HEALTH AND ENVIRONMENTAL CONSEQUENCES OF INDUSTRIAL WASTES AND TOXIC CHEMICALS

*Ofoezie, I.E.[1] and Sonibare, J.A.[2]
[1]*Institute of Ecology and Environmental Studies,* [2]*Department of Chemical Engineering, Obafemi Awolowo University, Ile-Ife. Nigeria. *Corresponding author. e-mail: iofoezie@oauife.edu.ng. Tel: 234 36 231022*

Accepted in January 2004.

Abstract

Industrial wastes and toxic chemicals constitute a major challenge in environmental management. This challenge has increased dramatically with the increasing rate of industrialization, especially in the developing countries where modern technologies for waste minimization and conversion are lacking, and where resources for efficient handling of wastes are limited. In this work, the various processes leading to waste generations in major industries (Agricultural and agrochemical, Brewery, Battery, Cement, Chemical and allied products, Dyestuffs, Foam, Food, Iron and Steel, Metal works, Petrochemicals, Petroleum refining, Petroleum explorations and production, Pharmaceuticals, Plastics, Pulp and paper, Rubber, Soap, Sugar, Tannery, and Textile mills) are reviewed. The existing pathways through which the individual is exposed to these wastes and the probable health and environmental consequences of the wastes are considered. The various mitigation measures against such waste effects are also discussed to enhance effective management and sustainable development.

Key words: Industrial waste, toxic chemicals, mitigation, environmental management.

Introduction

Industrial production is an essential component of development. According to World Bank, (1984), national economies, household living standards and individual wealth are increasingly linked to industrial growth and development, for which reason, industrialization has become a key factor for assessing the economic performance of nations. Consequently, there is a growing tendency for nations to establish more industries and to increase the production capacity of existing ones.

However, industrial development does not come without a cost. It gives rise to serious adverse health and environmental consequences including environmental pollution, deterioration and degradation (Bradshaw 1992). The quantity, type and composition of wastes determine to a larger extent their impact on the environment. It is therefore essential that wastes be properly classified, as this will immensely enhance programmes of both proactive and reactive interventions (Kornhauser *et al.,* (1997).

Industrial wastes are generally classified on the basis of state, hydrocarbon content, degradation potential and toxicology. When confirmed or suspected, toxic substances may need further classification to ascertain their hazard levels.

A number of some industrial activities (cement, fertilizer, asphalt production, quarry operations, steel manufacture, lead and bronze smelters, metal scrap incinerations) contribute to particulate emissions in the atmosphere (Samara *et al.* 2003) in addition to other solid wastes they release. Others like brewery, dyestuffs and dye, pulp and paper, tanneries, etc are known to generate waste water that requires special efforts to treat while NO_x and CO which are gaseous emissions resulting from combustion activities contribute significantly to urban air quality (Ikhamaise and Kaasik, 2003) . Combustion of fossil fuel containing sulphur leads to SO_2 production (DH, 1995), another gaseous pollutants from industrial activities. Akeredolu and Sonibare, (2001) also reported the emissions of volatile organic compounds from a Nigerian refinery. This implies that such gaseous emissions emanate from petroleum refining industries.

Kornhauser *et al* (1997) reported that out of 12 million chemical substances registered in the Chemical Registry File of the Chemical Abstracts Services (CAS, Columbus, Ohio, USA), over 50,000 are produced on a medium scale (≥1000 kg/year) worldwide, and 4,000 at a large scale (≥1,000,000 kg/year). In Nigeria, over 650 of these substances have been identified, coded and registered either as dangerous or as moderately dangerous (FEPA 1991). The release of these chemicals into the environment gives rise to air, soil and water pollution.

All these industrial wastes (solid, liquid and gas) have been found to be of concern both to the environment and health of the people (Rosendahl 1998) and there is urgent need to arrest the situation. This goal will be achieved through enhanced environmental awareness among industry managers and policy makers who are directly concerned with waste generation and management at industry and regional levels. This paper reviews the existing information on waste profile of different industries and their effects on the environment and human health to highlight modalities for (i) identifying sources of pollution along the production lines of different industries, (ii) classifying and characterizing wastes and toxic chemicals and (iii) evaluating the adverse consequences of wastes and toxic chemicals. This review is necessary to enhance understanding of waste generation and waste effects, and provide options for effective management of wastes from different industrial sectors.

