IS INDUSTRIAL DEVELOPMENT INCOMPATIBLE WITH CONSTRAINTS OF INDUSTRIAL ECOLOGY IN CAMEROON?

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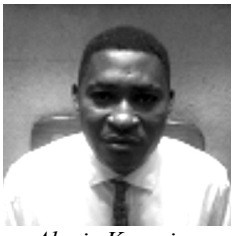
Received: 24 Sept 2007; accepted: 31 Oct 2007

The present industrial development trend in Cameroon does not give the expected results but rather accumulate environmental risks. This article analyzes industrial practices in a number of key sectors from the angle of industrial ecology, showing a non optimized consumption of inputs and energy as well as non-rationally exploited resources. If the increase of input is added to the dilapidated industrial fabric it would give a massive increase of waste which is a considerable pollution source. Examples and suggestions on the possibilities of applications of industrial ecology to Cameroon are presented at the end of this article.

Keywords: ecological problems of industrial megapolises, problems of factory and domestic waste utilization, sustainable development



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Introduction

Developing countries (DC) are confronted with several problems which include delay in technology development, dilapidation of industrial fabric [1], insufficient financial means, use of not optimal transformation and production processes, but also socio-political aspects such as poor governance, general level of education, continuous demographic growth or certain cultural impediments. In this era of globalization, the "classical" manner of economical development used by western countries during the two past centuries does not seem operational in these countries, notably those of the African continent. To the above enumerated constraints should be added that of global warming of the planet and international competitive rush for primary products (oil, ores). Several big-time DC are carrying out original developments activities which put the environment at the heart of development politics. Brazil has been recognized as pioneer in bio fuels for example, but the efforts of China are so enormous in this area, according to the level of challenges that she must face in a bid to modernize her industrial base [2]. China's leadership strives to set up a "cyclical" economy [2], which greatly ties in with the scientific notion of industrial ecology [3]. As such, could this original mode of industrial ecology be applied to another group of DC, given that Sub-Saharan Africa countries are bogged down by development problems for which classical solutions advocated by the western international experts do not seem to have an answer? If yes, which basic principles adaptations of industrial ecology or circular economy, will be required in order to take account of their local constraints and their development priorities? The representative sample country chosen for this study is Cameroon, given its position, size, and development level, often presented as "Africa in miniature". As early as 1999, the Institute for Communication and Analysis of Sciences and Technologies (ICAST) carried out a fact-finding mission to Cameroon on the concrete perspectives of industrial ecology in Africa [4]. We are now using this study as our takeoff point, while directing our research and investigations towards some key sectors of industrial ecology, especially the waste sector. The increase of input and energy flux, added to the current trend of economical growth in DC, have resulted in a massive increase in waste, which in itself is a source of pollution and degradation of the environment.

Furthermore, through inquiry carried out on a representative sample of Cameroonian corporations, this study will examine the treatment of domestic and industrial waste and make an inventory of actions and possibilities of industrial ecology in the informal sector. The ensuing results and discussions will bring out the possible contributions of industrial ecology to the setting up of models that would valorise waste management and optimize the flux of inputs and energies in Cameroon.
Above all else in this sector, industrial operators as well as politicians in charge and all development actors must ask the following question: how could we optimize the flux of input and energy while improving productivity and preserving the environment and available resources? This preoccupation goes beyond pollution problems and delves into the long term evolution of Cameroon's industrial fabric as a whole; it even delves into the sub regional framework of the Economic and Monetary Community of Central Africa (CEMAC) [5].

Context

Presentation of Cameroon

Geographic situation in Africa

Cameroon is often called "Africa in Miniature". This is because it is representative of the continent in several ways and is situated in the centre of Africa (Fig. 1). It covers varied vegetations, climatic and cultural zones, as well as comprising very varied populations. As compared to other African countries, Cameroon appears to be extremely rich in natural resources and in potentialities of all sorts. Farming and husbandry benefit from very favourable climatic conditions and vegetation.

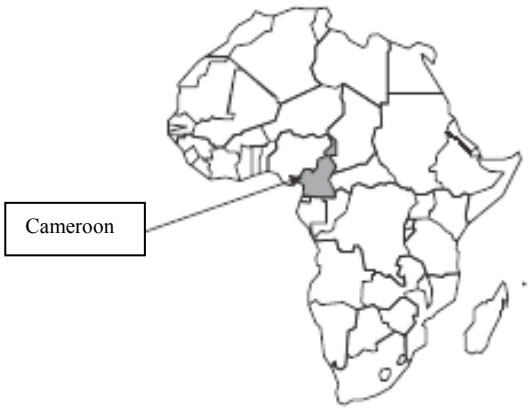

Fig. 1. *Cameroon in Africa*

Exploitation of the equatorial forest here is very lucrative. The subsoil is rich in oil, bauxite, iron and various minerals. In the South of Cameroon, the dense hydrographical network could guarantee water and the electricity for all. Well mastered tourism, currently a neglected domain, could be one of the pillars of development. Unfortunately, the management of the all these resources is not yet optimum and a great majority of the population lives below poverty line.

Some basic data [6]

The Republic of Cameroon is situated in the central region of Africa and extends northwards from the Gulf of Guinea by the ocean Atlantic to Lake Chad. This triangular-shaped country spreads out over a length of 1.200 km between latitudes 2° North and 13° North and a width of 850 km between the longitudes 8° Is and 16° Is.

