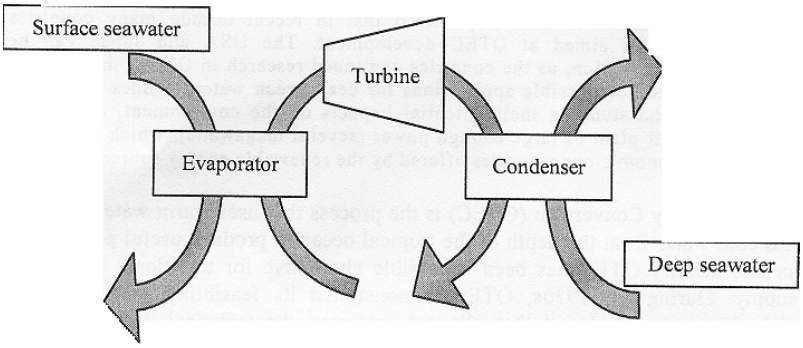

Fig. 1. *Simplified OTEC diagram*

The main components of the system are:
– supply pumps and pipes;
– evaporator with warm sea water;
– condenser with cold sea water;
– working fluid that is vaporized;
– steam turbine driven by the working fluid that generates mechanical energy.

The details of the process and technology of the components for OTEC systems depend essentially on the choice for the working fluid. There are basically two types of OTEC processes: closed-cycle and open-cycle.

ln the closed-cycle process the heat from the warm surface seawater is transferred through the evaporator to a working fluid, such as ammonia, with an appropriate vapour pressure at the temperature of the available warm to turn it into vapour. The expanding vapour drives a turbo alternator, which produces electricity. The cold seawater, passing through a condenser that contains the vaporized working fluid, turns the vapour back into a liquid, which is then recycled through the system in a "closed cycle".

Open-cycle OTEC uses the warm surface water itself as a coolant. In the near vacuum evaporator the water vaporizes at surface water temperatures. The expanding vapour drives a law-pressure turbine attached to a generator, which produces electricity. The vapour (which is indeed fresh water vapour) is condensed back into liquid water by mixing with cold deep ocean water. If a surface condenser is designed to keep the vapour from direct contact with the seawater, the condensed water can then be used for drinking or irrigation. A "direct contact" condenser that mixes the vapour and the cold seawater is more thermodynamically efficient, but the effluent is salty and not recycled. The process is repeated with a continuous supply of the surface seawater to the evaporator. The cycle of the coolant is "open".

Variations of OTEC open cycle include mist lift and foam lift processes, which use a hydraulic turbine instead of a very low vapour pressure steam turbine applied in Claude's open cycle, have been proposed and tested on a small scale in laboratory conditions. More investigation is required to establish their industrial potential that will not be further discussed in the present article. Also hybrid systems using parts of both open-cycle and closed-cycle systems are used to optimise the production of electricity and fresh water and better answer the users demand.

OTEC history

Jacques Arsene d'Arsonval, a French physicist, was the first to propose tapping the thermal energy of the ocean (1881) and Georges Claude, a former student of d'Arsonval, was the first to build an experimental open-cycle OTEC electric plant to demonstrate the feasibility of the process at sea. The plant was built onshore in Matanzas Bay, Cuba, in 1930. The system using a low-pressure turbine produced 22 kW of electricity. Later, in 1935, Claude constructed a 2.2 MW open-cycle floating plant aboard a 10000-ton cargo vessel "La Tunisie" to be moored off the coast of Brazil. Claude planned to sell industrial ice to Rio de Janeiro and give evidence of the economic potential of OTEC. Unfortunately, during the installation the cold-water pipe was destroyed by the effect of the waves and Claude became bankrupt (La Tunisie, 1991) (see: http://www.clubdesargonautes.org/otec/vol/ vol2-1-10.htm).

After W-W-II, French researchers designed a 3 MW electric open-cycle plants for two French Overseas Territories. However, the projects were not completed because the cost of OTEC energy was not competitive with inexpensive hydroelectric power available on both sites.

In 1974, the Natural Energy Laboratory of Hawaii (NELHA, formerly NELH) was established at Keahole Point on the Kona coast of the big Island of Hawaii. It has become the world's foremost laboratory and test facility for OTEC technologies. ln 1979, the first 50 kW electric closed-cycle OTEC demonstration plant went up at NELHA. Known as "Mini-OTEC", the plant was mounted on a converted U.S. Navy barge moored 2 kilometres off Keahole Point. The plant used a 0.7 m-diameter, 670 m-long cold-water pipe to produce 15 kW of net electric power.

In 1980, the U.S. Department of Energy built OTEC-1, a test laboratory for closed-cycle OTEC ammoniac heat exchangers installed onboard a converted U.S. Navy tanker. The results of the test identified the methods for designing commercial scale heat exchangers for OTEC, and a new design for a suspended cold-water pipe was validated at that test site. The OTEC-l experiment has demonstrated that OTEC systems can operate from slowly moving ships with little effect on the marine environment.

In 1981, Japan built a shore-based 100-kW(el.) closed-cycle plant in the Republic of Nauru in the Pacific Ocean. This plant employed cold-water pipe laid on the sea bed at the depth of 580 m. The working fluid was Freon-22 and a titanium shell-and-tube heat exchanger was used. The plant produced 31.5 kW (el.) of net power during continuous operating tests from October to December 1981.

The golden age for modern OTEC peaked in 1980 when the US Administration enacted laws [1] to promote commercial development of OTEC (US ACT,1980) and called for demonstration of 100 MW(el) OTEC power plant by 1985 and 500 MW installed by 1990. Unfortunately the construction program was not funded and then abandoned.

During the same period, France launched a study run by IFREMER for a 5 MW(el.) OTEC plant to be created in French Polynesia. The project was abandoned in 1986.

ln 1986 a severe drop in the oil price led to a worldwide reduction in political support and funding of OTEC development. Only the USA and Japan continued significant activities. Their efforts were more or less re-oriented with the objectives to:

– Improve knowledge of OTEC systems and possible environmental impact.

– Two examples of activity illustrating this objective are the construction and test of a 210 kW open-cycle OTEC with 50 kW Net Power Producing Experiment (NPPE) performed by the Pacific International Center for High Technology Research (PICHTR) at NELHA Keahole Point in 1993-1998, and the Japanese world's first experiment on artificial up-welling on the "Hoyo" ("Hoyo" means "productive ocean" in Japan) floating platform in 1989-1990.

– Develop technologies to cut OTEC capital and operation costs.

The activity included the development of aluminium alloys and constructIon of plate exchangers for OTEC close cycle. These were much cheaper than those previously used with titanium tubing. The activity also involved a research of material for the construction of cold water piping several meters in diameter and a research to adapt aerospace light materials to the construction of low-pressure turbine blades for large OTEC open-cycle plants. Development activities for such specific components are most often under the responsability of private companies and detailed results might not be fully available to public.

– Study a broader field of Deep Ocean Water Applications (DOWA), other than OTEC itself.

The deep ocean water is not only cold, but it is also richer in nutrients, "cleaner", and has fewer pathogens than surface water. These characteristics of Deep Ocean Water (DOW) are also stable with time and DOW is recognised as a favourable medium for growing marine organisms. By opening its facilities, including the supply of deep ocean water (NELHA, 2002), to public and private research teams the NELHA greatly contributed to increasing the vision of DOWA and has become an "incubator" for a wide range of new commercial DOW A for aquaculture of fish and sea food, (or cultivation of marine organisms of industrial interest, etc. Also, being available in the tropical region, DOW can be used as a cooling fluid for traditional thermal plants to improve their efficiency. Another simple and promising application is the usage of DOW as a "chilling" fluid for air-conditioning systems in big buildings and hotels. Visiting the NELHA web site to learn more about NELHA "tenants" and DOWA products is an exciting experience. ln Japan, similar smaller facilities exist in several Prefectures, Kochi being the first to be operated. All the above-mentioned make a convincing demonstration of new DOWA commercial success and substantial incomes.

– Identify best target sites and search for possible OTEC funding.

There are two main types of plant sites: the sites "on shore" or "close to shore" which are under the jurisdiction of nations within the limits of Exclusive Economic Zone (EEZ) and the sites located in "high seas" where the resource is accessible to any user. Beginning with the search of Georges Claude and his choice in favour of Cuba in the 1920s, the search for the best favourable sites to install OTEC plants has been – and still is – a "routine" activity for OTEC promoters. There exist long lists of favourable sites for which technical risks and costs have been evaluated and benefits for the local population clearly identified.

OTEC – the state of the art

The history of OTEC as briefly reviewed above recalls past technical successes in building and operating small experimental OTEC plants, but does not give evidence for any reliable assessment of a long-term future for commercial OTEC. Nevertheless, the analysis of the past activities addresses the following assertions and reservations.

The Ocean Thermal Energy resource is abundant and its usage to supply useful energy neither creates, nor adds new heat or chemical substances to the environment. OTEC just introduces a perturbation in the natural process of the Ocean Circulation. On the whole, OTEC is environmentally friendly, but limits and consequences of an intense exploitation of the resource are still to be studied.

OTEC requires rather "low" technologies readily available to build OTEC electric plants with a net production capacity up to several tens of MW – either "open" or "close" cycle, "on" or "close" to shore. They represent the "first generation" of OTEC commercial plants built and operated to supply small isolated communities with base load electricity and other products, e.g. desalinated water, cooling fluid, aquaculture, etc. When carefully planned and executed, the environmental impact caused by the construction of a plant will be similar to that of standard civil works with

very limited local consequences. In order to prevent adverse effects on the local environment during plant operation, the plant design can be adapted to the site characteristics. Since Claude's "La Tunisie" attempt and failure in 1935, a high capital cost and lack of experience in long-term operation for OTEC have dissuaded private investors to go commercial before a pilot OTEC plant of reasonable size – at least 1 MW – has been built and operated during a reasonable period of time – at least 1 year – with the support of public funds.

Analysis of the results gained from operating OTEC plants of the "first generation" is necessary before building big floating OTEC electric plants of 100 MW or more. The main technical issues for these OTEC plants of the "second generation" are related to the cold water pipes, transfer of electricity to land, and a big low-pressure turbine in case of an open-cycle OTEC. lndustrial study of construction design and materials for floating OTEC plants of 20 to 400 MW have been conducted [2] yielding a primary conclusion that there is a solution to build closed-cycle OTEC plants with metallic heat exchangers and cold-water pipes made of light concrete when located at a reasonable (10 miles) distance from land (Avery 1994). Uncertainties exist as to long-term effects of intensive exploitation on the environment on a regional and global scale. Also intensive exploitation should not be authorized before an international legislation is established to set the rights and duties of OTEC industry.

For a long term, conceptual designs and cost evaluation exist for big OTEC plants of the "third generation" whose goal is to produce synthetic fuels and supply liquid fuels for direct use in transportation, or for electric power production via fuel cells. Meeting all imported motor vehicle fuel demand in the US with OTEC fuels would require "only" three decades to develop (Avery 2002).

Conclusion – OTEC status at the dawn of the third millennium

Despite the fact that OTEC technology is available and offers many advantages compared to others, including such resources as solar PV, wind, biomass, etc., no OTEC plant of decent size (one to few MW seems appropriate) has been operated for a long period of time to permit a better evaluation of OTEC economy. Usual arguments to explain this situation are high capital investment costs and potential marine hazards. These factors dissuade promoters from stepping forward in OTEC development. When considering what is really at stake with OTEC, this explanation seems politically correct, but highly disputable.

Opening the OTEC tap would open access to an energy resource that could probably cover as much as the annual world demand for primary energy as predicted for 2020 (the total power that could be continuously tapped by using the OTEC resource is of the order of magnitude of 10000 GW, equivalent to the power of thermal plants burning 15 G t.o.e. a year), but exploring this opportunity is not a priority for rich and powerful countries which directly or indirectly control the present global energy market. Indeed, in the present state of the world, OTEC can be viewed as best adapted to developing nations. Many are located in the South (close to or within the tropical zone) where the OTEC resource resides, and OTEC technology is better adapted to their present industrial capacity than oil and nuclear technologies. Opening the OTEC tap could be a promise to soften their dependence, decrease the vulnerability of their supply, reduce the burden of their energy bill, and give them new development for opportunities to face their predicted increase in population.

OTEC detractors claim the OTEC costs are not competitive with traditional supplies. However, this categorical general statement might be erroneous in isolated zones where traditional fuel prices are very high and nuclear energy inappropriate. OTEC by-production, e.g. fresh water, aquaculture, cooling, etc. is also a promising approach to economic viability. Moreover, the market price of traditional energy does not reflect its real cost due to ignoring many social, environmental, and political expenses, known as "externalities". A fair evaluation of externalities is a prerequisite to comparing, production costs of energy from different sources (The ExternE Project [3]).

One step for OTEC progress is the construction of a pilot plant of adequate size to build up the confidence of private investors. The main obstacle to that step is the high capital investment required. It is financially out-of-reach for those poor nations that would need it the most. After 1985 it appeared that only an international co-operative effort could gather the expertise and the necessary funding. The IOA International OTEC/DOWA Association was established in 1990 to promote such co-operation (the IOA was established in 1990 at the initiative and with the support of Taiwanese Authorities). Its attempt failed and the IOA was disbanded in 2003.

Looking back, in the OTEC history there was no evidence of any real will on the part of developed nations to invest and proceed within an international project. So, the excitement was great within the World OTEC community when Saga University of Japan and NIOT(National Institute of Ocean Technology) of lndia announced in 1997 that they agreed to a joint development of OTEC in India: a country with a large access to an abundant OTEC resource (The Indian 1 MW OTEC Plant [4]) that faces a dramatic increase in population and future demand in clean) energy. This 1MW floating plant has been built and installed at sea. The success of this pilote operation plant could be an important milestone in the development of OTEC industry. Unfortunately to our knowledge the results obtained by the Indian-Japanese venture have not been release to public yet.