Industrial activities resulting in waste generation

Reviewing the various activities leading to waste generation in all industries known to current age may be an onerous task thus efforts are made in this work to limit discussions to few industries considered most common in developing nations such as Nigeria (Table 1).

A casual review of Table 1 and previous campaigns at monitoring the impacts of industrial activities on the environment revealed that waste activities and waste generations vary substantially among industries and depend largely on the processes and operations in each industry, the raw materials and intermediate products used and the final materials produced. In spite of this, some activities leading to the generation of common wastes appear common to most, if not, all industries. Prominent among these are the utility sections, use of raw materials, packaging and washings.

The utility section, for instance, is seen in nearly all industries in the developing nations probably as a result of poor public infrastructural development (Tyler 2002). It involves sundry support activities including steam generation from boilers, private electricity generation from electric generators, water supply, maintenance works etc. Utilities generate wastes that are sometimes specific to industries but at other times general to all industries. For instance, operations of electric power plants and boilers are known to result in emissions of gaseous pollutants, which include nitrogen oxides (NO_X), sulphur dioxide (SO_2), carbon dioxide (CO_2), carbon monoxide (CO), and particulates (DOE 2001). The constituents of these particulates may include Hg and carbon among other elements, depending on the type of fuel (natural gas, LPFO, diesel fuel, etc), among other factors, employed in firing the equipment.

Wastewater is another problem associated with utility in all industries but the physico-chemical characteristics of such wastewaters may vary from one industry to the other depending on industry's raw materials and final products. Maintenance works give rise to solid wastes, wastewaters, oil and grease and many other wastes. Packaging in many industries including chemical and allied, food, beverages and tobacco, soap and detergents, sugar etc. generate enormous amounts of solid waste in the form of waste papers, defective plastics and metal containers and/or broken bottles depending on the nature and type of packaging involved (Ojanuga *et al.* 1981).

In contrast to utility and packaging, there are other activities, which are peculiar to some industries and may lead to the generation of characteristic wastes. For instance most activities in the iron and steel industry, e.g., blast furnace operations, rolling, smelting and foundry are peculiar to that industry and so are saponification and salting out peculiar to the soap and detergent industry.

Besides these activities, some waste types and pollutants may be generated by many industries while others are industry specific. For instance, fumes, mist and dust result from several activities in many industries including the brewery, agricultural, battery, food, beverages and tobacco, iron and steel, metal works, petrochemicals etc. Similarly, wastewaters are discharged from nearly all industries although their characteristics may be industry related. For instance, wastewaters from the brewery, food, beverages and tobacco, rubber and sugar industries contain mainly biodegradable materials, for which reason BOD is a major concern in such industries. COD is an additional concern in the soap and detergent, tannery, textile, petroleum, plastics, paper and pulp as well as chemical and allied industries due to excessive use of chemical raw materials and/or intermediate products. Hydrogen sulphide which gives rise to foul odour in the environment is particularly a problem in the pulp and paper, rubber, tannery and textile industries. Oil and grease is not only a problem in the petroleum and allied industries but also in the iron and steel and the metal works industries where quenching and cooling are major activities.
The major pollutants in the agricultural industries are fluoride and ammonia emissions due to application of superphosphate and urea fertilizers respectively. Several industries such as the

battery, chemical and allied, iron and steel, petroleum and allied, pulp and paper, tannery and textile emit SO_X and NO_x which give rise to acid rain in the environment (Akeredolu and Badejo 2000). Although very few studies have analysed the contents of particulate matter from various industries, Ikamaise *et al.*, (2001) reported high concentration of Hg, Cd and Zn in samples collected from small scale battery charging, welding and paint spraying workshops in Ile-Ife, Nigeria. The results of this investigation suggests that the prospect of heavy metal pollution of the environment may be high in industries such as the petroleum and allied, tannery, textile, battery, iron and steel, sugar, etc. where PM emission is a major concern.