Surface area: 475 442 km^2.

Population: 16.4 millions of inhabitants (2006).

Density: 34 inhabitants/km^2.

Demographic growth: 1.93 % /year (2005) – for comparison, France: 0.35 %.

Principal resources: precious wood, cocoa, coffee, cotton, rubber, food plants (millet, sorghum, manioc-cassava), husbandry, bovine, aluminium and oil.

GDP: 12.5 billions €/year, representing half of CEMAC zone – GDP/inhabitant: 760 €/year.

Human Development Index: the HDI for Cameroon is 0.506, which ranks Cameroon at 144th out of 177 countries (206) [7]. The Cameroon HDI reached a maximum of 0.514 in 1990.

Industrial ecology and the requirements of industrial development

For Cameroon to attain the main Millennium Development Goals (MDG) [8] there is need to accelerate economic growth based on the industrialization of production sectors.

The main determinants of industrial development that have an impact on the environment is the exploitation of natural resources (primary products), technological processes used in the production of economic goods, as well as energy supply.

To meet with the challenge of sustainable industrial development, industrial ecology must be based on four principles [3]:

− cut down on all sorts of dissipation (energy or inherent to products, at manufacture, usage, and end of life);

− dematerialize products and the services, in order to ensure flux of inputs and energy not correlated with GDP growth and HDI improve;

− decarbonise energy, with as main objective to fight against the greenhouse effect;

− valorise waste management as secondary resources with the intention of attaining an industrial system friendly to the biosphere.

Is it possible to integrate these four principles in a national policy of sustainable economic development that respond in priority to the MDG? In this study we present some data and analysis, as well as propose some avenues for reflection on the possibility and means of integrating industrial ecology to the problematic of development in Cameroon.

The industrial development and the environmental constraints

Industrial evolution of Cameroon

The industrial development of post-independent Cameroon corresponds to three phases marked by a high political determination to progress, but whose implementation suffered from hazardous economical situations: the economy experienced a growth period (1960-1982), then a period of recession (1984-1993) and now one of revival (since 1994). The GDP growth rate is of 4 % per year since 2001, but a great part of this growth is absorbed by high demographic increase [9].

The Industrial fabric is concentrated geographically and covers only a small part of the industrial sectors. Douala is the industrial capital of the country, mostly due to its harbour and industrial zone. The principal businesses of the country are involved in such sectors as:

− agro-industry (Brasseries du Cameroun, SOCAPALM);

− agricultural transformation (SODECOTON);

− forestry exploitation;

− heavy industries (CIMENCAM for cement, ALUCAM for aluminium, etc);

− energy production and distribution (AES-SONEL, SNH: Société Nationale des Hydrocarures, SONARA: Société Nationale de Raffinage);

− distribution (FOKOU group for instance [10]);

− the banking sector;

− transport: CAMAIR (airline), CAMRAIL (railway);

− telecommunications: MTN and Orange companies, etc.

This fabric is on the whole aging. Corruption, slow administrative procedures, tax insecurity, etc, make investment difficult in the country. The informal sector (sector of non declared work and therefore as a rule subject to low income) has been on the increase since the economic crisis of 1983, and now stands at 90 % of urban manpower and becomes therefore essential for all studies or economic forecast.

Energy supply

Energy is one of the essential factors of productions for industrial development, because it is used in transportations and as means to operate equipments producing economic goods and activating these goods themselves. Though it is imperative to have access to necessary and sufficient energy, Cameroon unfortunately experienced since 2001 a considerable energy deficit of 100 MW/per annum. Competent companies, including the principal electric energy distributor AES-SONEL, invested massively in the production of thermal energy to maintain industrial production. An 85 MW heavy-duty fuel plant, with a capacity of 17 tons/hour of fuel, was put in service in 2004, but the production of 11.6 MW·h of electricity by combustion liberates 9.3 tons of Carbon Dioxide.

The thermal production of electricity by AES-SONEL is increasing, as it stood at 156 GW·h in 2004, and this trend is being maintained.

Companies also get involved in energy auto-production by the acquisition of diesel electric generators. A recent study [11] put CO_2 discharges by Cameroonian businesses at 26870 tons. The autonomous production of electricity is estimated in 2005 at 450 GW·h, with an annual growth rate of 2.17 %. That implies that CO_2 emissions will increase over the coming years, the more so as measures taken to reduce national electricity deficit seem to be inefficient [11].

Technology processes

The transformation of raw materials into economic goods is done in production units by implementing various technological processes. This transformation generates wastes that contain polluting substances for the environment. Industrialists are more interested in the increase of profits and competition, rather than in facing the dangers that these production residues represent [11]. The treatment of waste is never well envisaged, and it is thus with despair that one observes the burying of waste without respect of the norms, poorly adapted sites, spillages of toxic substances in the sea environments (the example of the Abidjan lagoon in Ivory Coast is very edifying). Technological processes must be able to reduce waste, cut down on their poisonous effects; but the present dilapidation of industrial fabric in Cameroon does not encourage such environmental policy. There is thus the lack of necessary investments to ensure modernization, in an economic environment marked by weak internal financial means and a general climate of not too attractive for business [12].