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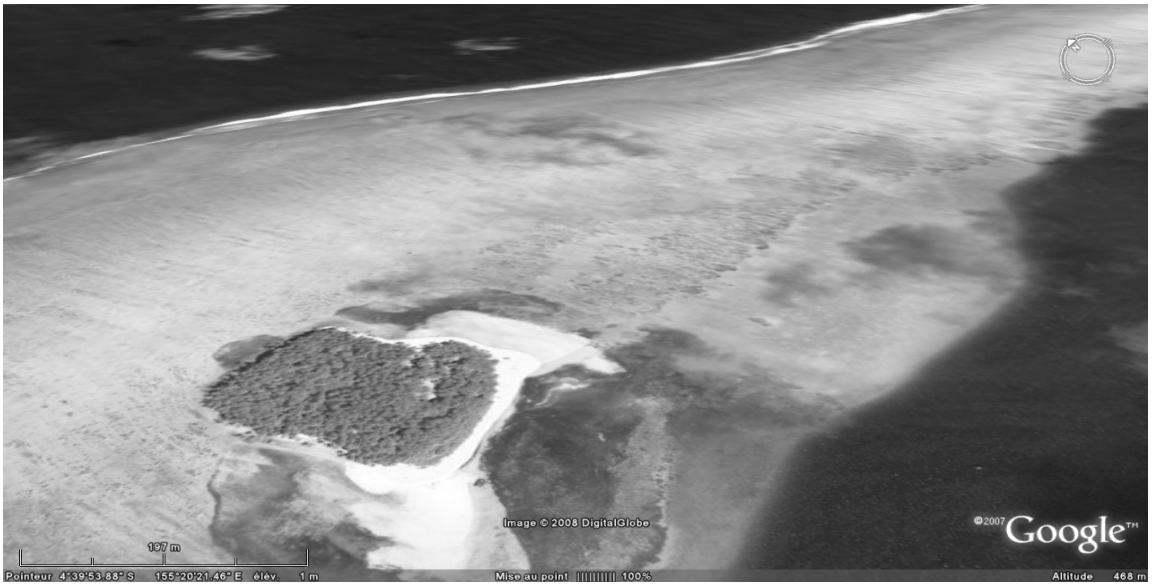
A CLIMATIC HELL ... IN PARADISE
EMERGENCY CALL FOR THE FIRST CLIMATIC REFUGEES

P. Saint-Grégoire



Space view of Iolassa island in Carterets atoll as obtained with Google Earth

As seen from the space, some islands of Pacific area appear as these small paradises that most of us have seen only on postcards; their populations have a legendary hospitality and an incommensurate kindness. However, when looking more carefully, a true nightmare is happening to some of them, with the complete collapse of their environment, ignored by our public opinion.

For these populations of Pacific islands, the anxiety is indeed already the every-day life: they have to face the concrete consequences of a concept that, for the public opinion, is still an abstraction: the sea level increasing due to global warming and to the melting of considerable quantities of ices. Already more than a decade ago, the scientific prediction was given, for this type of event and it actually occurs now, unfortunately.

What is the situation nowadays? The demoniac angels have appeared first in the paradise of Carteret islands, in Papua New Guinea, under the form of sea level rise, storms and floods over the lands. These idyllic south pacific islands have thus rapidly experienced a great disaster.

120 km northeast of mainland Bougainville, the Carterets are six small islands around an atoll about 25 km across. They are about 1m above high tide and made of sand. All six islands have been damaged. In 1995 a wave washed away most of the shorelines of Piul and Huene islands. Han island was then totally inundated and another was cut in half by the sea. The inhabitants have a very hard life. Some homes are regularly washed away.

Since several years (and events now accelerate) the erosion of the costs increases. The area of the islands diminishes, and as the sea level rises, salt water is invading the land the inhabitants have for cultivation. They are now forced to survive on coconuts, fish, and occasional food supplies from outside, whereas they used to grow tropical fruits and vegetables in gardens, today unusable. A terrible situation of malnutrition has spred and, now that wells are contaminated with salted water, even drinking water is a problem. Thus, water is now collected from rain, and when the rain-water is exhausted, the only drinkable liquid is from coconuts. For some years the islanders, who have nearly no money, have depended on emergency aid, arriving at random since without any air service, a government boat goes there only few times a year.

This situation, characterized by the increasing number of swamps with brackish water led to the appearance and extension of mosquitoes and their natural consequence: malaria.

Hunger, malnutrition, insecurity, anxiety for entire populations are unexpected consequences of the greenhouse effect. This shows that any problem concerning environment must be treated in a multidisciplinary approach, considering fully the human dimensions. This is a lesson for forthcoming similar situations in several other places in the world that will be submitted to the problem of rising waters.

But besides talks, what is the short term solution for the inhabitants of these pacific islands? What is proposed? Which countries or international organisms have reacted, to save these people?

The answer is sad and inacceptable: whereas the contribution of these populations to the greenhouse gas emission is zero, whereas their ecological footprint is zero (there is no car on these islands, no use of fossile fuels except for a small electric generator working few hours a month for a DVD player), no solution is proposed! Schematically, what is said to them is "leave your sinking islands if you don't want to die", but no real means for that are available.

Can we, if we pretend to be humans, leave these innocent populations alone facing the force of Ocean? Can we pretend now to ignore their situation?

The fate of the Carteret islands inhabitants, and soon the fate of the inhabitants of other low-lying islands (Tuvalu, Kirabati, Fiji, Vanuatu, the Cook Islands, Marshalls, etc) will prefigurate the fate that will be reserved to any one that will have to be confronted to ecological disasters: either there will be an international action to help them, or they will disappear either as humans or as groups.

Such an event, that can be named genocide, would be a shame for any human being on the surface of our small planet.

The 1951 International Convention on Refugees does not include people displaced by a changed climate, such as rising seas, expanding deserts and shrinking ice. In the neighbooring Australia, Senator Christine Milne of the Australian Greens tried to change this. She proposed a motion, that the government should use its influence in the U.N. in order that people displaced by consequences of global warming can be recognized as refugees. Both major parties voted against and Australia will not accept such refugees in its wide territory.

"Unless people can be relocated as a group we run the risk of people losing their languages and becoming socially, culturally and economically isolated, said representants of Carteret's islanders. If the convention could be expanded to recognize climate refugees, then resettlement could be done in a way that keeps language and culture together".

An estimation is given, that a 2 degrees rise in temperature could create at least 100 millions refugees by the end of the century. On the basis of scientific estimations, the Canadian environment Minister, David Anderson has warned that "if climate goes unchecked there could be 500 millions refugees created in one human lifetime".

Ignored by the other nations, the nations of these pacific islands have the feeling that they are victims of something that they are not responsible for. A lot of inhabitants of these islands claim they love their island and they are prepared to die there...

Why is the international community not more active with respect to this problem? This question merits interrogation. Does this innocent population, so full of kindness, not attract the international sympathy? Or is it because what is happening is the cruel result of a situation that was not yet recognized few years ago, namely the global warming?.. whose expected consequences are already happening, thus confirming scientific predictions? Is there a fear to panic our public opinions? Or is this because these populations are far away from the world decision centers?

Whatever the cause of the silence and of the lack of action, it is highly time to wake up and to act.

Human rights exist also for the inhabitants of Pacific islands!

Call for solidarity towards Carteret islanders

Pacific islanders need concrete solutions with respect to the cruel problem they are facing. All aspects of helps are needed: financial supports to provide them with food and medicaments, financial supports to allow them to relocate to other places.

As scientists, we have also the possibility to help them with expertizes and scientific studies of what is happening there.

Whereas some countries build completely artificial islands, larger than Carteret's islands, whereas other ones build dams in much more extended regions, why would the international community be unable to finance and organize backfilling and construction of dams for stopping the floods and making islands of Pacific inhabitable?

We call all scientists over the world, having a conscience, to join an action in favour of the inhabitants of these islands.

CONTACT: scientia.association@yahoo.fr

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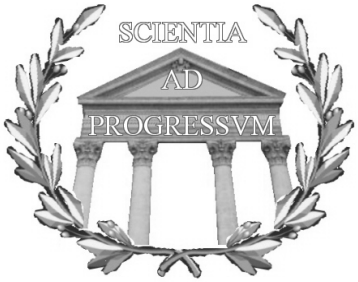

ПОДПИСКА-2008

Международный научный журнал
«Альтернативная энергетика и экология»

ISJAEE

Уважаемые коллеги! Продолжается подписка на второе полугодие 2008 г.

Наименование:
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«Альтернативная энергетика и экология»
Индекс издания: ISSN1608-8298
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http://isjaee.hydrogen.ru
Подписка: через редакцию или по каталогам: Роспечать, МК-Периодика, Интерпочта и др.

Уважаемые читатели!

Вы можете подписаться на Международный научный журнал «Альтернативная энергетика и экология» на 2008 год, заполнив извещение (форма ПД-4) и перечислив на счет НТЦ «ТАТА» сумму в соответствии с таблицами 1 и 2. Копию корешка извещения, пожалуйста, направьте по адресу:

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Извещение

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(*наименование платежа)

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**Внимание! В графе извещения «Наименование платежа» просьба указать Ф.И.О., почтовый адрес получателя, порядковый номер и год выпуска журнала(ов), например: Иванов И.И., 197198, Санкт-Петербург, пр. Добролюбова, 67–14, № 1–6 за 2004 г., или № 4 за 2002 г.*

Внимание!

Начиная с 31 марта 2007 года всем членам Редколлегии Международного научного журнала «Альтернативная энергетика и экология» предоставляется скидка на подписку:

– членам Редакционного научного комитета — 40% от базовой стоимости*;

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При осуществлении подписки сразу на весь год базовая стоимость годовой подписки равна удвоенной базовой стоимости на первое полугодие 2008 г. с дополнительной скидкой 5 %.

Заявка на подписку направляется в Редакцию журнала в произвольной форме по адресу: gusev@hydrogen.ru или по факсу: 8-83130-63107.

* При определении базовой стоимости подписки на первое полугодие 2008 г. необходимо руководствоваться Таблицей 1 или Таблицей 2 для различных категорий подписчиков.

Стоимость подписки для различных категорий подписчиков на первое полугодие 2008 года

Таблица 1

Россия

Категория	Стоимость, руб.
Аспиранты	3000
Пенсионеры	3300
Физические лица	4200
Фирмы-распространители	3900
Научные библиотеки организаций	4800
Научно-исследовательские организации	5600
Научно-производственные организации	6000
Российские научные центры	7200
Российские научные ассоциации	7800
Международные научные ассоциации	8700
Национальные и муниципальные научные библиотеки	9000

Таблица 2

Страны СНГ

Категория	Стоимость, руб.
Физические лица	4800
Фирмы-распространители	4200
Научные библиотеки организаций	5400
Научно-исследовательские организации	6000
Научно-производственные организации	6600
Национальные научные центры	7200
Национальные научные ассоциации	8100
Международные научные ассоциации	8400
Национальные и муниципальные научные библиотеки	9000

Информация о плательщике:

(Ф.И.О., адрес плательщика)

(ИНН налогоплательщика)

N

(номер лицевого счета (код) плательщика)

Информация о плательщике:

(Ф.И.О., адрес плательщика)

(ИНН налогоплательщика)

N

(номер лицевого счета (код) плательщика)

ВНИМАНИЕ! По этой квитанции Вы можете оплатить как годовую подписку, так и отдельные номера нашего журнала за 2002–2007 гг.

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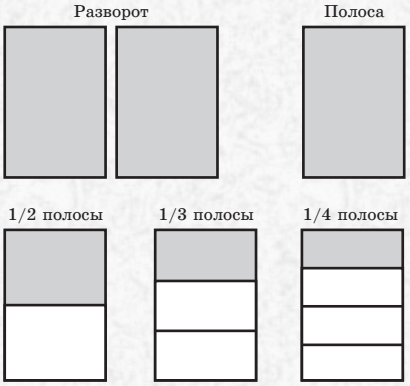
РЕКЛАМА В МЕЖДУНАРОДНОМ НАУЧНОМ ЖУРНАЛЕ «АЛЬТЕРНАТИВНАЯ ЭНЕРГЕТИКА И ЭКОЛОГИЯ»

Международный научный журнал «Альтернативная энергетика и экология» приглашает научные институты, организации и промышленные предприятия разместить информацию о конференциях, выставках, разрабатываемой и выпускаемой продукции в области альтернативной энергетики и экологии.

Площади рекламного модуля



Требования к макетам рекламных модулей, изготовленных заказчиком

Макет рекламного модуля должен иметь размер, соответствующий размеру печатного оттиска. Форматы макетов: растровый — TIFF (см. требования), векторный — Corel Draw (см. требования). Использование редактора Microsoft Word для проектирования макетов рекламных модулей не допускается.

Допускается предоставление макета модуля (кроме обложки) в формате Adobe Pagemaker версий 6.0, 6.5, 7.0. В этом случае должны предоставляться все связанные элементы, а также все используемые шрифты.

Требования к исходным рекламным материалам

Все элементы рекламного модуля (иллюстрации, логотипы, текст и др.) предоставляются в отдельных файлах.

1. Текст

Текст набирается гарнитурой Times New Roman, кегль 14, интервал полуторный. Допускается выделение важной информации полужирным начертанием. Формат Microsoft Word for Windows.

Использование OLE-объектов (графики, слайды презентаций, диаграммы в формате Microsoft Excel, результаты вычислений в математических и иных, в том числе собственных программах) в документах не допускается. Такие объекты присылаются в формате исходной программы и дублируются изображением (см. требования к иллюстрациям).