Fate and pathways of pollutants in industrial wastes

Nature is well equipped to deal with its waste, and except in cases of proven poor sanitation, these wastes rarely give rise to adverse consequences (Bull 1992). The overall effect of pollutants depends on their fate and pathways in the environment. Gaseous wastes spread faster polluting large areas of the environment in a very short time, while liquid wastes, especially those disposed directly into flowing water bodies, follow this in speed and expanse. On the other hand, solid wastes have only a local effect although they persist in the environment for a very long time (Anderson and Prescod 1992). Inert gases with long half-life have the combined effect of gaseous and solid wastes, spreading over large areas of the environment and persisting in the environment for a very long time (Bull, 1992).

The pathways for industrial waste can be direct or indirect (EPA, 2002). In direct pathway, an individual is directly exposed to the contaminated medium, such as air or groundwater, into which the waste is released. But in indirect pathway, an individual is indirectly exposed when a contaminant that is released into one medium (for example, air) is subsequently transported to other media, such as water, soil or food, to which a receptor is exposed. For instance, pollutants released from the industries are dispersed through the air, and deposited on crops, pastures, soil, and surface water. If the plants or animal tissues take these, humans can be exposed by ingesting soil (through hand-to-mouth contact), ingesting plant products, or ingesting animal products (including fish). Also, consumption of contaminated groundwater and surface water as drinking water sources can be another major indirect pathway of such wastes.

The environmental consequences of wastes from a specific industrial sector, depends on the composition of waste generated by that sector at different stages and times, the quantities generated per unit time, how and where the wastes are processed and/or disposed, people responsible for the processing and disposal and the risks involved at each stage. This information must be properly collated, processed and interpreted before a meaningful conclusion can be drawn on the health and environmental consequences of the waste and industry involved (Kornhauser, *et al.*, 1997).

Consequences to the environment

The mist, dust and smoke emitted in industries may cause fog or smog in the environment, each of which obscures visibility and impairs pulmonary functions in humans and animals (Gilpin 1996). Although nearly all industries emit one form of aerosol or the other, these are of major concern in the petroleum, mining, cement and iron and steel industries (Obioh *et al.* 1994).

The acid rain effect of SO_X and NO_X emissions from different industries has important environmental implications to several natural processes including soil fertility, deforestation, infrastructure durability, water quality and aquatic life balances (Forster 1984; Akeredolu and Badejo, 2000; Akeredolu *et al.*, 1994; Ojanuga *et al.*, 1981).

The emission of green house gases such as CO_2 and CH_4 from brewery, food, beverages, tobacco and petroleum industries may contribute to global warming. Emission of H_2S from the food, beverages and tobacco, tannery and other industries may causes odour problems in the environment if not properly treated before discharge. Odour problems also occur from the discharge of biodegradable wastewaters on soil or into water bodies, without treatment. In addition, such wastewaters create conducive environment for the breeding of important animal and human parasites as well as vectors and/or intermediate hosts of human diseases (Bradshaw, 1992). It also reduces the quality of the water, making it unfit for drinking and for many other uses (Ogunfowokan and Fakankun, 1998). Oily wastewaters from petroleum and food related industries cause severe respiratory problems to aquatic life and depending on duration and spread in water may significantly limit both the density and diversity of aquatic species in affected water bodies (Bradshaw, 1992). The discharge of acidic and thermally polluted wastewaters from chemical industries onto soil or water bodies give rise to instant mortality of organisms. Solid wastes may pollute the environment as much as wastewaters. They also persist at the point of discharge and have a longer-term effect.

Consequences to human health

The adverse health effects outlined in Table 2 may occur at the individual, community, regional or global levels depending on the emission and exposure patterns and the environmental fate and pathways of the pollutants. The most vulnerable individuals are the factory workers, company contractors, the scavengers and waste disposal personnel. Because members of these groups are usually directly exposed, they are most at risk of being affected. However, the severity of the toxic effect will depend on the susceptibility of the individual and the interaction of the pollutants with other metal chemicals in the environment. This is because, while some interactions are synergistic, others e.g. cadmium-zinc, mercury-selenium are antagonistic (Akeredolu 1998).

Table 1. Environmental effects of pollutants from different industrial sectors.