Exploitation of natural resources

Industrial performance is conditioned by the supply of raw materials which are basically natural resources. Unfortunately, this non rational exploitation of natural resources led to a degradation of the ecosystems. The surface area of forests reduced by 2.4 % between 1990 and 2000 [8], and as such leading to a dramatic impoverishment of wildlife and big animals due to poaching, while our resources in waters will undergo a reduction of 33 % in average in 20 years. The advance of the desert consecutive to global warming of the planet can affect farming and water resources in the northern zone of the country and especially destabilize neighbouring countries (Chad, Nigeria), with repercussions on Cameroon. The extraction of subsoil resources deeply modified the morphology and sea bed of certain regions of the globe, and Cameroon is part of the exposed countries (exploitation of hydrocarbons in the Guinea gulf, mining projects of breadth in the East and the North).

Environmental constraints

Knowing environmental constraints [13] is a response to the numerous perils that we know: global warming which induces an elevation of the level of seas, climatic disruptions (phenomenon of El Nino, frequency of cyclones, etc.). The United nations through its specialized bodies has organised several summits and lectures elaborating these environmental constraints; there is the "Earth Summit" at Rio (Brazil) some 15 years ago, and that of Johannesburg (South Africa, 2002) [5], specific summits to a special group of countries as the Summit of the Small Insular States in Development held at Mauritius Island (2005) [14].

At the international level, these constraints concern four big themes: the reduction of the transmissions of greenhouse gases, sustainable development, preservation of biodiversity and the rational management of energy resources.

Cameroon did not stay away from the dynamics of the search for solutions; it ratified and signed several conventions and protocols, while law No. 96/12 of August 05 1996 relating to the management of the environment was adopted [15]. Industrial actions must respect certain norms contained in this law, especially as control organisms were set up. Concretely, this will entail the respect of the Montreal protocol and its amendments, the preservation of the regulatory role of forests, the elimination or recycling of industrial waste, the carrying out of environmental impact assessment studies for all project with direct or indirect incidence on the environment (examples: construction project of the Lom-Pangar Dam, the construction of the Chad-Cameroon pipe line), the need to inform the populations on the harmful effects of wastes.

Cameroon signed the adhesion to the Kyoto protocol of July 23 2002 and participates in actively in the activities of the Clean Development Mechanism (MDP) [16].

The perception of changes involved here implies taking into account the protection of the environment and the investments that it generates shall be stretch onto industrial development and respect of the principles of the industrial ecology, which are two incompatible concepts in DC.

Specificity of the countries in the process of development: the weight of the informal sector

The poor inhabitants of DC are usually confronted with the problem of their day-to-day subsistence. The purchasing power of households is very weak, feeding and health care are a daily headache, and this encourages the development of an informal sector alongside the formal sector. So long as these basic questions are not determined, these populations cannot pay themselves the "luxury" of ecological preoccupations. Cameroon is not free from this reality. Her informal sector considerably developed since 1990 following a conjunction of facts: salary cuts of the officials by 60 %, blocking of the recruitments of university graduates into the public service and severity of the of structural adjustment plans [17]. The informal sector actors work in all domains of activity: production, commerce, recuperation, textiles, etc. It is in this wake that the importations of used clothing, whose

noxious effects on health are known, increased to the point where its market parts in this domain are higher than that of Cameroonian Textile Industry (CICAM). The recuperation business developed and concerns all products (scrap iron, used electric and electronic devices, plastic). The production of the consumer goods also developed as well as a variety of manufactured and handicraft products sold in markets (yogurt, fruit juice, dairy products). The advent of the Chinese cheap manufactured motorcycles ("taxi-bikes") that imposed, next to classic public transport and original trends such as common township taxis is an indicator of the dynamism of the informal sector in this activity domain.

From the foregoing, it can be deduced that in Developing Countries safeguard of the environment in the informal sector is not integrated in their vision of the world in the same manner as in the rich countries [4]. The question here is whether the growth of informal sector activities hat puts is itself the one of respects the protection constraints of the environment in Cameroon. Is the industrial ecology capable of help this informal sector in the problematic, and, through its systemic and collaborative approach, to bring back progressively its actors towards the definite sector? An attempted response to these preoccupations is brought by our research described hereafter.

Enquiry on Cameroonian businesses

General framework of the study

This study concerns on the one hand Cameroonian businesses that produce important quantities of industrial waste and on the other hand those that work in the collection and treatment of production residues. This study further covers actors of the informal sector. The geographic framework of this study covers the cities of Douala and Yaounde which, according to the statistics of the Ministry of the Industrial and Commercial Development (MINDIC) contain more than 80 % business in the country. This inquiry was specific to corporations involved in the business of waste treatment such as HYSACAM (Hygiene and Sanitation Corporation Cameroon), BOCAM (group Fokou [10]) and BOCOM, the industrial corporation ALUCAM, and of the domain food processing. These companies were chosen because the responded to certain criteria, such as the nature of the industrial activity, the typology and the mass of the industrial waste products, and the flux of raw materials and energies.

Our findings were based on statistics of the services of customs and taxes, on registers provided by the Chamber of Commerce, Mines and Energy, as well as from the Business Directory; we covered 70 companies. Since the informal sector is not well structured and almost infinite in size, we were not able to extract enterprises-test. Our study thus limited its research to ten big participants of the formal sector whose activities have links with the methods of industrial ecology. Through our study of these corporations, we wanted to analyze two questions:

− What is the weight of the informal sector market and what waste does it produce?