Использование дополнительных шрифтов (например, логотип выполнен специфической гарнитурой) оговаривается дополнительно. В этом случае предоставляется файл, содержащий начертание букв в формате TTF. Использование PS-шрифтов не допускается.

2. Иллюстрации

Все иллюстрации, находящиеся в рекламном модуле, должны предоставляться в отдельных файлах в форматах TIFF или BMP. Не допускается использование многослойных изображений. Черно-белые изображения должны быть в модели Grayscale. Цветные (обложка) — в модели CMYK. Все ч/б растровые изображения должны иметь разрешение 200 dpi, цветные — 250–400 dpi.

Для векторных изображений предпочтительным является использование формата Corel Draw (*.cdr) до версии 12.0 включительно.

Все встроенные эффекты (линзы, текстурные заливки, тени и т.д.) должны быть переведены в растровое изображение (bitmap). Векторные эффекты (Extrude, Envelope, Contour, Add Perspective, Blend, Distortion, Artistic media) должны быть преобразованы в кривые. Все текстовые объекты должны быть переведены в кривые. Размещение растровых рисунков в документе Corel Draw не допускается.

Стоимость размещения рекламных модулей

Объем рекламного модуля	Технические параметры	Цена публикации в одном номере (руб.)
Обложка (полноцветная)	285x205 мм	300 000
2-я или 3-я страницы обложки (полноцветная)	285x205 мм	50 000
Полный разворот на две полосы*	257x336 мм	25 000
Полная полоса 1/1*	257x168 мм	10 000
1/2 Полосы*	128x168 мм	7 500
1/3 Полосы*	85x168 мм	2 500
1/4 Полосы*	64x168 мм	2 000
СИСТЕМА СКИДОК		
При публикации в 2-3 номерах	10%	
При публикации в 4-6 номерах	15%	
При публикации в 7-9 номерах	20%	
При публикации в 10-12 номерах	50%	

Для заказа рекламной площади и получения счета необходимо заполнить форму заявки и отправить ее по адресу gusev@hydrogen.ru или по факсу (83130) 6-31-07.

Редакция журнала оставляет за собой право отбора поступивших рекламных объявлений.

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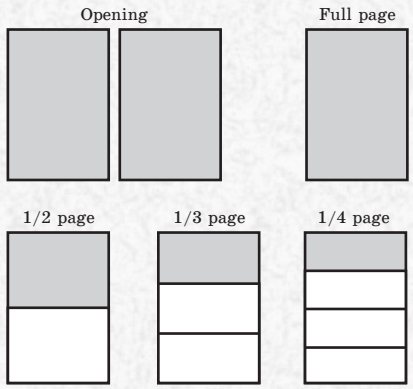
The International scientific journal "Alternative energy and economy" invites scientific institutes, organizations and industrial enterprises to place advertisements on conferences, exhibitions, designed and production products in the field of alternative energy and ecology.

Spaces for advertisement module



General information on lay-outs of advertisement modules fabricated by a customer

The lay-out of an advertisement module is to have the dimension in accordance with that of a print. Lay-out formats: raster — TIFF (see General information), vector — Corel Draw (see General information). The use of Microsoft Word editor to design lay-outs of advertisement modules is not allowed.

The module lay-out (except the cover) in the format of 6.0, 6.5, 7.0 Adobe Pagemaker versions is allowed to be provided. In this case, all combined elements, and also all available fonts that are not included in the Microsoft Windows structure are to be provided.

Information on original advertisements

All elements of the advertisement module (illustrations, symbols, text, etc.) have to be put in individual files.

1. Text

Text is has to be composed by Times New Roman types, font 14, print interval: one and a half. Important information can be printed in italics. Format — Microsoft Word for Windows.

OLE-objects (graphs, presentation slides, diagrams in Microsoft Excel format, results of computations in mathematical and others including own programmes) are not allowed in documents. The objects as such are required to be sent in original programme format, and are copied by illustrations (see General information on illustrations).

The use of additional fonts (for example, a symbol is given by a specific type) is additionally specified. In this case, a file containing letter design in TTF format. PS-fonts is not allowed.

2. Illustrations

All illustrations available in the advertisement module are to be displayed in TIFF or BMP formats. Multilayer displays are not allowed. Black-and white displays are to be used in Grayscale model. Coloured displays (cover) are in CMYK model. All black-and-white raster displays are to be of resolution of 200 dpi, colour — of 250–400 dpi.

The use of Corel Draw (*.cdr) format to 12 version inclusive is considered to be advantageous for vector display.

All incorporated effects (lenses, texture fillings, shadows, etc.) are to be converted to raster display (bitmap). Vector effects (Extrude, Envelope, Contour, Add Perspective, Blend, Distortion, Artistic media) are to be transformed to curves. All text objects are to be converted to curves. Raster figures are not allowed to be placed in Corel Draw document.

Advertisement space price

Advertisement module space	Technical parameters	Publication price in one issue ($US)
1st page of the cover (full-coloured)	160x145 мм	15000
Full opening in two pages	257x336 мм	2000
2nd or 3d pages of the cover (full-coloured)	257x168 мм	4000
Full page	128x168 мм	1000
1/2 page	85x168 мм	500
1/3 page	64x168 мм	150
1/4 page	64x168 мм	100
Price rebate		
When published in 2-3 issues	5%	
When published in 4-6 issues	7%	
When published in 7-9 issues	10%	
When published in 10-12 issues	15%	

To order an advertisement space and make up a bill, please fill in an order form and send it using the following address: gusev@hydrogen.ru or by fax +7 (83130) 6-31-07.

The editorial board reserves the right to choose advertisements entered.

ПЕРЕЧЕНЬ
НЕОБХОДИМЫХ МАТЕРИАЛОВ ДЛЯ ПУБЛИКАЦИИ В МЕЖДУНАРОДНОМ НАУЧНОМ ЖУРНАЛЕ «АЛЬТЕРНАТИВНАЯ ЭНЕРГЕТИКА И ЭКОЛОГИЯ»

Для своевременного выхода журнала и быстрой публикации работ авторы должны предоставлять в редакцию материалы по перечню, приведенному в таблице ниже. Авторы должны заполнить знаками (+) или (-) графы в столбце «Наличие»

№ п/п	Материал	Наличие
1	Твердая копия рукописи статьи	
2	Электронная версия рукописи статьи	
3	Название статьи на русском языке	
4	Название статьи на английском языке	
5	УДК (PACS)	
6	Автор(ы) статьи	
7	Координаты организаций авторов (включая телефоны и e-mail)	
8	Рисунки (фотографии, схемы)	
9	Подрисуночные подписи на русском языке	
10	Подрисуночные подписи на английском языке	
11	Таблицы	
12	Названия таблиц на русском языке	
13	Названия таблиц на английском языке	
14	Ссылки в тексте на таблицы и рисунки	
15	Список литературы (библиография)	
16	Библиографические ссылки в тексте в соответствии со списком литературы	
17	Структурированность текста, наличие подзаголовков	
18	Аннотация на русском языке	
19	Аннотация на английском языке	
20	Реферат на русском языке	
21	Реферат на английском языке	
22	Резюме на каждого автора (если авторов не более 6) или на главного автора*	
23	Фотография автора (авторов)*	
24	Разрешение на опубликование в открытой печати (экспертное заключение)	
25	Интернет-сообщение на русском языке*	
26	Интернет-сообщение на английском языке*	
27	Соглашение авторов на публикацию статьи в журнале	
28	Рецензии	
29	Сопроводительное письмо руководителя организации (или письмо автора)	
30	Акт проведенных испытаний (если в статье присутствует экспериментальная часть), подписанный участниками испытаний*	

* Материалы, предоставляемые по желанию

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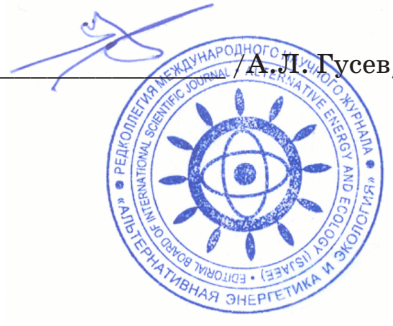

ЕЖЕМЕСЯЧНЫЙ РЕЦЕНЗИРУЕМЫЙ И РЕФЕРИРУЕМЫЙ МЕЖДУНАРОДНЫЙ НАУЧНЫЙ ЖУРНАЛ «АЛЬТЕРНАТИВНАЯ ЭНЕРГЕТИКА И ЭКОЛОГИЯ»

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Таблицы, рисунки, фотографии (желательно черно-белые) размещаются внутри текста и имеют сквозную нумерацию по статье (не по разделам!) и собственные заголовки. Буквенно-цифровая нумерация (1а, 2б) нежелательна. **Названия всех рисунков, фотографий и таблиц приводятся на русском и на английском языках!**

Нумерация обозначений на рисунках дается по порядку номеров по (против) часовой стрелки (для чертежей) или сверху вниз (снизу вверх). Файлы иллюстраций предоставляются в формате TIFF или BMP с разрешением не менее 300 dpi.

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Во избежание недоразумений и ошибок редакция рекомендует авторам использовать в формулах буквы латинского, греческого и других (не русских) алфавитов.

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Все литературные ссылки обозначаются порядковой цифрой в квадратных скобках (например, [3]). Литературным ссылкам присваивается порядковый номер по мере их упоминания в тексте.

Библиографические ссылки в списке литературы располагаются в той последовательности, в какой упоминаются в тексте, и оформляются по следующим правилам:

- **для книг**: фамилия и инициалы автора(-ов), название книги, место издания, издательство, год (для трудов конференций — город, страна, год). Например: Ландау Л. Д., Лившиц Е. М. Квантовая механика. М.: Наука, 1988. Или: Elton R. C. X-Ray Lasers. Boston: Academic Press, 1990;
- **для статей** в журнале, сборнике, газете: фамилия и инициалы автора(ов), название статьи, название журнала (сборника), год, том, номер (или номер выпуска), страницы. Например: Полякова А. Л., Васильев Б. М., Купенко И. Н. и др. Изменение зонной структуры полупроводников под давлением // Физика и техника полупроводников. 1976. Т. 9, № 11. С. 2356–2358. Или: Афанасьев А. М. Оптимизация распределения энерговыделения в реакторе с помощью «советов оператору» // Вопросы атомной науки и техники. Сер. Физика и техника ядерных реакторов. 1986. Вып. 2. С. 32–36. Или: Mezain I. H. Rolling circuit boards improves soldering // Electronics. 1977. Vol. 34, No. 16. P. 193–198;
- **для диссертаций и авторефератов диссертаций**: кроме фамилии автора и его инициалов следует указать название диссертации, степень, место защиты (город) и год; для препринтов — название, место издания, год, номер. Например: Горшкова Т. И. Термодинамические свойства и применение некоторых сплавов церия: Автореф. дис. … канд. хим. наук. М., 1976;
- **для патентной документации**: вид патентного документа (авторское свидетельство или патент), номер, название страны, выдавшей документ, индекс международной классификации изобретений, или индекс международной классификации промышленных образцов, или индекс международной классификации товаров и услуг, название патента (а. с.), авторы, название издания, опубликовавшего документ, год и номер издания. Например: А. с. 100970 СССР МКИ^3 В 251 15/00. Устройство для захвата неориентированных деталей типа валов / Ваулин В. С., КенайкинВ.Г. // Открытия. Изобретения. 1983. № 11.

При необходимости в заголовке библиографической ссылки на работу четырех и более авторов могут быть указаны имена всех авторов или первых трех с добавлением слов «и др.».

В списке литературы инициалы авторов должны стоять после фамилий.

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Для максимального ускорения процесса прохождения статьи автор должен направить в адрес главного редактора (e-mail: gusev@hydrogen.ru) обязательный пакет электронных файлов (см. ниже).

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Файлы обозначаются следующим образом (пример):

Article#1_Gusev AL_Hydrogen detectors_(1300).doc,

где: **Article** — рукопись, **#1** — обозначает номер рукописи, присвоенный автором (рукописей может быть несколько на электронном носителе), **Gusev AL** — фамилия первого автора и инициалы, **Hydrogen detectors** — первые два слова из названия рукописи, **(1300)** — номер тематического направления или тематической секции из Тематики журнала (приведена в конце каждого номера журнала).

1. Рукопись — Article#1_Gusev AL_Hydrogen detectors_(1300).doc
2. Аннотация — Summary#1_Gusev AL_Hydrogen detectors_(1300).doc
3. Реферат — Abstract#1_Gusev AL_Hydrogen detectors_(1300).doc
4. Резюме — Resume#1_Gusev AL_Hydrogen detectors_(1300).doc (резюме и фотографии на всех авторов в одном файле)
5. Фотографии и рисунки — Pic-1#1_Gusev AL_Hydrogen detectors_(1300).bmp (Pic-1 — номер рисунка)
6. Разрешение на опубликование в открытой печати — Sanction#1_Gusev AL_Hydrogen detectors_(1300).pdf
7. Интернет-сообщение — Internet#1_Gusev AL_Hydrogen detectors_(1300).doc
8. Соглашение — Agreement#1_Gusev AL_Hydrogen detectors_(1300).pdf
9. Форма передачи рукописи и материалов для публикации — Form#1_Gusev AL_Hydrogen detectors_(1300).doc (MANUSCRIPT TRANSMITTAL FORM)
10. Рецензии — Review-1#1_Gusev AL_Hydrogen detectors_(1300).doc (Review-1 — номер рецензии).
11. Сопроводительное письмо руководителя организации (или письмо автора, если автор — частное лицо) — Letter#1_Gusev AL_Hydrogen detectors_(1300).doc

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Вместе с электронной версией всех перечисленных документов необходимо направить в редакцию оригиналы всех документов обычной почтой заказным письмом.