Industry	Source (Activity)	Waste type	Pollutant	Environmental Effect
Agricultural and agrochemical	Mixing, Chemical Reactions, Utilities	Dust, mist; Acid and gypsum, wastewater	PM, F-, NH_4+, pesticides, SS, $PO_4$3-, As, NO_3-	Air pollution, water pollution, soil contamination
Brewery	Raw materials Preparation, Brewing, Washing, Packaging, Utilities	Fume, mist, spent grain, wastewaters, defective packages and labels	CO2, CH_4, H_2S, BOD, COD, TSP, SO_2	Odours, air and water pollution
Battery	Currying, Bobbing, Mixing, Packaging	Dust, Fume, Mist, Acid wastewater Plastic scraps	SS, Fe, Cd, Ni, Cu, Pb, Co, As, NO_2, SO_2	Air and water pollution, acid rain, soil contamination
Cement	Raw materials extraction, Crushing, Milling, Calcinations, Grinding, Packaging, Utilities	Dust, fume, slurry, wastewater, sludge	TSP, NO_X, SO_2, Heavy metals	Air pollution, water pollution, soil contamination
Chemical and allied products	Reactions, Washing, Utilities, Packaging, Effluent treatment discharge	Dust, fume, mist, smog, acid waste water, gypsum sludge	PM, SS, Cl-, Hg NO_x, $SO_4$2-, SO_2, F-, NO_3, acetic acid, COD, Heavy metals	Air pollution, water pollution, soil contamination
Dyestuffs and dye intermediates	Nitration, chlorination, and sulphonation of aromatic rings, milling	Organic vapour, wastewater	Zn, organics, Cr	Air pollution, Water pollution, odours
Foam	Foaming, cutting, grinding, utilities	Fume, Mists, Foam scraps	VOCs, NO_X, SO_2, TSP,	Odours, Solid wastes
Food, beverages and tobacco	Milling, Grinding, Mixing, Utilities, Packaging	Fume, mist, dust, oily wastewaters	PM, TSS, CH_4, H_2S, SO_2, NO_X	Odours, water pollution, Solid waste

Table 1: (Contd.)

Industry	Source (Activity)	Waste type	Pollutant	Environmental Effect
Iron and steel	Rolling, smelting and foundry processes	Dust, wastewaters, slag, sludge, fumes	TSS, phenols, $NH_4$3-N, CN, Fe, SOx, NOx, oil and grease	Air pollution, water pollution
Metal works, plating and finishing	Cuttings, anodizing, cleaning, rust proofing and stripping operations	Fume, wastewaters, sludge	Acids, CN, Hg, Cu, Ni, Cr, Zn, Pb, Cd, Sn, SS,	Air pollution, water pollution, soil degradation
Petrochemicals	Nitration, Oxidation, Alkylation, Hydrocracking, Polymerization, Washing, Utilities	Fume, waste water, sludge, spent catalyst etc.	Oil and grease, phenol, NH_4+, H_2S, TSS, BOD, COD, Pb_2+, Cr, Cd2+, SOx, NOx, CO, VOCs	Odours, air pollution, water pollution, soil contamination
Petroleum exploration and production	Cutting, Drilling, Utilities	Dust, fume, drilling fluids and muds, oily wastewater	Oil and grease, TSS, BOD, COD, Pb2+, Cr (VI), Zn2+, Cu2+, Cd2+, hydrocarbons	Air and water pollution, soil contamination, impaired photosynthesis
Pharmaceuticals	Pharmaceuticals intermediates, mixing, grinding, washing, packaging	Dust, fumes, Wastewater	Process dependent, BOD, TSS, SO2, NO_X	Air, water and soil pollution
Plastics and synthetics	Extraction, Moulding, Washing/cooling, Utilities, Mould preparation	Fumes, wastewater, waste plastic products	VOC, hydrocarbons, BOD, TSS, COD, phenols, Zn, Cr, oil and grease, fluorides, Cu	Air, water and soil pollution
Petroleum refining	Crude distillation, Thermal/ catalytic cracking, Heat exchanging operations, Decoking, Sulphur removal, Utilities	Gaseous emissions, waste water, oily sludge, spent catalyst, VOCs	Oil and grease, phenol, BOD, COD, hydrocarbons, NH_4, H_2S, TSS, Cr, Pb2+, Cd, SO_2, NOx, CO, VOC, PM	Odours, acid rain, air pollution, water pollution, soil contamination

Table 1: (Contd.)