− What means can be used to sensitize and train manufacturers, the informal sector and others stakeholders?

Methodology

This chapter dwells on the methodology that we systematically adopted for our different investigations and analysis.

Inductive method

The inductive method [18] in principle use the estimation of the variables per the whole population statistics collected from the data in the sample. We constituted a sample of 20 corporations that were grouped together in strata and whose results after correction will enable the obtention of reliable indicators on industrial ecology in Cameroon.

Stratification [19]: our assessment base of N broken down in in k strata in which one take off sample, and consider a variable X of which one would want to estimate the average M. One obtains:

− at the sample:

$$m_h = \frac{1}{N_h}\sum_{s=1}^{N_h} X_{hs}\ , \tag{1}$$

$$\overline{X}_h = \frac{1}{n_h}\sum_{i=1}^{n_h} X_{hi}\ ; \tag{2}$$

− at the level of populations:

$$m_h = \sum_{h=1}^{k} \frac{N_h}{N}\ . \tag{3}$$

This average is estimated at

$$\overline{X}' = \sum_{h=1}^{k} \frac{N_h}{N}\overline{X}_h \tag{4}$$

with $\overline{X}'$ being the assessor of average m.

X_{hs} is the value of the variable X for the company U_{hs} having number s inside strata h.

X_{hi} is the value of the variable X for the sample-company U_{hi} pointed out at the number i drawing inside strata h.

N_h/N represent the weight of the different strata in the population, n_h/n their weight in the sample. The estimation of the rate of waste treated is an important indicator which makes us see the management level of production wastes of economic goods in a more global perspective aimed at reducing flux of raw material and energy that will enhance of the matter flows and of energy than recommend the methods of the industrial ecology.

Estimated proportion of treated waste

This estimation is based on data collected in corporations that produce waste and in those specialized in the collection and treatment of industrial and domestic

wastes. By weighing the residues we could determine the percentage of the industrial waste treated. The debits of treated liquid flows were measured in each of the sample companies.

We note:

$Q_{hd_{ti}}$: the mass of waste produced by the corporation U_{hi} and processed;

Q_{hd_i}: the mass of waste produced by the corporation U_{hi};

ψ_{hi}: the rate of waste from corporation U_{hi} which are treated.

$$\Psi_{h_i} = \frac{Q_{hd_{ti}}}{Q_{hd_i}}. \quad (5)$$

Rectified at the population scale, the equation (4) leads to an average $\overline{\Psi'}$:

$$\overline{\Psi'} = \frac{1}{N}\sum_{h=1}^{k}\frac{N_h}{n_h}\sum_{i-1}^{n_h}\Psi_{hi}. \quad (6)$$

Results

This inquiry in companies enabled us, after treatment of the data, to obtain on the one hand quantitative results that were rectified with the assistance of our estimators and on the other hand of quality data that are presented following the two avenues of this study, namely waste and the informal sector.

Domestic and industrial waste

Domestic waste

The company HYSACAM takes care of the collection and treatment of domestic waste [20] in the cities of Douala, Yaoundé, Bafoussam, Limbe and Garoua. The quantity of waste collected represents 40 % of the produced waste and is constantly on the increase as illustrated in the Fig. 2.

Domestic wastes are mostly made up of a fermentable fraction (78.8 %), an inert fraction (10.0 %), and a combustible fraction (11.2 %). HYSACAM exploits several waste dumps of which the main ones are in the neighbourhoods of Makèpe and PK10 in Douala and Nkolfoulou in Yaoundé. The density of waste entering into dump is of 4.5 kN/m^3 and their composition is presented in the Table 1 hereafter.

Table 1

Composition of waste

Fractions	Average (%)
Wood	0.82
Rubber	0.59
Paper	9.86
Gravel	0.91
Metal	1.26
Plastic	8.34
Textiles (leather and cloth)	4.26
Glass and ceramics	1.13
Organic matter	65.79
Finished elements (< 20 mm)	6.95
Hospital waste	0.08