Редколлегия обращает внимание авторов на то, что несоблюдение приведенных выше правил может задержать публикацию материала!

Отклоненные редколлегией рукописи (в бумажном и электронном виде) авторам не возвращаются.

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MONTHLY REVIEWED AND ABSTRACTED INTERNATIONAL SCIENTIFIC JOURNAL
"ALTERNATIVE ENERGY AND ECOLOGY"

GUIDE TOAUTHORS OF MANUSCRIPTS

To submit manuscripts to be published in the International Scientific Journal for Alternative Energy and Ecology, authors are to follow guides as follows

Each manuscript is compulsory reviewed by 3 referees, two of whom are referees of the International Scientific Journal for Alternative energy and Ecology, and 1 of those being invited by the Editorial Board. Each article is put through a preliminary and final reviewing. In the event of controversies on scientific problems occur, an article is submitted to the International Reviewers Board of the International Scientific Journal for Alternative energy and Ecology to be criticized. In the event of controversies on feasible implementation of the idea, presented in the manuscript the latter is submitted to the Experts Board of International Scientific Journal for Alternative energy and Ecology.

The publication period does not exceed 5 months. Assuming a letter of introduction from a member of the Editorial Board of the International Scientific Journal for Alternative energy and Ecology, the period for reviewing a manuscript may be kept down to 2 months. The publication period of manuscripts submitted to the competition organized by the Editorial Board does not exceed 4 months. The publication period for registered scientific reviews does not exceed 3 months.

In the event of pressing need for publication, the author or a team of authors may address the Editorial Board to make a justified request to publish a manuscript in the course of 3 months.

The Editorial Board will promptly and without any interest assist all post-graduates and competitors in publishing their materials in the journal and in the International Scientific Information System "Hydrogen" in the shortest possible time. All publications in the journal are issued free of charge.

In any event, all manuscripts submitted to the journal are criticized and abstracted in popular international scientific journals.

Articles are published in Russian and English. Each communication submitted to the Editorial Board is assigned a number and date.

The journal publishes nothing but original articles. The author is responsible for following this guide.

I. For publishing the journal in due time, please follow the guide given below:

1. Manuscript must be submitted either in a typed form or in e-mail: The hard copy of the manuscript must be submitted in 2 copies, the authors must necessarily sign the second copy overleaf.

Manuscripts words:

- brief communications are up to 5 pages (1800 symbols);
- articles, as a rule, are up to 9 pages;
- letters to the Editorial Board are up to 3 pages;
- scientific reviews should not in general be longer than 30 pages.

2. Manuscripts should be accompanied by:

- a letter of the head of the institution who presents the manuscript with the experts' opinion or other document permitting the publication in the press (1 copy) confirmed and affixed by the head of the institution. Authors must present the experts' permission from Russia.
- a CD-disk or diskette containing the essential text of electronic files listed in **Section III.**

3. Abstract text in Russian and English should be typed in normal font Times New Roman in one file as follows: article title, authors, name of an organization, abstract in Russian, and then in 2 lines in the same sequence — in English. The abstract should be given in indicative, and is up to 600 symbols in length. The abstract is also published on site of the International Scientific Information Portal "Hydrogen" (in Russian, and English).

4. The abstract text (15 lines) in Russian and English is printed in font Times New Roman (font size 10) and shall contain the place of organization, title, education, scientific degree, rewards and scientific prizes, experience, main range of scientific interests, number of publications.

5. Authors' photos in TIFF or JPEG format to be published in abstract text.

6. Compact text (one page) to be published in Compact journals (CJ) VINITI, «Letters to the "Alternative energy and ecology"» (in English).

Page format:

- format A4 (210×297 mm)
- print interval: one and a half
- font: Times New Roman (font size 12) in one file as follows: article title, authors, name of an institution, abstract in Russian, and then in 2 lines in the same sequence — in English

7. Internet information for announcing an express-information on sites of the International Scientific Information Portal "Hydrogen", and also on sites of the information network devoted to energy and ecology. Information is given in an arbitrary way:

- format A4 (210×297 mm)
- print interval: one and a half
- font: Times New Roman (font size 12)

The information may include photos and diagrams.

II. Information on manuscript writing

- the Editorial Board recommends authors writing reviews and articles organize their materials using subtitles (for example: "Introduction", "Theoretical Analysis", "Experimental Methods", "Results And Discussion", "Conclusion", "References");
- text for publication must be reviewed carefully by authors; no replica, and one does not need to describe the illustrations in detail;
- text must be typed on white paper:
- format A4 (210×297 mm)
- print interval: one and a half
- font: Times New Roman (font size 12)

A manuscript may contain photos and diagrams.

Text section sequence:

- **universal decimal classification (UDC or PACS);**
- **paper title in Russian and English** (capital letters, font size 14, bold, center-alignment. No division of words is allowed. Do not use quotation marks. Do not use underlining;
- **authors** (initials, surname, font size 14, italic bold, center-alignment, no period in the end);
- **name of organization, address, city, country, postcode, telephone, fax, e-mail** (font size 12, center-alignment. If the authors are from different organizations, the method of superscript references shall be used; for example: A. V. Ivanov, Yu. S. Sedov*);
- **section title** (font size 14, center-alignment, no period in the end);
- **text of the article:** (font size 12, left justification — 1 cm);
- **subtitle:** (italic, font size 14, full justification);
- **references:** (font normal, size 14, full justification).

When drawing up the article one should use generally accepted terms, units and symbols. All designations being used by the authors shall be determined at their first appearance in the text.

When the article is typed on the computer, all Latin designations of physical quantities (*A, I, d, h,* etc.) shall be typed in italic, Greek designations, names of functions (β, sin, exp, lim), chemical elements (H_2O) and units (MW/cm^2) — in upright (normal) font. The symbols (ℜ, ℘, ⊗, ∈, etc.) shall be specified in the manuscript margin.

Tables, figures, photos (black-and-white only) shall be placed inside the text and be consecutive over the article and have own titles. Notation numbering in figures shall be given clockwise

(counter-clockwise) (for drawings) or from top to bottom (from bottom to top) (in numerical order). No figure or diagram plotting by Microsoft Word tools **is allowed.** All figures legends shall be given in Russian and English.

Formulae shall be constructed by means of the integrated formula editor (Math Type, Microsoft Equation) and numbered in parentheses (2), centre-aligned; notation (letters) deciphering in formulae is given as they are mentioned therein. References numbering shall be given in square brackets [3].

If is not allowed to denote different notions by a common letter. Indexes for literal signs in the article text are given in Lation or Russian only (for example, in a Russian-written paper ane should use T_m — melting point).

References in the reference list shall be placed in the sequence with which they are mentioned in the text and shall be written according to the following rules:

▪ **for books:** surname and initials of the author(s), title of the book, then the place of publication, publishing house, year (for proceedings of conferences — city, country, year). For example: Landau L. D., Lifshits E. M. Quantum Mechanics. Moscow, "Nauka", 1988. Or: Elton R. C. X-Ray Lasers. Boston: Academic Press, 1990;

▪ **for articles** in a journal, collection, newspaper: initials of the author(s), title of the article, name of the journal (collection), year, volume, No. (or Issue No.), pages. For example: Polyakova A. L., Vassiliev B. M., Kupenko I. N. et al. Variation of the zone structure of semiconductors under pressure // Semiconductor Physics and Technology. 1976. Vol. 9, No. 11. P. 2356–2358. Or: Afanasiev A. M., Optimization of energy release distribution in a reactor by means of "advices of operator" // J. of Nuclear Science and Technology. Physics and Nuclear Reactor Engineering Series. 1986. No. 25. P. 32–36. Or: Mezain I. H. Rolling circuit boards improves soldering // Electronics. 1977. Vol. 34, No. 16. P.193–198;

▪ **for dissertations and dissertation abstracts,** besides the author's surname and initials, one shall indicate the title of the dissertation, degree, place of defence (city) and year, and for preprints — title of the preprint, place of publication, year and number. For example: Gorshkova T. I. Thermodynamic properties and application of certain cerium alloys: Dissertation Abstract. ... Candidate of Chemical Science. Moscow, 1976;

▪ **for patent documentation:** type of the patent document (Authors's certificate or Patent), its number, name of the country issuing the document, index of the international classification of inventions, name of publication where the subject of invention was published, year and number of publication. For example: Author's Certificate 100970 USSR Inc^3 V 251 15/00. Adevice for gripping non-oriented shaft-type parts/Vaulin V. S., Kenaikin B. G. // Discoveries. Inventions. 1983. No. 11.

If the title of a bibliographic reference is to contain four and more authors, all the names can be indicated or only three first names shall be indicated plus the words "et al." The initials in the reference list shall be placed after surnames.

III. Guides to authors presenting e-mail version of materials for express-publication

To foster the process of reviewing the article the author should submit a **required packet of electronic files** to the Editor-in-Chief (e-mail: gusev@hydrogen.ru).

List of required electronic files:

A files is described as follows (example):

Article#1_Gusev AL_Hydrogen detectors_(1300).doc,

where: **Article** is the manuscript, **#1** is the number of the manuscript given by the author (there may be several manuscripts on one electronic file), **Gusev AL** is the name of the first author, **Hydrogen detectors** are first two words from the title of the manuscript, **(1300)** is the number of the topics or topics section in the Journal topics (given in the last page of the journal).

1. **Article** — Article#1_Gusev AL_Hydrogen detectors_(1300).doc
2. **Summary** — Summary#1_Gusev AL_Hydrogen detectors_(1300).doc
3. **Abstract** — Abstract#1_Gusev AL_Hydrogen detectors_(1300).doc
4. **Resume** — Resume#1_Gusev AL_Hydrogen detectors_(1300).doc (resumes and photos of all authors in one file)
5. **Photos and figures** — Fig-1#1_Gusev AL_Hydrogen detectors_(1300).bmp (Fig-1 — number of figure)
6. **Internet information** — Internet#1_Gusev AL_Hydrogen detectors_(1300).doc
8. **Agreement** — Agreement#1_Gusev AL_Hydrogen detectors_(1300).pdf
9. Form to submit manuscripts and materials to be published — Form#1_Gusev AL_Hydrogen detectors_(1300).doc (MANUSCRIPT TRANSMITTAL FORM)
10. **Reviews** — Review-1#1_Gusev AL_Hydrogen detectors_(1300).doc (Review-1 — number of review).
11. **Official letter (or author letter if author is the individual person)** — Letter#1_Gusev AL_Hydrogen detectors_(1300).doc

Attention!

The Editorial Board calls the authors' attention to the fact that the ignorance of the recommendations mentioned above may impede the publication of the material!

Manuscripts (in hard copy and e-mail form) declined by the Editorial Board will not be returned.

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1-2-2-0 Системы обдува инертными газами

1-2-3-0 Безопасность криогенных систем

1-2-4-0 Технологии безопасного использования водорода на борту транспортных средств

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1-4-3-2 В газообразном состоянии в баллонах

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1-4-6-0 В твердофазном связанном состоянии в металлогидридных системах
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1-4-7-0 В адсорбированном состоянии на криоадсорбентах

1-4-8-0 В комбинированных системах

1-4-9-0 Новые способы хранения водорода

1-5-0-0 Методы получения водорода
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В. В. Лунин, *акад.РАН (Россия, Москва, МГУ) (РНС)*

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1-5-2-0 Электролиз

1-5-3-0 Термохимическое разложение воды

1-5-4-0 Разложение аммиака
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1-5-5-0 Каталитическая конверсия (риформинг) газообразных и жидких углеводородов

1-5-6-0 Неполное окисление углеводородов

1-5-7-0 Высокотемпературный метод

1-5-8-0 Гидраты
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1-5-9-0 Бортовые конверторные устройства преобразования органических веществ в водород

1-5-10-0 Генерирование водорода на борту в реакции взаимодействия воды с различными металлами (алюминий, магний и т.д.)