Industry	Source (Activity)	Waste type	Pollutant	Environmental Effect
Pulp and paper	Wood digestion, bleaching, mixing, Utilities	Dust, foul gas, bark, sawdust, clarifier sludge, waste water	BOD, COD, TSS, PM, H_2S, SO_2, NOx, $SO_4$2-	Air, water and soil pollution, acid rain
Rubber	Tapping and straining, coagulation, milling, vulcanization	Foul gas, waste water, waste latex	VOC, BOD, TSS, Pb, Cr, Zn	Odours, air, water and soil pollution
Soap and detergent	Saponification, salting out, washing, utilities, packaging	Gaseous emissions, wastewaters	BOD, COD, TSS, Oil and grease, PM, SO_2,	Air, water and soil pollution
Sugar	Extraction, concentration and crystallization, cubbing, washing, utilites, and packaging	Bagasse ash, cake and dust, wastewater	BOD, TSS, PM	Air, water and soil pollution
Tannery	Tanning, hide washing and treatment, rendering and screening processes, shaving, drying	Fumes, wastewater, sludge	BOD, COD, TSS, Cr (III and VI), oil and grease, Cl-, SO_2, NOx, H_2S, PM	Odours, colour, acid rain, air, water and soil pollution
Textile mills	Yarn preparations, weaving, scouring, dyeing, printing, utilities	Gaseous waste, wastewater, solid waste	BOD, COD, TSS, Cr, SOx, phenols, coliform, PM	Odours, colour, air pollution, water and soil contamination

Source: FEPA (1991); UNEP (1991); BMA, (1991); Francis (1994); Faboya (1997).

Table 2. Health consequences of common pollutants in industrial wastes

Signs and symptoms	Inorganic pollutants												Organic pollutants						
	Pb	Hg	Cd	F	As	Zn	Cu	Se	Te	Co	Cr	Ni	C_6H_6	CCl_4	DDT	C_6H_5OH	C_2H_5	PCB	PCT
Abortion	x			x															
Abdominal pain	x	x		x	x														
Alopecia	x			x	x														
Anaemia	x	x		x	x	x													
Anorexia	x	x			x					x									
Arthritis				x															
Skin bronzing					x			X											
Carcinogenesis	x				x						x	x							
Cirrhosis							x												
Dental mottling				x															
Dermatitis		x			x			x			x	x							
Fatigue	x	x			x														
Foetal damage	x												x	x	x	X	X	x	x
Garlic breath								x	x										
Headache	x	x	x	x	x														
Hepato-splenomegaly						x												x	
Hyperkeratosis					x														
Hypogonadism						x													
Metallic taste	x	x	x																
Myocarditis										x		x							
Myopathy	x																		
Nausea	x	x	x		x		x			x		x							
Vomiting	x	x	x		x		x			x		x							
Nephritis	x	x	x	x															

Table 2: (Contd.)

Signs and symptoms	Inorganic pollutants												Organic pollutants						
	Pb	Hg	Cd	F	As	Zn	Cu	Se	Te	Co	Cr	Ni	C_6H_6	CCl_4	DDT	C_6H_5OH	C_2H_5	PCB	PCT
Osteomalacia			x																
Peripheral neuritis	x				x														
Polycythaemia										x									
Pulmonary effects		x	x	x		x	x				x	x							
Rhinitis										x	x								
Salivation		x																	
Skeletal deformity			x	x															
Thirst		x																	
Thyroid disorder										x									
Tremor		x			x														
Vertigo								x											
Weight loss	x	x			x													x	x
Mutagenesis													x	x	x	X	x		
Tumorgenesis													x	x	x	X	x		
Irritation													x	x		X			

Source: UNEP (1991); BMA (1991); Akeredolu (1998); Kornhauser et al. (1997).

Consequences at the community, national, regional and global levels affect people who are unsuspecting and who are not directly involved in the generation, processing or disposal of wastes. They are usually associated with gaseous emissions or liquid effluents discharge into flowing waterways with several downstream riparian users. Either in air or water, the pollutants may be inhaled, taken with water or bio-accumulate in other organisms e.g. fish which humans later eat. The most typical example is the Mina Mata disease which killed over 800 persons, several thousand domestic animals and destroyed the fish stock and other aquatic life in Mina Mata Bay and adjoining rivers and oceans due to indiscriminate discharge of mercury-containing effluent from an acetaldehyde making factory in Japan (BMA 1991; Francis 1994).