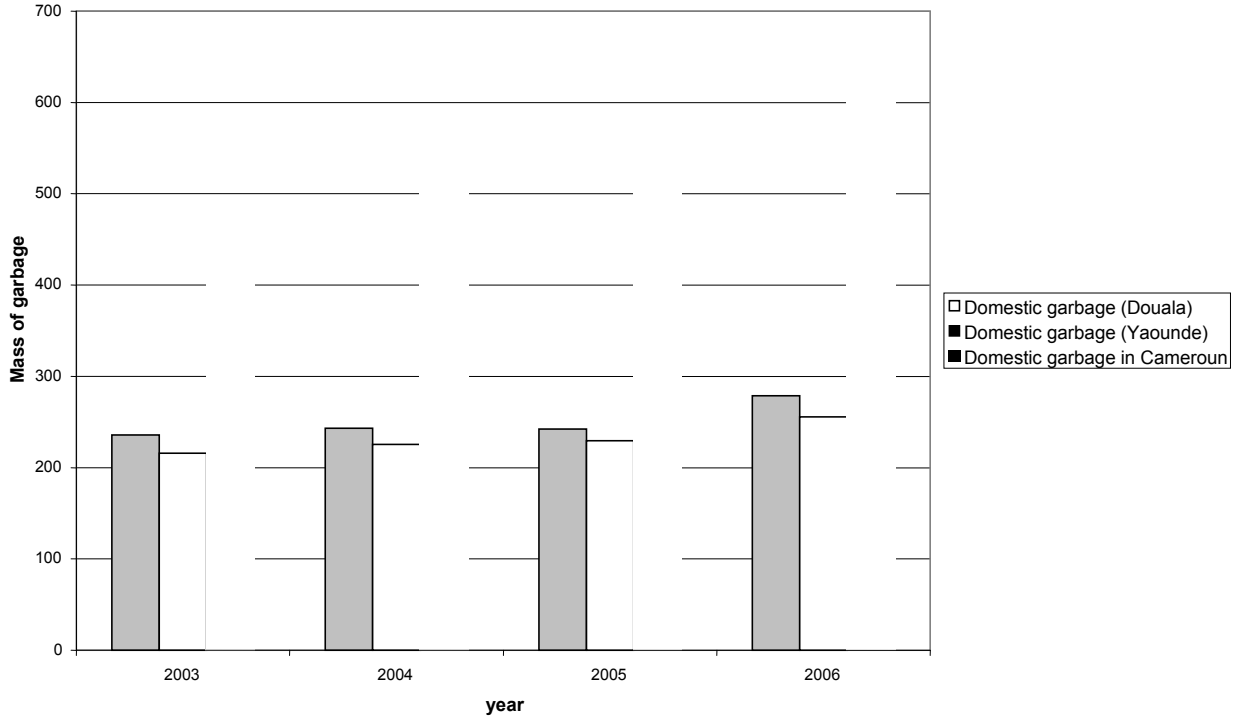

Fig. 2. *Evolution of household waste mass collected by HYSACAM*

Within the framework of environmental protection and development of domestic waste, several initiatives were taken in collaboration with various partners (the National Institute of the Applied Sciences (INSA) of Lyon and the Agency for Environment and Mastery of Energy (ADEME) in France, the Agronomy and Agricultural Sciences Faculty (FASA) of the University of Dschang, and the National Higher School of Engineering ENSP of the University of Yaounde I); this led to the obtention of 25 % of compost matter from household waste [21].

Industrial waste

Most of the industrial waste matter [20] has a high toxicity and their treatment is costly. Two corporations, BOCOM and BOCAM situated in the industrial zone of Bonabéri in Douala, are specialized in the treatment and the recycling of industrial waste which are essentially used oil and waste waters, hydrocarbons slough, used filters, soiled rags, soiled hydrocarbons earths, plastic, lead, cadmium, paint waste and other liquid effluents. Table 2 shows the evolution of the quantities of industrial waste treated by these two corporations during the three last years.

Their main customers are the following national or multinational corporations: ALUCAM, Cameroon Oil Transportation Company (COTCO), MOBIL, TOTAL, CAMRAIL, NESTLE, AES-SONEL, PERENCO, Cameroonian Corporation of oil deposits (SCDP), SAGA, Douala Autonomous Port (PAD).

ALUCAM, in its process for generating electrodes into electrolyzes, produces lead that is toxic and polluting. [20]. This corporation produced 15,000 kg of oily waste, 2,000 kg of oily residues and 500 kg of lead in 2006. It also became involved in a vast program of environmental management that enabled the reduction of its waste by 10 % in three years and disposes henceforth of an underground dump with a technical of a cost of 2.5 million Euros.

Table 2

Evolution of treated industrial waste (2004-2006) [20]

Types of industrial waste (kg)	Year		
	2004	2005	2006
Oily waste	45000	75000	65000
Used Filtres	200000	215000	220000
Used oils and water	90000	125000	105000
Slough	1100	1325	1250
Hydrocarbon waste	1250	1500	1350
Paint waste	7000	7500	9000
Used tyres	6000	6500	7200
Lead from batteries	1000	1300	1700
Plastics	15	25	40

In the domain of agro-industry, this study estimated the proportion of industrial waste produced by activities in this sector and processed by the corporations specialized in recycling and cleanup. This ratio underwent important variations between 2004 and 2006 in each of the companies as shown in Fig. 3. This percentage is situated between 15 and 18 % for main agro-industries in Cameroon after adjustment. The agro-industrial wastes are of several types such as molasses (sugar factory), cotton waste, palm nut shells, and humid effluents (breweries). Table 3 indicates the quantities of waste produced by agro-industries.