1-5-10-1 Механические и электрические способы удаления окисной пленки во время реакции

1-5-10-2 Химические способы удаления окисной пленки во время реакции

1-5-10-3 Ультразвуковые способы удаления окисной пленки во время реакции

1-5-10-4 Способы увеличения удельной поверхности металлов реагентов

1-5-10-5 Термические и барические методы интенсификации реакции генерации водорода

1-5-10-6 Устройства для генерации водорода в реакции взаимодействия воды и металлов для бортового применения

1-5-10-7 Устройства для генерации водорода в реакции взаимодействия воды и металлов для бытового применения

1-5-10-8 Устройства для генерации водорода в реакции взаимодействия воды и металлов для промышленной энергетики

1-5-10-9 Физико-математические модели описания процессов генерации водорода

1-5-10-10 Перспективные направления развития метода для воплощения его на борту транспортных средств

1-5-11-0 Получение водорода из глубинного морского сероводорода
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1-6-1-0 Транспортирование жидких криогенных продуктов по трубопроводам
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1-6-2-0 Охлаждение магистралей криогенных систем

1-6-3-0 Неустановившиеся процессы в криогенных системах

1-7-0-0 Топливные элементы
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В.П. Пахомов *(Россия, Москва, РНЦ «Курчатовский институт») (МРК)*

1-7-1-0 Разработка и производство топливных элементов
1-7-1-1 Мембраны для топливных элементов
1-7-1-2 Компьютерное моделирование функционирования топливных элементов
1-7-2-0 Применение топливных элементов
1-7-2-1 Устройства питания на топливных элементах с конверсией метанола в водород
1-7-3-0 Топливные элементы с предварительной обработкой водородсодержащего топлива
1-8-0-0 Конструкционные материалы
П. Г. Бережко *(Россия, Саров, РФЯЦ-ВНИИЭФ) (МРК)*
А. М. Полянский *(Россия, С.-Петербург, ООО «НПК Электронные пучковые технологии») (МРК)*
В. М. Чертов *(Россия, Москва) (МРК)*
Ю. Н. Шалимов *(Россия, Воронеж, ВГТУ) (МРК)*
П.Сан-Грегуар (*Франция, Тулон-Вар, Университет Тулон-Вара) (ЗГР)*
А. Т. Пономаренко *(Россия, Москва, Институт синтетических полимерных материалов им.Н.С.Ениколопова РАН) (МНКСР)*
Л. В. Спивак *(Россия, Пермь, ПГУ) (МНКСР)*
А. А. Курдюмов *(Россия, С.-Петербург, СПбГУ) (МНКСР)*
М. В. Гольцова *(Украина, Донецк, ДонНТУ) (МНКСР)*
Я. И. Бляшко *(Россия, С.-Петербург, АОЗТ «МНТО ИНСЭТ») (МРК)*
Н. М. Власов *(Россия, Подольск, НИИ НПО «Луч») (МРК)*
И. И. Федик *(Россия, Подольск, НИИ НПО «Луч») (МРК)*
1-8-1-0 Водород в металлах и сплавах
В. А. Гольцов *(Украина, Донецк, ДонНТУ) (МРК)*
Л. Ф. Гольцова *(Украина, Донецк, ДонНТУ) (МРК)*
1-8-2-0 Водородная деградация
1-8-3-0 Системы наводороживания конструкционных материалов
1-8-4-0 Статическая и динамическая прочность материалов
Н. Н. Гердюков *(Россия, Саров, ИФВ РФЯЦ-ВНИИЭФ) (МРК)*
1-8-5-0 Газары. Применение газаров
1-8-6-0 Электропечи для термовакуумных процессов. Вакуумные электропечи сопротивления
Э. Н. Мармер *(Россия, Москва, ОАО «ВНИИЭТО») (МРК)*
1-8-7-0 Новые конструкционные материалы для объектов альтернативной энергетики
1-9-0-0 Методы получения синтез-газа
А. Я. Столяревский *(Россия, Москва, РНЦ «Курчатовский институт») (МРК)*
1-9-1-0 Адиабатическая конверсия природного газа
1-10-0-0 Транспортные средства и приводы на водородном топливе
Т. Гертиг *(Германия, Берлин) (МРК)*
А. Л. Дмитриев *(Россия, С.-Петербург, РНЦ «Прикладная химия») (МРК)*
А. М. Домашенко *(Россия, Балашиха, ОАО «Криогенмаш») (МРК)*
Б. А. Соколов *(Россия, Королев, РКК «Энергия» им.С.П.Королева) (МРК)*
А. Ю. Раменский *(Россия, Москва, «Аудит-Премьер») (МНКСР)*
В. С. Соколов *(Россия, С.-Петербург) (МНКСР)*
1-11-0-0 Водородные автозаправочные станции
1-12-0-0 Водород для энергообеспечения зданий (водородные миниэлектростанции на базе топливных элементов)

2. Термодинамический анализ в альтернативной энергетике

В. А. Хуснутдинов *(Россия, Москва, РАО «ЕЭС России») (МРК)*
2-1-0-0 Термодинамический анализ основных энергетических процессов в альтернативной энергетике
2-2-0-0 Эксергетический анализ основных энергетических процессов в альтернативной энергетике

3. Атомная энергетика

Ю.А.Трутнев*, акад. РАН (Россия, Саров, РФЯЦ-ВНИИЭФ) (ПГР)*
А. Я. Столяревский *(Россия, Москва, РНЦ «Курчатовский институт») (МРК)*
А. В. Ивкин *(Россия, Саров, РФЯЦ-ВНИИЭФ) (МНКСР)*
А. Г. Чудин *(Россия, Москва, Федеральное Агентство по атомной энергии РФ) (МНКСР)*
В.А.Афанасьев *(Россия, Саров, РФЯЦ-ВНИИЭФ) (МРК)*
М.А.Прелас *(США, ш.Коламбия, Университет Миссури) (МРК)*
3-1-0-0 Атомно-водородная энергетика
Н. Н. Пономарев-Степной*, акад. РАН (Россия, Москва, РНЦ «Курчатовский институт») (РНС)*
А. Я. Столяревский *(Россия, Москва, РНЦ «Курчатовский институт») (МРК)*
В. Н. Фатеев *(Россия, Москва, РНЦ «Курчатовский институт») (МРК)*
А.Л.Гусев *(Россия, Саров, НТЦ «ТАТА»)*
3-1-1-0 История атомно-водородной энергетики
Н. Н. Пономарев-Степной*, акад. РАН (Россия, Москва, РНЦ «Курчатовский институт») (РНС)*
А.Я.Столяревский *(Россия, Москва, РНЦ «Курчатовский институт») (МРК)*
А.Л.Гусев *(Россия, Саров, НТЦ «ТАТА»)*
3-1-2-0 Высокотемпературные газовые реакторы (ВТГР) для производства водорода высокотемпературными (Т = 1000 °С) методами
3-1-3-0 Быстрые реакторы с натриевым охлаждением (БН) для получения среднетемпературного тепла (Т = 500 °С), производства синтетического газа и водорода
3-1-4-0 Быстрые реакторы со свинцовым охлаждением (БРЕСТ) как реакторы следующего поколения для получения высокотемпературного тепла (Т > 500 °С)
Г. Л. Хорасанов *(Россия, Обнинск, ФГУП «ГНЦ РФ – Физико-энергетический институт им. А. И. Лейпунского») (МРК)*
3-2-0-0 Атомная энергетика для транспортных средств
М. А. Казарян *(Россия, Москва, ФИАН им. П. Н. Лебедева) (МРК)*
И. В. Шаманин *(Россия, Томск, Томский политехнический университет) (МРК)*
3-2-1-0 Радионуклидные источники тепла
3-2-2-0 Радионуклидные термоэлектрические генераторы
3-2-3-0 Термо- и радиационно-стимулированные фазовые превращения в сплавах внедрения (карбидах, нитридах, нитридогидридах, карбогидридах и гидридах переходных металлов, высокотемпературных сверхпроводящих материалах, интерметаллических соединениях)

4. Солнечная энергетика

А. Штейнфелд *(Швейцария, Цюрих, Швейцарский федеральный институт технологий) (МРК)*
Г.И.Исаков *(Азербайджан, Баку, Институт физики НАН) (ЗГР)*
И. Г. Хидиров *(Узбекистан, Ташкент, Институт ядерной физики НАН Узбекистана) (МРК)*
С. Геруни *(Армения, Ереван, Ереванский государственный университет) (МНКСР)*
С. М. Раза *(Пакистан, Кветта, Университет Белуджистана) (МРК)*
С. З. Ильяс *(Пакистан, Кветта, Университет Белуджистана) (МРК)*
А. М. Пенджиев *(Туркменистан, Ашхабат-32, Туркменский политехнический институт) (МРК)*
В. Ф. Гременок *(Белоруссия, Минск, Объединенный институт физики твердого тела и полупроводников) (МНКСР)*
4-1-0-0 История солнечной энергетики
4-2-0-0 Солнечно-водородная энергетика
4-2-1-0 Материалы для солнечно-водородной энергетики
4-3-0-0 Солнечные электростанции
4-3-1-0 Кремниевые солнечные электростанции
4-3-2-0 Космические солнечные станции
4-3-3-0 Фотоэлементы
4-3-4-0 Фотовольтаический эффект в полупроводниковых структурах. Фотоэлектрические модули
4-4-0-0 Наземные солнечные станции
4-4-1-0 Солнечные коллекторы
4-5-0-0 Солнечные города
4-5-1-0 Солнечный дом
4-5-2-0 Солнечные холодильные установки
4-5-3-0 Солнечные водоподъемные системы
4-5-4-0 Гелиоэнергетические установки
4-6-0-0 Солнечный транспорт
4-7-0-0 Концентраторы солнечного излучения

5. Ветроэнергетика

И. З. Богуславский *(Россия, Москва, ОЭЭП РАН) (МРК)*
5-1-0-0 История ветроэнергетики
5-2-0-0 Ветро-водородная энергетика

5-3-0-0 Электрогенераторы для ветроэнергетики
5-4-0-0 Ветроэнергетические установки
5-5-0-0 Ветрогелиоэнергетические установки

6. Приливная энергетика и энергетика морских течений

6-1-0-0 История приливной энергетики
6-2-0-0 Энергетика морских волн
6-3-0-0 Энергетика морских течений

7. Геотермальная энергетика

7-1-0-0 История геотермальной энергетики
7-2-0-0 Фундаментальные исследования в области геотермальной энергетики
7-3-0-0 Проблемы освоения геотермальной энергии
7-4-0-0 Роль моделирования и мониторинга при освоении геотермальной энергии. Оценка геотермального резерва
7-5-0-0 Геотермальные станции
  7-5-1-0 Геотермальные электростанции
  7-5-2-0 Геотермальные тепловые станции
7-6-0-0 Эффективность и надежность геотермальных тепловых и электрических станций
7-7-0-0 Геотермальные ресурсы стран мира и перспективы их освоения

8. Взрывная энергетика

В. Е. Фортов, *акад. РАН (Россия, Москва, Институт теплофизики экстремальных состояний Объединенного института высоких температур РАН) (РНС)*
А. Л. Михайлов *(Россия, Саров, ИФВ РФЯЦ ВНИИЭФ) (МРК)*
Н. Н. Гердюков *(Россия, Саров, ИФВ РФЯЦ-ВНИИЭФ) (МРК)*
А. А. Штерцер *(Россия, Новосибирск, ООО «НПП "МАТЕМ"») (МРК)*
В. Н. Герман *(Россия, Саров, ИФВ РФЯЦ-ВНИИЭФ) (МРК)*
8-1-0-0 Взрывные технологии
8-2-0-0 Компьютерное моделирование задач взрывной энергетики
  8-2-1-0 Постановки задач взрывной энергетики
  8-2-2-0 Подвижные лагранжево-эйлеровы сетки
8-3-0-0 Взрывная дейтериевая энергетика
8-4-0-0 Взрывная энергетика для синтеза новых веществ
  8-4-1-0 Синтез и спекание материалов взрывом
  8-4-2-0 Ударно-волновое спекание материалов
  8-4-3-0 Компьютерное моделирование процессов ударно-волнового спекания материалов
8-5-0-0 Взрывчатые вещества
8-6-0-0 Взрывные камеры
А. А. Штерцер *(Россия, Новосибирск, ООО «НПП "МАТЕМ"») (МРК)*
8-7-0-0 Экстремальные состояния вещества. Детонация. Ударные волны
8-8-0-0 Энергетические материалы и физика детонации
8-9-0-0 Уравнения состояния и фазовые переходы

9. Энергия биомассы

9-1-0-0 Биогазовые установки
9-2-0-0 Термохимические газогенераторы

10. Малые и микрогидроэлектростанции

С. Шатворян *(Армения, Ереван, Энергетический стратегический центр) (МНКСР)*
10-1-0-0 Оборудование малых и микрогидроэлектростанций
10-2-0-0 Деривационные микрогидроэлектростанции

11. Углеродные наноструктуры

А.М.Липанов, *акад. РАН (Россия, Ижевск, Институт прикладной механики УрО РАН) (МРК)*
Ю. М. Шульга *(Россия, Черноголовка, ИПХФ РАН) (МРК)*
В. И. Кодолов *(Россия, Ижевск, Научно-образовательный центр химической физики и мезоскопии УдНЦ УрО РАН) (МНКСР)*
Ю. С. Нечаев *(Россия, Москва, ФГУП «ГНЦ РФ – Центральный институт черной металлургии им.И.П.Бардина») (МНКСР)*
Б. П. Тарасов *(Россия, Черноголовка, ИПХФ РАН) (МНКСР)*
Ю.Д.Третьяков, *акад.РАН (Россия, Москва, ФНМ МГУ) (РНС)*
11-1-0-0 Наносистемы: синтез, свойства, применение
Е. А. Гудилин *(Россия, Москва, ФНМ МГУ) (РНС)*
11-2-0-0 Фуллереновые структуры и углеродные наноматериалы для теплоизоляции
11-3-0-0 Фуллереновые структуры и углеродные наноматериалы для сенсоров водорода
М. В. Воробьева *(Россия, Москва, ГИРЕДМЕТ) (МРК)*
В.М.Арутюнян, *акад.НАН Армении (Армения, Ереван, Ереванский государственный университет) (РНС)*
11-4-0-0 Компьютерное моделирование синтеза углеродных наноматериалов с заданными свойствами
11-5-0-0 Углеродные наноструктуры для автотранспорта