Consequences to animal health

Animals inhale or ingest the waste substances and depending on the sensitivity of the organism, the concentration of the toxic chemical in the environment and the toxicity of the chemical substances the organism may experience varying toxicity effects ranging from neurological dysfunction, haemorrhage to instant death (Badejo 2000). However, the overall consequences are largely dependent on the threshold limit value (TLV) and the sensitivity of the animal to the toxic substance (Van Straalen 2000). Exposure to lethal concentrations of sensitive pollutants may lead to instant toxicity effect and death while sub-lethal concentrations give rise to chronic toxicity reactions, which though may not be fatal, do have other significant consequences including bioaccumulation and biomagnifications along trophic levels (Badejo, 2000). Besides, hazardous wastes and toxic chemicals also affect the immune response in many aquatic organisms especially fish (Solomon 1998). In many instances, immunity is adversely affected and the organism becomes more vulnerable to subsequent exposures.

Mitigation Measures

The various health and environmental effects of industrial activities highlighted in the above sections point to a clarion need to balance its overwhelming benefits with its adverse consequences to ensure sustainable development. To achieve this goal, it is essential that wastes generated at all levels should be recognized, classified and discharged into the environment only when it is certain to constitute minimal risk to the environment. Several institutions, global, regional and national have provided useful limitation guidelines for assessing risk levels in wastes and recipient air, water or land environment. Table 3 outlines the Nigeria Ministry of Environment's (FEPA, 1991) limitation standards for effluent discharge into the Nigerian freshwaters and land. Where a given waste fails to meet these standards it is essential to treat such wastes before they are discharged into the environment (FEPA, 1991). The various options for waste management are outlined below:

Wastewater Control

If the compositions of wastewater generated from an industrial activity fall below the threshold limit, such water should be treated before being discharged to public waterways to avoid environmental contamination. Conventional methods of wastewater treatment employ physical, chemical and/or biological processes depending on the type, quantity and toxicity of the wastes

(Mara 1977; Horan 1993, Ogedengbe 1998). Physical methods involve the separation of solids from liquid using simple screening operations or the complex processes such as sedimentation, grit removal, conditioning, floatation, thickening etc. (Obioh, 1998).

Chemical methods are used when physical processes alone are inadequate to achieve set goals. They involve the addition of chemical substances such as lime and alum or lime and ferrous sulphate to coagulate or flocculate suspended solids that are then removed by physical means (Mara 1977). The biological methods are primarily used to reduce BOD components of wastes to acceptable levels by converting unstable organic compounds to stable forms using micro-organisms (Gloyna 1971; Horan 1993; Obioh 1998). This process is carried out under the aerobic or anaerobic conditions. In the aerobic process, oxygen may be provided by the trickling filters, activated sludge systems, lagoons or spray irrigation.

Solid waste treatment

As indicated in Table 1, industrial wastes at times come in solid form. For a treatment of waste of this nature, many techniques have been developed and the selected one at a point in time depends among other factors on compositions, quantity, and form. The most commonly used methods of solid waste treatment include reduction, incineration, compactment, sizing and disposal (DOE 1997).

Solid waste reduction is a treatment method in which waste volume are reduced in some ways such as incineration, compaction, and sizing. The volume waste reduction assists in minimizing the storage and disposal sites that may eventually be required for final disposal. This generally results in extending the period by which an existing disposal site can be used.

Incineration is an engineered process that uses high temperature thermal oxidation to convert organic or organic-inorganic wastes to a less bulky, less toxic or less noxious material. It may be thermal or catalytic. High efficiency incinerators can control harmful effluents so as to comply with all environmental and regulatory laws. Resulting incineration ash which may contain radioactive and heavy metals that were in the initial stream, is packaged and disposed of using much less space than the original waste volume would require. Associated airborne effluents can also be carefully processed to ensure safety.

In solid waste compaction, the volume of noncombustible waste is reduced by compressing it into a smaller, denser form. Crushing drums and shredding wastes are some of the methods used in achieving this goal. If sizing process is to be used, a plasma arc torch is required to cut large pieces of contaminated metals into smaller pieces that require less packaging space. Once reduced in size, the metal pieces can be stacked in containers and then burned to low-level waste.