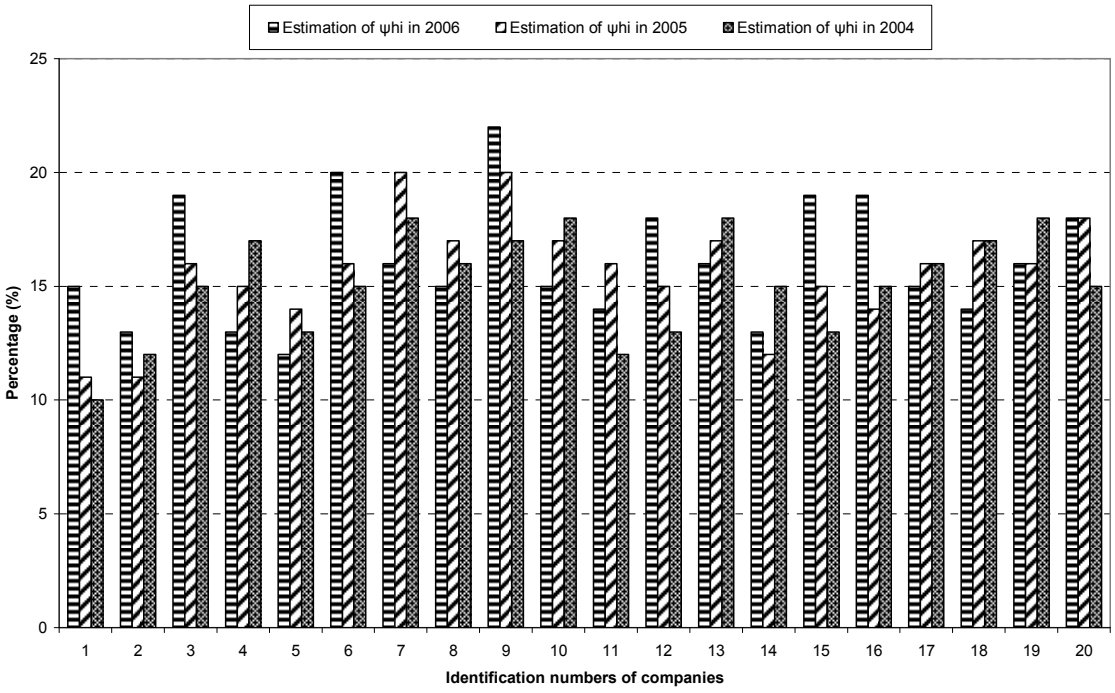

Fig. 3. *Evolution of percentage of treated agro-industry waste (2004-2006)*

Table 3
Weight of agro-industry wastes in thousands of tons

Types of waste	Year		
	2004	2005	2006
Palm nut residue	250	275	260
Molasses	405	412	408
Cotton	700	630	715
Wood	2100	2050	2150
Water	120	132	140
Oil	6	6.3	6.5
Plastic	0.45	0.57	0.65

Gas waste are so high and are a great source of nuisances, and their evaluation is a difficult task and consequently does not feature in this study. Among these residues are those resulting from such activities as transportation, where vehicles are in their majority old and worn out, with poorly regulated engines motors, and where the use of unleaded fuel remains the rule.

Complying to quality norms in agro-industries

Compliance to quality norms that integrate protection of the environment in agro industries is an important preoccupation for both public authorities and the industrialists. Decree No. 98/313 of December 20 1998 to organize the Ministry of Industrial and Commercial Development (MINDIC) created a Normalization and Quality Unit whose missions are: elaboration of the norms, certification and accordance, promotion of quality and assistance to corporations [1]. The adoption of the SME (system of environmental management) enabled the agro-industrial Corporation "GUINESS S.A.-Cameroon" (brewery) to reach certain convincing results, such as: reduction of rejections by 30 % in 2006, reduction of greenhouse gases rejections by the improvement of energy effectiveness, elaboration of an environmental management policy spread out over 13 years, and the construction in 2005 of a wastewater treatment station.

The process to ensure compliance of companies to universal norms, such as the ISO 9001 (ISO 9001:2000 is today the standards universally accepted as giving assurance on the quality of goods and services in supplier-customer relationship) and ISO 14001 (relating to environmental protection and to the promotion of sustainable development) is still on-going, but the question that still stands is whether these constraints will be respected in the long term, the more so as national control organs do not have all the required expertise.

To illustrate local difficulties of implementing quality and environment norms, it should be pointed out that the number of structures having an ISO 9001 certification in Cameroon, all sectors put together, dropped from height in December 2001 to two in December 2003 (for comparison, it rose from 302 to 403 in Tunisia, and the world-wide increase is by 10 % during the same periods). The number of ISO 14001 certificates in Cameroon, all sectors put together, moved form two to only one during this same period, the world-wide growth being of 80 % in the same interval [22].

Informal sectors and waste

Markets of the informal sector are in the increase in all the sectors of activities just as is the number of workers that work in this domain. Fig. 4 indicates the evolution of the percentage of workers in this sector since 1980. Waste produced by the informal sector does not undergo any specific treatment and are dumped in the open or poured in drains. Data in this domain is sparse and imprecise. According to the statistics fro Customs, concerning used clothes, the quantity imported per year is of 120 tons. After sorting, 10 % is of poor quality, giving 12 tons and constitute non-biodegradable waste. In the same vein, the collection of scrap is a rather lucrative informal activity, estimated at almost 500 tons per year of quantities extracted from surrounding environment, representing 30 % of metals wasted rejected by various production chains. Still in this regard, the advent of Chinese low-cost motorcycles gave rise to the multiplication of hand-crafted units for oil change (mechanics) that reject waste in streams and sewers.