12. Катализ

З. Р. Исмагилов *(Россия, Новосибирск, Институт катализа им. Г. К. Борескова СО РАН) (МРК)*
С.М. Алдошин, *акад.РАН (Россия, ИПХФ РАН, Черноголовка, Россия) (РНС)*
В.Н.Пармон, *акад. РАН (Россия, Новосибирск, Институт катализа им.Г.К.Борескова СО РАН) (РНС)*
В. А. Кириллов *(Россия, Новосибирск, Институт катализа им. Г. К. Борескова СО РАН) (МРК)*
О. Н. Ефимов *(Россия, Черноголовка, ИПХФ РАН) (МРК)*
12-1-0-0 Каталитические методы синтеза альтернативного топлива
12-2-0-0 Катализ в совмещенных схемах «производство энергии и получение полезных продуктов из природного газа»
12-3-0-0 Катализ в генерации рабочего тела в газотурбинных установках
12-4-0-0 Катализ в топливных элементах
12-5-0-0 Катализ в процессах получения синтез-газов и водорода
12-6-0-0 Каталитические методы очистки водорода
12-7-0-0 Катализ в очистке промышленных газовых выбросов энергетических систем
12-8-0-0 Катализ в системах очистки технических вод
12-9-0-0 Фотокаталитические и электрокаталитические методы получения водорода
12-10-0-0 Разработка и исследование свойств материалов для формирования каталитических слоев в топливных элементах
12-11-0-0 О механизмах каталитического действия. Влияние природы металлов и степени их окисления на каталитическую активность
12-12-0-0 Нанокомпозиты для применения в качестве катализаторов. Влияние размерного фактора на каталитическую активность
12-13-0-0 Альтернативные катализаторы без применения платины
12-14-0-0 Проблемы отравления катализаторов
12-15-0-0 Носители катализаторов: дизайн, синтез, свойства
12-16-0-0 Каталитические слои для топливных элементов в планарном исполнении
12-17-0-0 Золь-гель метод для получения катализаторов и носителей катализаторов

13. Термоградиентная энергетика

В. А. Хуснутдинов *(Россия, Москва, РАО «ЕЭС России») (МРК)*

14. Ледниковая энергетика

14-1-0-0 Применение льда в энергетике. Ледяные электростанции
14-2-0-0 Использование холода вечной мерзлоты для термостатирования бытовых и технических объектов

14-3-0-0 Физико-химические свойства льда
14-4-0-0 Теплофизические свойства льда
14-5-0-0 Термодинамические основы получения и применения льда
14-6-0-0 Оборудование для исследования льда
14-7-0-0 Установки для получения льда
14-8-0-0 Способы и механизмы экстренного вскрытия льда для спасения под водой
14-9-0-0 Бинарный лед и его применение
А.Л.Гусев (Россия, Саров, НТЦ «ТАТА»)
14-10-0-0 Применение льда для создания инженерно-технических и архитектурных сооружений
14-11-0-0 Динамика и прочность льда. Динамика хрупкого разрушения. Экспериментальные методы динамической механики разрушения льда
14-12-0-0 Численные и смешанные численно-экспериментальные методы динамической механики разрушения льда
14-13-0-0 Способы удаления ледяных покрытий на водных объектах
14-14-0-0 Аккумулирование холода и применение энергии льда
14-15-0-0 Транспортировка айсбергов и получение пресной воды

15. Термоядерная энергетика

***В. Н. Лобанов** (Россия, Саров, РФЯЦ-ВНИИЭФ) (МРК)*
15-1-0-0 Исследования в области управляемого термоядерного синтеза
15-2-0-0 Рентгеновский термоядерный синтез
15-3-0-0 Пучковый термоядерный синтез
15-4-0-0 Инерциальный термоядерный синтез
15-5-0-0 Изотопный эффект
15-6-0-0 Криогенные тритиевые мишени
15-7-0-0 Мишени высокого давления для исследования процессов мюонного катализа ядерных реакций синтеза
15-8-0-0 Международный проект термоядерного энергетического реактора ИТЭР
15-9-0-0 Радиологическая защита и ядерная безопасность
15-10-0-0 Производство радиоизотопов и их применение
***М. А. Казарян** (Россия, Москва, ФИАН им. Лебедева) (МРК)*
15-11-0-0 Топливный цикл и экология
15-12-0-0 Проектирование, строительство и эксплуатация ядерных исследовательских и энергетических реакторов
15-13-0-0 Промышленное производство компонентов и материалов, необходимых для использования в ядерных реакторах и их топливных циклах
15-14-0-0 Снятие с эксплуатации, дезактивация и обращение с отходами энергетических реакторов
15-15-0-0 Исследования в области технологии производства лазеров и их применения
15-16-0-0 Системы ТОКАМАК
15-17-0-0 Промежуточные системы с магнитным удержанием

16. Криогенные и пневматические транспортные средства

***А.Л.Гусев** (Россия, Саров, НТЦ «ТАТА»)*
16-1-0-0 Криогенный азотный транспорт
16-2-0-0 Автомобили на инертных газах для опасных объектов (пожарные, служебные аэропортов, складов горючесмазочных материалов, для взрывоопасных химических производств и др.)
16-3-0-0 Пневматические транспортные средства

17. Основные проблемы энергетики и альтернативной энергетики

17-1-0-0 Аккумулирование электрической энергии
17-2-0-0 Сверхпроводящие материалы. Сверхпроводимость. Сверхпроводимость в энергетике
17-3-0-0 Новые циклы и схемы термотрансформаторов
17-4-0-0 Проблемы освещения мегаполисов

18. Применение гелия и специальных материалов в транспортных средствах

***Ю.А.Рыжов,** акад.РАН (Россия, Москва, Международный инженерный университет) (РНС)*
18-1-0-0 Дирижабли для перевозки крупногабаритных грузов
18-2-0-0 Дирижабли для контроля за чрезвычайными ситуациями в мегаполисах: автоинспекция, пожарная безопасность, антитерроризм, наблюдение за техническим и экологическим состоянием промышленных зданий и сооружений. Энергонадзор (контроль тепловых утечек зданий в масштабе города)
18-3-0-0 Пожарные, нейтрализационные, полицейские дирижабли

19. Ювенильный водород в процессах геотектоники и геохимии

***С.В.Дигонский** (Россия, Екатеринбург, ФГУП «Урангеологоразведка») (МРК)*
***В.Л.Сывороткин** (Россия, Москва, МГУ им. М. В. Ломоносова)(МРК)*
19-1-0-0 Роль водорода в химическом строении мироздания
19-2-0-0 Движущие силы развития Земли и планет
19-3-0-0 Водород в ядре Земли
19-4-0-0 Геология и геохимия природных газов зон глубинных разломов
19-5-0-0 Транспорт ювенильного водорода через толщу Земли и формирование электрозаряженных зон
19-6-0-0 Природный синтез углеродистых веществ
19-7-0-0 Глубинная дегазация Земли, глобальные катастрофы и аномальные явления

20. Бортовые аккумуляторы энергии

20-1-0-0 Тепловые аккумуляторы энергии
А.Л.Гусев (Россия, Саров, НТЦ «ТАТА»)
- 20-1-1-0 Температура выше 273 К
- 20-1-2-0 Температура ниже 273 К
- 20-1-3-0 Температура ниже 77 К

20-2-0-0 Маховичные аккумуляторы энергии
20-3-0-0 Электрические аккумуляторы энергии
20-4-0-0 Пружинные аккумуляторы энергии
20-5-0-0 Пневматические аккумуляторы энергии
20-6-0-0 Химические аккумуляторы энергии

21. Законодательная база

***П. Б. Шелищ** (Россия, Москва, Государственная Дума РФ, президент НАВЭ) (МНКСР)*
21-1-0-0 Законодательная база альтернативной энергетики в России
21-2-0-0 Законодательное обеспечение инновационного развития водородной энергетики
21-3-0-0 Законодательная база альтернативной энергетики стран СНГ
21-4-0-0 Законодательная база экологии

22. Экономические аспекты

22-1-0-0 Инвестиционная привлекательность различных стран мира и фирм
22-2-0-0 Запасы традиционных энергоресурсов стран экспортеров и мировые запасы
22-3-0-0 Государственные научно-технические программы развития водородной энергетики
22-4-0-0 Экономический анализ
***В. А. Хуснутдинов** (Россия, Москва, РАО «ЕЭС России») (МРК)*
22-5-0-0 Бизнес-планирование

23. Энергетика и экология

О. Л. Фиговский *(Израиль, Мигдал Ха'Емек, Израильский исследовательский центр «Polymate») (МРК)*
М. В. Воробьева *(Россия, Москва, ГИРЕДМЕТ) (МРК)*
23-1-0-0 Парниковый эффект
23-2-0-0 Экологические проблемы мегаполисов
23-3-0-0 Экология воздушной среды и космического пространства
23-4-0-0 Экология водных ресурсов
23-5-0-0 Проблемы вредных выбросов в атмосферу тепловыми электрическими станциями
23-6-0-0 Проблемы загрязнения почвы традиционными энергоносителями
23-7-0-0 Экологический туризм и экокурорты
23-8-0-0 Проблемы переработки промышленных и бытовых отходов

24. Энергоэффективные способы и устройства разделения и очистки агрессивных газовых смесей

А.Л.Гусев *(Россия, Саров, НТЦ «ТАТА»)*
М.А.Казарян *(Россия, Москва, ФИАН им. П. Н. Лебедева) (МРК)*
А.А.Боброва *(Россия, Саров, РФЯЦ-ВНИИЭФ)*

26. Образование и научно-исследовательские центры

Л. А. Илькаева *(Россия, Саров, РФЯЦ-ВНИИЭФ) (МНКСР)*
Б. Ф. Реутов *(Россия, Москва, Федеральное агентство образования и науки РФ) (МРК)*
А. В. Чувиковский *(Россия, Саров, ИПК РФЯЦ-ВНИИЭФ) (МРК)*
Ю.П.Щербак *(Россия, Саров, СарФТИ) (МНКСР)*
Ж.-П. Концен *(Бельгия, Кармановский институт гидрогазодинамики) (МРК)*
26-1-0-0 Образовательные программы в области водородной экономики
26-2-0-0 Водородные технопарки, наукограды
26-3-0-0 Молодежь в науке и технике

27. Информация

А.И. Саликов *(Россия, Москва, ДОР ЦНИИатоминформ) (МНКСР)*
Е. М. Тарараева *(Россия, Москва, ДОР ЦНИИатоминформ) (МНКСР)*
Е.А.Гудилин *(Россия, Москва, ФНМ МГУ им. М.В.Ломоносова) (РНС)*
Т.Н.Кондырина *(Россия, Саров, НТЦ «ТАТА»)*
27-1-0-0 Периодические издания
27-2-0-0 Интернет-ресурсы
27-3-0-0 Научные биографии ученых мира
27-4-0-0 Научные фонды, научные проекты
27-5-0-0 Международные научные конференции
27-6-0-0 Рекламные материалы инвестиционных фирм и фирм-производителей
27-7-0-0 Новые научные книги
27-8-0-0 Патенты
27-9-0-0 Энциклопедия альтернативной энергетики. Термины и определения
27-10-0-0 Отзывы, письма в редакцию, краткие сообщения
27-11-0-0 Обращения членов редакционного научного совета

1. Hydrogen economy

F.Karaosmanoglu *(Turkey, Istanbul, Istanbul Technical University) (IEB)*
Z.Sen *(Turkey, Istanbul, Istanbul Technical University) (IEB)*

1-1-0-0 History of hydrogen economy
T.N.Veziroglu *(USA, Miami, IAHE, UNIDO-ICHET) (HECH)*
A.G.Galeev *(Russia, Sergiev Posad, JSC "NIIHIMMASH") (IEB)*

1-2-0-0 Safety of hydrogen energy
A.G.Galeev *(Russia, Sergiev Posad, JSC "NIIHIMMASH") (IEB)*
A.L.Gusev *(Russia, Sarov, STC "TATA")*
J.Kleperis *(Latvia, Riga, University of Latvia) (IEB)*
L.F.Belovodskiy *(Russia, Sarov, RFNC-VNIIEF) (IEAB)*

1-2-1-0 Hydrogen recombinators
A.L.Gusev *(Russia, Sarov, STC "TATA")*

1-2-2-0 Systems of inert gas blowing off

1-2-3-0 Ensuring of the safe operation of cryogenic systems

1-2-4-0 Safe application of hydrogen on board the vehicle

1-3-0-0 Gas analytical systems and hydrogen sensors
J.Kleperis *(Latvia, Riga, University of Latvia) (IEB)*
A.M.Polyansky *(Russia, S.-Petersburg, OOO "Electronic & Beam Technologies Ltd.") (IEB)*
V.M.Aroutiounian, *Academician NAS of Armenia (Armenia, Yerevan, Yerevan State University) (SEB)*
J.Schoonman *(Netherlands, Delft, Delft University of Technology) (IEAB)*
L.I.Trakhtenberg *(Russia, Moscow, N.N.Semenov Institute of Chemical Physics RAS) (IEB)*

1-4-0-0 Hydrogen storage
J.Kleperis *(Latvia, Riga, University of Latvia) (IEB)*
O.N.Srivastava *(India, Varanasi, Banaras Hindu University) (IEB)*
S.M.Aldoshin, *Academician RAS (Russia, Chernogolovka, IPCP RAS) (SEB)*
B.P.Tarasov *(Russia, Chernogolovka, IPCP RAS) (IEB)*

1-4-1-0 Hydrogen storage in carbon nanosystems
O.N.Efimov *(Russia, Chernogolovka, IPCP RAS) (IEB)*
B.K.Gupta *(India, Varanasi, Banaras Hindu University) (IEB)*
A.V. Vakhroushev *(Russia, Izhevsk, Institute of Applied Mechanics of Ural branch of RAS) (IEB)*

1-4-2-0 Hydrogen storage in an incapsulated gaseous state: in microspheres,in foam metals,in zeolites and others
V.S.Kogan *(Ukraine, Khar'kov, NSC Kharkov Institute of Physics and Technology) (IEB)*
A.F.Chabak *(Russia, Moscow, Academy of perspective technologies) (IEB)*
E.F.Medvedev *(Russia, Sarov, RFNC-VNIIEF) (IEB)*

1-4-3-0 Hydrogen storage in gaseous state under pressure
A.S.Koroteev, *Academician RAS (Russia, Moscow, Keldysh Research Center) (SEB)*