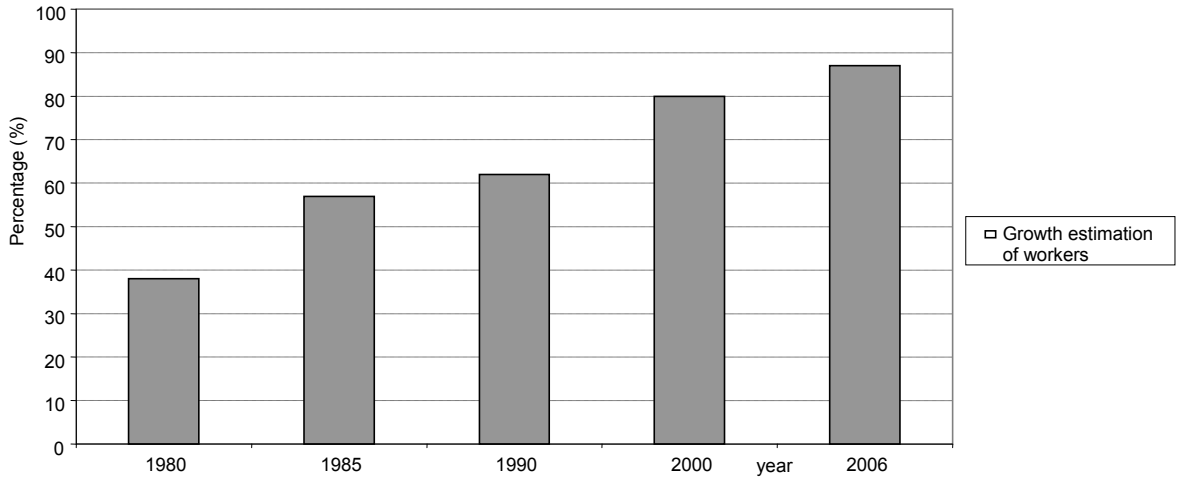

Fig. 4. *Growth estimation of workers*

If we suppose that each "taxi bike" rejects 3 litres of effluents a months and that the cities Douala and Yaoundé dispose altogether of 100,000 motorcycles, that gives up to 3600 m^3 of chemical non-treated substances that contaminate the water table each year.

Analysis and discussions

Treatment of domestic waste

The treatment of domestic waste improved and the last analyses of lixiviates carried out by Centre Pasteur of Cameroon [20] show that the concentration of heavy metals falls below European norms but that such parameters as the DBO5 and the DBO require constant controls; this implies envisaging experimentation of a specific treatment using biological filters for low levels of organic pollution.

Qualitative analysis carried out by ICAST [4] in the sector of waste management broadly revealed that certain unemployed persons create their own activities in the sector of recycling waste ("rag-and-bone men", "plastic waste collectors", "manufacturers of barbecues"). The conditions in which these activities are carried out are variously appreciated, from the viewpoint of work ethics. Nevertheless if recycling was organized activity, it is evident that it would provide a lot of jobs. It is this possibility to create unskilled jobs that explains the boom of this type of activity in most countries of the South; it also explains why several countries of the North maintain such jobs in multinational corporations specialized in the management and treatment of waste. Certain towns or regions, in Asia mostly, are also involved in waste management at global level: dealing with ships at the end of their lifespan, disposal of electrical and electronic waste, etc.

Similar examples of recuperation activities can be described in other Cameroonian industries (Union Allumettière équatoriale (UNALOR), Société des Oléagineux du Cameroun (SOC) for example). An industrial ecology approach, especially in the sector of recycling, can only but enhance the creation of jobs in a country such as Cameroon.

Treatment of the industrial waste

The management of the industrial waste is a global preoccupation because of the ever increasing flux of materials. The poisonous nature of the industrial waste and their potential to degrade environmental quality lead to the need to treat them before any rejection in the nature. The treatment and recycling of industrial production residues requires a know-how and means that are not within reach of all companies, and has as direct consequences a low treatment rate of industrial waste at 15 %, according to the investigation presented above.

The absence of a system for the management of industrial waste leads to spillages of waste in rivers, a source of pollution with disastrous consequences on health and the environment, as well as the liberation of CO_2 due to the dumping of industrial residues without confinement. Lead generated notably in the manufacture of electrodes by the aluminium factory ALUCAM must undergo specific treatment as the stipulated in the Basel Convention [15] but BOCOM, which works locally in the domain of recycling industrial residues, does not have all the required competences. The waste and energy flows going out of their incinerators are not treated but rejected into nature.

With regard to waste production in the agro-industry, mostly liquid waste, they are poured in gutters that drain rainwater and this provokes blockages and consequently frequent and serious floods in the cities during the rains. Compliance to quality norms that integrate protection of the environment in agro industries is an important preoccupation for both public authorities and the industrialists. The flux of material and energy is so important while companies do not dispose the financial and technological means to treat or to recycle industrial waste originating from their different production activities. The application of the principles and methods of industrial ecology led to slowing down the impact of green waste in certain developing countries; this is the case of India [3] or China [2].

What can therefore be the contributions of industrial ecology in the functioning of Cameroonian industries? Industrial ecology can contribute to the optimization of the flux of materials and energy through certain projects such as:

− valorising domestic garbage;
− valorising industrial waste;
− recovering gas produced by oil refineries;
− producing electricity from biomass;
− treating water and protecting the water table;
− ensuring complementarities between industrial production handicraft the informal sector.

Sensitisation of actors of the informal sector is an imperative even to authorities, elected officials, development groups and actors of the industry that must integrate this vision in the definition of national policy orientation on industrial development. Beyond sensitisation, actions aimed at ensuring training of decision-makers would logically complete the setup.

Other steps remain to be met in order to activate an industrial ecology process, such as the collection and sharing of reliable and updated data on industries and groups. It should be noted that a symposium in Cameroon recently treated this complex subject [23]. So too should several laws in Cameroon and the zone CEMAC be analyzed so as to handle imperatives on industrial ecology, especially texts relating to waste management.