1-4-3-1 Hydrogen storage in gaseous state in large reservoirs

1-4-3-2 Hydrogen storage in gaseous state in tank

1-4-4-0 Hydrogen storage in liquid state
A.M.Arkharov *(Russia, Moscow, Bauman Moscow State Technical University) (IEB)*
A.M.Domashenko *(Russia, Balashikha, JSC "Cryogenmash") (IEB)*
V.I.Kupriyanov *(Russia, Balashikha, JSC "Cryogenmash") (IEB)*
A.A.Makarov *(Russia, Sergiev Posad, JSC "NIIHIMMASH") (IEB)*
G.G.Shevyakov *(Russia, Balashikha, JSC "Cryogenmash") (IEB)*
V.S.Travkin *(USA, Los Angeles, University of California) (IEB)*
V.S.Kogan *(Ukraine, Khar'kov, NSC Kharkov Institute of Physics and Technology) (IEB)*
I.F.Kuz'menko *(Russia, Balashikha, JSC "Cryogenmash") (IEAB)*
A.G.Galeev *(Russia, Sergiev Posad, JSC "NIIHIMMASH") (IEB)*

1-4-4-1 Hydrogen storage in cryogenic liquid state in large reservoirs

1-4-4-2 Hydrogen storage in cryogenic liquid state on board the vehicles
B.A.Sokolov *(Russia, Korolyov, S.P.Korolyov Energia RSC) (IEB)*

1-4-5-0 Hydrogen storage in chemically-bonded state in liquid media

1-4-6-0 Hydrogen storage in solid phase state in metal hydride systems
M.D.Hampton *(USA, Orlando, University of Central Florida) (DECH)*
B.P.Tarasov *(Russia, Chernogolovka, IPCP RAS) (IEB)*
S.P.Gabuda *(Russia, Novosibirsk, IIC SO RAS) (IEB)*
V.L.Kozhevnikov *(Russia, Ekaterinburg, ISSC Ural Branch of RAS) (IEB)*
R.N.Pletnev *(Russia, Ekaterinburg, ISSC Ural Branch of RAS) (IEB)*

1-4-7-0 Hydrogen storage in combined systems

1-4-8-0 Hydrogen storage in adsorbed state in cryogenic adsorbents

1-4-9-0 Novel methods of hydrogen storage

1-5-0-0 Hydrogen production methods
I.F.Kuz'menko *(Russia, Balashikha, JSC "Cryogenmash") (IEAB)*
V.V.Lunin, *Academician RAS (Russia, Moscow, M. V. Lomonosov MSU)*

1-5-1-0 Radiolysis
M.A.Prelas *(USA, Columbia, University of Missouri-Columbia) (IEB)*

1-5-2-0 Electrolysis

1-5-3-0 Hydrogen production via thermochemical dissociation of water

1-5-4-0 Hydrogen production by ammonia decomposition
V.A.Kirillov *(Russia, Novosibirsk, Boreskov Institute of Catalysis) (IEB)*

1-5-5-0 Method of catalytic conversion (reforming) of gaseous and liquid hydrocarbons

1-5-6-0 Hydrogen production by partial oxidation of hydrocarbons

1-5-7-0 High-temperature process for hydrogen production

1-5-8-0 Hydrates
R.N.Pletnev *(Russia, Ekaterinburg, ISSC Ural Branch of RAS) (IEB)*
S.P.Gabuda *(Russia, Novosibirsk, IIC SO RAS) (IEB)*

1-5-9-0 Hydrogen production on board of the vehicle from organic fuels

1-5-10-0 On board hydrogen production via reaction of interaction of water and metals (aluminium,magnesium etc.)

1-5-10-1 Mechanic and electric methods of removal of oxide layer during reaction

1-5-10-2 Chemical methods of removal of oxide layer during reaction

1-5-10-3 Ultrasonic methods of removal of oxide layer during reaction

1-5-10-4 Methods of increase of specific surface of metals

1-5-10-5 Thermal and pressure methods of intensification of hydrogen production

1-5-10-6 Devices for on board hydrogen production via reaction of interaction of water and metals

1-5-10-7 Devices for hydrogen production via reaction of interaction of water and metals for domestic apllications

1-5-10-8 Devices for hydrogen production via reaction of interaction of water and metals for commercial apllications

1-5-10-9 Physico-mathematical model of processes of hydrogen production

1-5-10-10 Novel lines of development of method for on-board application

1-5-11-0 Hydrogen production from deep-sea hydrogen sulphide
I.M.Neklyudov *(Ukraine, Khar'kov, Khar'kov Physical Technical Institute) (IEB)*
N.A.Azarenkov *(Ukraine, Khar'kov, Khar'kov Physical Technical Institute) (IEB)*

***V.I.Tkachenko** (Ukraine, Khar'kov, Khar'kov Physical Technical Institute) (IEB)*

1-5-11-0 Novel hydrogen production methods

1-6-0-0 Hydrogen transport

***A.G.Galeev** (Russia, Sergiev Posad, JSC "NIIHIMMASH") (IEB)*

1-6-1-0 Transport of liquid cryogenic products by pipelines

***A.M.Domashenko** (Russia, Balashikha, JSC "Cryogenmash") (IEB)*

1-6-2-0 Cooling of cryogenic system mains

1-6-3-0 Transient processes in cryogenic systems

1-7-0-0 Fuel cells

***B.A.Sokolov** (Russia, Korolyov, S.P.Korolyov Energia RSC) (IEB)*
***Yu.N.Shalimov** (Russia, Voronezh, VSTU) (IEB)*
***V.P.Pakhomov** (Russia, Moscow, RRC "Kurchatov Institute") (IEB)*

1-7-1-0 Research and production of fuel cells

1-7-1-1 Membanes for fuel cells

1-7-1-2 Computer simulation of fuel cell operation

1-7-2-0 Fuel cells application

1-7-2-1 Power supply on fuel cells with methanol conversion for portable devices

1-7-3-0 Fuel cells with hydrogenous fuel pre-processing

1-8-0-0 Structural materials

***P.G.Berezhko** (Russia, Sarov, RFNC-VNIIEF) (IEB)*
***A.M.Polyansky** (Russia, S.-Petersburg, OOO "Electronic & Beam Technologies Ltd.") (IEB)*
***V.M.Chertov** (Russia, Moscow) (IEB)*
***Yu.N.Shalimov** (Russia, Voronezh, VSTU) (IEB)*
***P.Saint-Gregoire** (France, Universitй de Toulon et du Var) (DECH)*
***F.A.Lewis** (Great Britain, Belfast, The Queen's University of Belfast) (SEB)*
***A.T.Ponomarenko** (Russia, Moscow, Enikolopov Institut of Synthetic Polymer Materials of RAS) (IEAB)*
***L.V.Spivak** (Russia, Perm', Perm' State University) (IEAB)*
***M.V.Gol'tsova** (Ukraine, Donetsk, Donetsk STU) (IEAB)*
***N.M.Vlasov** (Russia, Podol'sk, SRI SIA "Luch") (IEB)*
***I.I.Fedik** (Russia, Podol'sk, SRI SIA "Luch") (IEB)*

1-8-1-0 Hydrogen in metals and alloys

***V.A.Gol'tsov** (Ukraine, Donetsk, DonSTU) (IEB)*
***L.F.Gol'tsova** (Ukraine, Donetsk, DonSTU) (IEB)*

1-8-2-0 Hydrogen degradation

1-8-3-0 Structural materials hydrogenation systems

1-8-4-0 Static and dynamic strength of structural materials

***N.N.Gerdyukov** (Russia, Sarov, Institute of Experimental Gasdynamics and Physics of Explosion RFNC-VNIIEF) (IEB)*

1-8-5-0 Gasars. Application of gasars in marine and air fleet, motor-car construction

1-8-6-0 Electrical furnaces for thermovacuum processes

***E.N.Marmer** (Moscow, VNIIETO)*

1-8-7-0 New structural materials for renewable energy structures

1-9-0-0 Synthesis-gas production methods

***A.Ya.Stolyarevskiy** (Russia, Moscow, RRC "Kurchatov Institute") (IEB)*

1-9-1-0 Adiabatic conversion of the natural gas

1-10-0-0 Hydrogen fuel vehicles and engines

***T.Gaertig** (Germany, Berlin) (IEB)*
***A.L.Dmitriev** (Russia, S.-Petersburg, RSC "Applied Chemistry") (IEB)*
***A.M.Domashenko** (Russia, Balashikha, JSC "Cryogenmash") (IEB)*
***B.A.Sokolov** (Russia, Korolyov, S.P.Korolyov Energia RSC) (IEB)*
***A.Yu.Ramenskiy** (Russia, Moscow, Audit-Premier) (IEAB)*
***V.S.Sokolov** (Russia, S.Petersburg) (IEAB)*

1-11-0-0 Hydrogen filling stations

1-12-0-0 Hydrogen for providing buildings, structures and houses with energy. Micro hydrogen power plants based on fuel cells

2. Thermodynamic analysis in renewable energy

***V. A. Khusnutdinov** (Russia, Moscow, RAO UES of Russia) (IEB)*

2-1-0-0 Thermodynamic analysis of basic energy generation processes in alternative energy

2-2-0-0 Exergetic analysis of basic energy generation processes in alternative energy

3. Atomic energy

***Yu.A.Trutnev**, Academician RAS (Russia, Sarov, RFNC-VNIIEF) (HECH)*
***A.Ya.Stolyarevskiy** (Russia, Moscow, RRC "Kurchatov Institute") (IEB)*
***A.V.Ivkin** (Russia, Sarov, RFNC-VNIIEF) (IEAB)*
***A.G.Chudin** (Russia, Moscow, Federal Agency for Nuclear Energy) (IEAB)*
***V.A.Afanas'ev** (Russia, Sarov, RFNC-VNIIEF) (IEB)*
***M. A. Prelas** (USA, Columbia, University of Missouri) (IEB)*

3-1-0-0 Atomic-hydrogen energy

***N.N.Ponomaryov-Stepnoy**, Academician RAS (Russia, Moscow, RRC "Kurchatov Institute") (SEB)*
***A.Ya.Stolyarevskiy** (Russia, Moscow, RRC "Kurchatov Institute") (IEB)*
***V.N.Fateev** (Russia, Moscow, RRC "Kurchatov Institute") (IEB)*
***A.L.Gusev** (Russia, Sarov, STC "TATA")*

3-1-1-0 History of atomic-hydrogen energy

***N.N.Ponomaryov-Stepnoy**, Academician RAS (Russia, Moscow, RRC "Kurchatov Institute") (SEB)*
***A.Ya.Stolyarevskiy** (Russia, Moscow, RRC "Kurchatov Institute") (IEB)*
***A.L.Gusev** (Russia, Sarov, STC "TATA")*

3-1-2-0 High-temperature gas reactors (HTGR) for hydrogen production via high-temperature processes

3-1-3-0 Fast reactors with sodium cooling (SC) to produce mid-temperature heat,and synthesis gas and hydrogen

3-1-4-0 Fast reactors with lead cooling as reactors of future generation to produce high-temperature heat

***G.L.Khorasanov** (Obninsk, SSC of the RF – Institute for Physics and Power Engineering Named After A.I.Leypunsky) (IEB)*

3-2-0-0 Atomic energy for vehicles

***M. A. Kazaryan** (Russia, Moscow, P.N.Lebedev FIAN) (IEB)*
***I.V. Shamanin** (Russia, Tomsk, Tomsk Polytechnical University) (IEB)*

3-2-1-0 Radionuclide heat sources

3-2-2-0 Radionuclide thermoelectric generators

3-2-3-0 Thermo- and radiation-stimulated phase transformation in alloys incorporated (carbides, nitrides, nitrides-hydrides, carbohydrides and hydrides of transition metals, high-temperature, super-conducting materials, intermetallic composition)

4. Solar energy

***A.Steinfield** (Switzerland, Zurich, ETH-Swiss Federal Institute) (IEB)*
***G.I.Isakov** (Azerbaijan, Baku, Institute of Physics of NAS of Azerbaijan) (DECH)*
***I.G.Khidirov** (Uzbekistan, Tashkent, Institute of Nuclear Physics of NAS of Uzbekistan) (IEB)*
***S.Geruny** (Armenia, Yerevan, Yerevan State University) (IEB)*
***S.M.Raza** (Pakistan, Quetta, University Of Balochistan) (IEB)*
***S.Z.Ilyas** (Pakistan, Quetta, University Of Balochistan) (IEB)*
***A.M.Pendjiev** (Turkmenistan, Ashkhabat-32, Tutkmenian polytechnic institute) (IEB)*
***V. F. Gremenok** (Belorussia, Minsk, Joined Institute of Solid State and Semi-conductor Physics) (IEAB)*

4-1-0-0 History of solar energy

4-2-0-0 Solar-hydrogen energy

4-2-1-0 Materials for solar-hydrogen energy

4-3-0-0 Solar power plants

4-3-1-0 Silicone solar thermal electric plants

4-3-2-0 Space solar stations

4-3-3-0 Photoelectric cell

4-3-4-0 Photovoltaic effect in semiconductor structures. Photoelectric modules

4-4-0-0 Ground solar stations

4-4-1-0 Solar collectors

4-5-0-0 Solar cities

4-5-1-0 Solar buildings

4-5-2-0 Solar refrigerators

4-5-3-0 Solar water-lifting systems

4-5-4-0 Solar energy units

4-6-0-0 Solar transport
4-7-0-0 Solar radiation concentrators

5. Wind energy

I.Z.Boguslavskiy *(Russia, Moscow, DBREPE RAS) (IEB)*
5-1-0-0 History of wind energy
5-2-0-0 Hydrogen-wind energy
5-3-0-0 Electric generators for wind energy
5-4-0-0 Wind energy plants
5-5-0-0 Wind-solar energy plants