At the level of Municipalities, reflections can examine the positioning of industrial zones, which initially are set up at the outskirts of the city (such as in Douala) but which are later surrounded by considerable population densities. The problematic of the environmental management of these Zones can be enlightened by the industrial ecology approach. A global analysis of Industrial Zones and material and energy flux therein

could lead to measures aiming at creating to encouraging the establishment of specific transformation companies that will enable the completion of these flows and consequently a decrease of industrial waste. The idea here is to envisage the transformation of classical industrial zones into eco-parks it of Kalundborg models [3] or Chinese eco-parks [2].

Conclusion

Industrialisation has contributed to an increase of productivity of Cameroonian companies, thus improving the living conditions of populations. But this increase of production activity in corporations was carried out for a long time without the integration of environmental constraints, and they have nevertheless shown their importance of the effects of pollution on populations. Industrial ecology constitutes a privileged approach that must allow the economy and in particular the private sector to play an active and constructive role in sustainable economic development strategies. Nevertheless, the industrial development and the principles of the industrial ecology appear at the present time as incompatible notions within the Cameroonian industries. The investigation conducted in a representative sample of the Cameroonian industries showed that input and energy consumption in the industry is not optimized, while the available resources are not used rationally. In addition, the recent phenomena of explosion of the informal sector and urban population to Cameroon, alongside an economic crisis that slowed down the attraction of investors to the country for international competition, as well as other structural weaknesses, all make it difficult to implement recipes for the deployment of industrial ecology.

Cameroon is a key nation in the attempt to implement an original way of sustainable economic and industrial development south of the Sahara, through industrial ecology and by respecting the Millennium Development Objectives alongside environmental constraints. This method can get inspiration from western and Chinese experiences underway. Several actions were evoked in this article. The idea now is to identify potential blockages to change and to formulate the specific adaptations to Cameroon and Sub-Saharan Africa.

References

1. Nkutchet M. L'énergie au Cameroun. Paris: L'Harmattan, 2004.
2. Fan X., Bourg D., Erkman S., L'économie circulaire en Chine // Futuribles. 2006. No. 234. P. 21-42.
3. Erkman S. Vers une écologie industrielle. Paris: Editions Charles Léopold Mayer, 2004.
4. Schmidlin M. Perspectives concrètes pour l'écologie industrielle en Afrique: l'Exemple du Cameroun. Report on a prospecting mission ICAST in Cameroon. January to May 1999. Geneva/Douala: ICAST, 2000.
5. World Summit on Sustainable Development, Johannesburg, 26th August to 04th September 2002, http://www.sommetjohannesburg.org.
6. Encyclopedia WikiDCia, http://fr.wikiDCia.org/wiki/Cameroun.
7. Statistical data from the Human Development Report, "UNDP", 2006, http://hdr.undp.org/hdr2006/statistics/.
8. Noumsi S., Tekeu J.C. Dimension industrielle du développement durable au Cameroun, ONUDI report, "ONUDI", 2001, http://www.unido.org/userfiles/timminsk/RIO10-IND-cameroon-french.pdf.
9. Kamgnia B., Touna M. Le comportement d'investissement privé au Cameroun: un resserrement de la contrainte fiscale. University of Yaoundé II, 2002.
10. Description of the activities of the group Fokou, including the companies BOCOM and BOCAM, http://www.fokou.com.
11. Diboma B. Offre d'énergie électrique et développement des industries au Cameroun, mémoire DEA, Université de Douala, 2007. P. 17-18, 62-63.
12. Latreille T., Leenhardt B., Massuyeau B. Perspectives économiques et financières des pays de la zone franc, projections Jumbo 2004-2005. Paris: AFD, 2004.
13. Ngnikam E. Energie et Ecodéveloppement au Cameroun // Revue hélio-international. 2006.
14. United Nations conference on Small Islands Developing States – Mauritius, January 2005, http://www.un.org/smallislands2005.
15. Clean Development Mechanism in Cameroon, http://www.cdmcameroon.org.
16. Kyoto Protocol, http://unfccc.int/2860.php.
17. Fohopa R., Garro O., Mortelette J.P. L'emploi et la formation au Cameroun, l'enquête génération 2000. Yaoundé: Edition Proximité, 2006.
18. Baillargeon G. Méthodes statistiques de l'ingénieur, volume I. Trois-Rivières: Les éditions SMG, 2006.
19. Grais B. Méthodes statistiques, tome II. Paris: Dunod, 2001.
20. Ndame M.K. Modélisation de la production de biogaz et conception d'un système d'acquisition de données sur le bio réacteur discontinue du laboratoire d'énergie de l'EDSFA de Douala, Master degree report, University of Douala, 2007.
21. Ngnikam E., Tanawa E. Les villes d'Afrique face à leurs déchets. Belfort-Montbéliard: Editions UTBM, 2006.
22. The ISO survey of ISO 9001:2000 and ISO 14001 Certificates – 2003, International Organisation for Standardization report, www.iso.ch/iso/en/iso9000-14000/pdf/survey2003.pdf.
23. Conference, Les TICE au service de la ville camerounaise, ENSP Yaoundé – January 2007, publication in progress, http://ticetville.projetcometes.org.