6. Tide energy and sea tide energy

6-1-0-0 History of energy of tides
6-2-0-0 Sea waves energy
6-3-0-0 Sea tide energy

7. Geothermal energy

7-1-0-0 History of geothermal energy
7-2-0-0 Basic research into geothermal energy
7-3-0-0 Problems of geothermal energy assimilation
7-4-0-0 Role of modeling and monitoring in geothermal energy assimilation. Appraisal of geothermal resources
7-5-0-0 Geothermal plants
7-5-1-0 Geothermal power plants
7-5-2-0 Geothermal heat plants
7-6-0-0 Efficiency and reliability of geothermal heat and power plants. Major ways to improve the efficiency of geothermal heat and power plants
7-7-0-0 Geothermal resources of world countries and prospects of their development

8. Explosion energy

V.E.Fortov*, Academician RAS (Russia, Moscow, Institute of thermal physics of extremal state RAS) (SEB)*
A.L.Mikhailov *(Russia, Sarov, Institute of Experimental Gasdynamics and Physics of Explosion RFNC-VNIIEF) (IEB)*
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A.A.Sterzer *(Russia, Novosibirsk, MATEM Co. Ltd) (IEB)*
V.N.German *(Russia, Sarov, Institute of Experimental Gasdynamics and Physics of Explosion RFNC-VNIIEF) (IEB)*
8-1-0-0 Explosion technologies
8-2-0-0 Computer simulation of problems for explosion energy
8-1-1-0 Setting up problems for explosion energy
8-1-2-0 Mobile Lagrangian and Euler grids
8-3-0-0 Explosion deuterium energy
8-4-0-0 Explosion energy for syntheses of new materials
8-4-1-0 Materials synthesis and sticking by the explosion
8-4-2-0 Shock-wave sticking
8-4-3-0 Computer modelling of processes of material shock-wave sticking
8-5-0-0 Explosives
8-6-0-0 Blasting chambers
A.A.Sterzer *(Russia, Novosibirsk, MATEM Co. Ltd) (IEB)*
8-7-0-0 Extremal state of matter. Detonation. Shock waves
8-8-0-0 Energy materials and physics of detonation
8-9-0-0 Equations of the state and phase transition

9. Energy of biomass

S.A.Markov *(USA, Greencastle, DePauw University) (IEB)*
9-1-0-0 Biogas plants
9-2-0-0 Thermochemical gas generators

10. Small and micro hydro-power plants

S.Shatvoryan *(Armenia, Yerevan, Energy Strategy Center) (IEB)*
10-1-0-0 Equipment for small and micro hydro-power plants (HPP)
10-2-0-0 Derivation micro hydro-power plants

11. Carbon nanostructures

A.M.Lipanov*, Academician RAS (Russia, Izhevsk, Institute of Applied Mechanics UB RAS) (IEB)*
Yu.M.Shul'ga *(Russia, Chernogolovka, JSC "Cryogenmash") (IEB)*
V.I.Kodolov *(Russia, Izhevsk, BRHE Centre of Chemical Physics and Mesoscopy) (IEAB)*
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B.P.Tarasov *(Chernogolovka, IPCP RAS) (IEAB)*
Yu.D.Tretiakov*, Academician RAS (Russia, Moscow, FMS MSU) (SEB)*
11-1-0-0 Nanosystems: synthesis,properties,and application
E.A.Goodilin*, Member Corresponding RAS (Russia, Moscow, FMS MSU) (SEB)*
11-2-0-0 Fullerene structures and carbon nanomaterials for heat insulation
11-3-0-0 Fullerene structures and carbon nanomaterials for hydrogen sensors
M.V.Vorobiova *(Russia, Moscow, GIREDMET) (IEAB)*
V.M.Aroutiounian*, Academician NAS of Armenia (Armenia, Yerevan, Yerevan State University) (SEB)*
11-4-0-0 Computer simulation of synthesis of carbon nanomaterials with specified properties
11-5-0-0 Carbon nanostructures for vehicles

12. Catalysis for renewable energy

Z.R.Ismagilov *(Russia, Novosibirsk, Boreskov Institute of Catalysis) (IEB)*
S.M.Aldoshin*, Academician RAS (Russia, Chernogolovka, IPCP RAS) (SEB)*
V.N.Parmon*, Academician RAS (Russia, Novosibirsk, Boreskov Institute of Catalysis of SD RAS) (SEB)*
V.A.Kirillov *(Russia, Novosibirsk, Boreskov Institute of Catalysis of SD RAS) (IEB)*
O.N.Efimov *(Russia, Chernogolovka, IPCP RAS) (IEB)*
12-1-0-0 Catalytic methods for synthesis of alternative fuel
12-2-0-0 Catalysis in combined schemes «energy generation and production of useful products from natural gas»
12-3-0-0 Catalysis in generation of working fluid in gas turbines as an effective alternative flare generation method
12-4-0-0 Catalysis of fuel cells
12-5-0-0 Catalysis in processes of production of synthesis gas and hydrogen
12-6-0-0 Catalytic methods of hydrogen treatment
12-7-0-0 Catalysis in treating of power reactor waste gases
12-8-0-0 Catalysis in process water treatment systems
12-9-0-0 Photocatalytic and electrocatalytic methods for hydrogen production
12-10-0-0 Development and study of material properties to form catalytic layers in fuel cells
12-11-0-0 On mechanism of catalytic action. Effect of metal nature and degree of oxidation thereof on catalytic activity
12-12-0-0 Nanocomposites for application as catalysts. Effect of dimension factor on catalytic activity
12-13-0-0 Alternative catalysts with no platinum
12-14-0-0 Problems of catalyst poisoning
12-15-0-0 Catalyst carriers: design,synthesis,and properties
12-16-0-0 Catalytic layers for fuel cells in planar design
12-17-0-0 Sol-gel process for production of catalysts and catalyst carriers

13. Thermogradient energy

***V.A. Khusnutdinov** (Russia, Moscow, RAO UES of Russia) (IEB)*

14. Ice energy

14-1-0-0 Application of ice in energy. Glacial power stations
14-2-0-0 Application of cold of permafrost for thermostatic control of domestic and process structures
14-3-0-0 Physical and chemical properties of ice
14-4-0-0 Thermal properties of ice
14-5-0-0 Thermodynamic basis for production and application of ice
14-6-0-0 Equipment for ice testing
14-7-0-0 Facilities for ice production
14-8-0-0 Methods and machinery for ice emergent break up for safety depth devices and over-land vehicles undergoing disaster
14-9-0-0 Binary ice in science and technique
***A.L.Gusev** (Russia, Sarov, STC "TATA")*
14-10-0-0 Application of ice for construction of engineering and technical,and architecture structures
14-11-0-0 Ice dynamics and strength. Embrittlement dynamics. Experimental methods of ice breaking up dynamic mechanics
14-12-0-0 Numerical and combined numerical and experimental methods of ice breaking up dynamic mechanics
14-13-0-0 Techniques for removing ice from water reservoirs
14-14-0-0 Cold storage and application
14-15-0-0 Transport of icebergs and production of fresh water

15. Thermonuclear energy

***V. N. Lobanov** (Russia, Sarov, RFNC-VNIIEF) (IEB)*
15-1-0-0 Investigations on the controlled thermonuclear fusion
15-2-0-0 X-ray thermonuclear fusion
15-3-0-0 Beam fusion
15-4-0-0 Inertial fusion
15-5-0-0 Isotope effect
15-6-0-0 Cryogenic tritium targets
15-7-0-0 High-pressure targets designed for research of nuon catalysis processes in nuclear fusion
15-8-0-0 International project of thermonuclear fusion reactor,ITER
15-9-0-0 Radiological protection and nuclear security
15-10-0-0 Production of radioisotopes and application
***M. A. Kazaryan** (Russia, Moscow, FIAN Lebedev Institute of Physics of RAS) (IEB)*
15-11-0-0 Fuel cycle and ecology
15-12-0-0 Design, construction and maintenance of nuclear research and power reactors
15-13-0-0 Production of components and materials required for application in nuclear reactors and fuel cycles thereof
15-14-0-0 TOKAMAK systems
15-15-0-0 Auxiliary magnetocumulative systems

16. Cryogenic and pneumatic vehicles

***A.L.Gusev** (Russia, Sarov, STC "TATA")*
16-1-0-0 Cryogenic nitrogen transport
16-2-0-0 Inert gas-based cryogenic vehicles for hazardous structures: fire engines,air port auxiliary vehicles, fuel and lubricant storage,vehicles in dangerously explosive chemical production
16-3-0-0 Pneumatic vehicles

17. Basic problems of energy and renewable energy

17-1-0-0 Electric energy storage
17-2-0-0 Superconductive materials. Superconductivity. Superconductivity of energy
17-3-0-0 New cycles and schemes for thermotransformers
17-4-0-0 Problems of megapolise illumination

18. Application of helium and special materials in vehicles

***Yu.A.Ryjov**, Academician RAS (Russia, Moscow, International University of Engineering) (SEB)*
18-1-0-0 Airships to transfer large-sized cargoes
18-2-0-0 Airships to control states of emergency in megapolises: car inspection, fire safety, terrorism combat, technical and ecological state control of industrial buildings and structures. Energy control (heat leak control in buildings on a city's scale)
18-3-0-0 Fire fighting airships, counteracting, and police airships

19. Juvenile hydrogen in geotectonics and geochemistry processes

***S.V.Digonskiy** (Russia, Ekaterinburg, FGUP "Urangeologorazvedka") (IEB)*
***V.L.Syvorotkin** (Russia, Moscow, M.V.Lomonosov Moscow state university) (IEB)*
19-1-0-0 Role of hydrogen in chemical composition of the universe
19-2-0-0 Diving forces in the evolution of Earth and planets
19-3-0-0 Hydrogen in the Earth's core
19-4-0-0 Geology and geochemistry of natural gases in deep fault areas
19-5-0-0 Transport of juvenal hydrogen through the Earth stratum and formation of electrically charged zones
19-6-0-0 Natural synthesis of carbon-based substances
19-7-0-0 Deep degasifying of the Earth, global disasters and anomalous phenomena

20. On-board energy accumulators

20-1-0-0 Thermal energy accumulators
***A.L.Gusev** (Russia, Sarov, STC "TATA")*
20-1-1-0 Temperature above 273 K
20-1-2-0 Temperature below 273 K
20-1-3-0 Temperature below 77 K
20-2-0-0 Flywheel energy accumulators
20-3-0-0 Electrical energy accumulators
20-4-0-0 Spring energy accumulators
20-5-0-0 Compressed-air energy accumulators
20-6-0-0 Chemical energy accumulators

21. Legislative basis

***P.B.Shelishch** (Russia, Moscow, RF State Duma, President of National Association of Hydrogen Energy) (IEAB)*
21-1-0-0 Legislation basis for renewable energy in Russia
21-2-0-0 Legislation assurance for innovation development of hydrogen energy
21-3-0-0 Legislation basis for renewable energy in CIS
21-4-0-0 Legislation basis for ecology

22. Economical aspects

22-1-0-0 Investment attractiveness of various countries and companies in renewable energy
22-2-0-0 Resources of conventional energy sources in exporting countries and world resources
22-3-0-0 National scientific and technological programmes of the development of hydrogen economy
22-4-0-0 Economical analisys in renewable energy
V. A. Khusnutdinov *(Russia, Moscow, RAO UES of Russia) (IEB)*
22-5-0-0 Business-planning in renewable energy

23. Energy and ecology

O.L.Figovsky *(Israel, Migdal Ha'Emek, Israel Research Center Polymate) (IEB)*
M.V.Vorobiova *(Russia, Moscow, GIREDMET) (IEB)*
23-1-0-0 Greenhouse gas effect
23-2-0-0 Ecological problems of industrial megapolises
23-3-0-0 Ecology of air atmosphere and space
23-4-0-0 Ecology of water resources
23-5-0-0 Problems of unhealthy atmospheric emissions by heat-electric generating plants
23-6-0-0 Problems of groung pollution by energy carriers
23-7-0-0 Ecological tourism and ecological resorts
23-8-0-0 Problems of factory and domestic waste utilization

24. Energy efficiency methods and facilities for agressive gas mixture separation and purification

A.L.Gusev *(Russia, Sarov, STC "TATA")*
M. A. Kazaryan *(Russia, Moscow, P.N.Lebedev FIAN) (IEB)*
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26. Education and scientific research centres

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Yu. P. Shcherbak *(Russia, Sarov, Sarov Physicotechnical Institute) (IEB)*
J.-P. Contzen *(Belgium, von Karman Institute for Fluid Dynamics) (IEB)*
26-1-0-0 Educational programmes in hydrogen economy
26-2-0-0 Hydrogen trading estates and science and research cities
26-3-0-0 Young people in alternative energy and ecology science and technology

27. Information

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27-1-0-0 Review of periodicals
27-2-0-0 Review of leading internet-resources
27-3-0-0 Prominent scientists' biographies
27-4-0-0 Scientific funds and scientific projects
27-5-0-0 International scientific conferences
27-6-0-0 Advertising matters of investment companies and manufacturers
27-7-0-0 Review of new scientific books
27-8-0-0 Patents
27-9-0-0 Encyclopedia of renewable energy. Terms and definitions
27-10-0-0 Opinions,letters in publishing office,short articles
27-11-0-0 Messages of members of Scientific editorial board

Аббревиатуры

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МРК — Международный редакционный комитет
МНКСР — Международный научно-консультативный совет редакции
ЭС — Экспертный совет
МСР — Международный совет рецензентов

Abbreviation

SEB — Scientific Editorial Board
IEB — International Editorial Board
IEAB — International Editorial Advisory Board
EB — Experts Board
IRB — International Reviewers Board

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