Remediation of contaminated land utilizes a variety of methods depending on whether treatment is in-*situ* or non-in-situ (Amusan, 1998). In-situ technologies include volatilisation, biodegradation, leaching and chemical processes, verification, passive remediation and isolation/containment (Ross *et al*., 1988). Non-in-situ technologies include land treatment, thermal treatment, asphalt incorporation, solidification/stabilization, chemical extraction and excavation (Sozco and Straps 1988).

Table 3. Interim Effluent Limitation Guidelines in Nigeria for all Categories of Industries

Parameter	Limits for discharge into surface water (mg/l)	Limit for land application (mg/l)
Temperature (°C)	<40	<40
PH	6-9	6-9
BOD_5	50	500
Total suspended solids (TSS)	30	-
Total dissolved solids (TDS)	2000	2000
Chloride (as Cl^-)	600	600
Sulphate (SO_4^{2-})	500	1000
Sulphide (as S^{2-})	0.2	-
Cyanide (as CN^-)	0.1	-
Oil and grease	10	30
Nitrate (as NO_3^-)	20	-
Phosphate (as PO_4^{2-})	5	10
Arsenic (as As)	0.1	n.a.
Barium (as Ba)	5	5
Tin (as Sn)	10	30
Iron (as Fe)	20	n.a.
Manganese (as Mn)	5	n.a.
Phenolic compounds (as phenol)	0.2	n.a.
Chlorine (free)	1	n.a.
Cadmium (as Cd)	<1	n.a.
Chromium (Cr III and VI)	<1	n.a.
Copper (Cu)	<1	n.a.
Lead (Pb)	<1	n.a.
Mercury (Hg)	0.05	n.a.
Nickel (Ni)	<1	n.a.
Selenium (Se)	<1	n.a.
Silver (Ag)	0.1	n.a.
Zinc (Zn)	<1	n.a.
Calcium (Ca^{2+})	200	n.a.
Magnesium (Mg^{2+})	200	n.a.
Boron (as B)	5	5

Source: (FEPA, 1991).
n.a. – not available

Gaseous waste treatment

Gaseous waste come in different forms but one of the most common ways of treating them is the use of wet scrubbing (Akeredolu 1984). A wet scrubber is a device utilizing a liquid, designed to separate particulate matter of gaseous contaminants from a gas stream by one or more mechanisms such as inertial impaction, interception, diffusion, absorption, condensation, etc. If waste gas streams are combustibles, flares can also be employed (Stone et al 1992) for treatment.

Clean Technology Options

In contrast to the conventional methods which only aim at improving the quality of generated wastes, new technologies are being developed to reduce the quantity of wastes generated at source or convert wastes to more useful forms. Most available waste minimization technologies utilize biological agents that have the ability to consume the various pollutants and substrates in the environment (Solomon, 1998). For instance, bakers' yeast (*Saccharomyces cerevisiae*) may be used to remove fermentable sugars (maltose, glucose, sucrose) in the environment while lactose can be handled with such yeasts as *Candida pseudotropicalis*, *C. kyfer* and *Kluyveromyces fragilis* (Solomon, 1998).

Also, at the design stage of a proposed industrial activity, several process routes should be considered so as to be sure that those with likely minimum waste generation, among other factors are considered.

Conclusion

The various processes leading to wastes generation in the industries have been discussed in an introductory manner and the pathways as well as the implications of these wastes on animal, man, and the environment highlighted. With proper attention given to these wastes, it has been shown that they can be controlled for the benefit of the society.

Acknowledgement

The authors are grateful to Dr. F. A. Akeredolu of the Department of Chemical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria for useful contributions to the original manuscript.

Nomenclature

BMA- British Medical Association
BOD- Biochemical oxygen demand
COD- Chemical oxygen demand
DDT- Dichloro-diphenyl-trichloro-ethane
DH- UK Department of Health
DOE- US Department of Energy
EPA- US Environmental Protection Agency
PCB- Polychlorinated biphenyls
PCT- Polychlorinated triphenyls
PM- Particulate matter
TSP- Total suspended particle
TSS- Total suspended solids
UNEP- United Nations Environment Programme
VOC- Volatile organic compounds

References

Akeredolu, F (1984). A Review of Wet Scrubbing in Air Pollution Control. *Journal of the Nigerian Society of Chemical Engineers*, Vol. 3. pp. 10 – 25.

Akeredolu, F. A. (1998). Sources, classification and characterization of industrial wastes and toxic chemicals. A paper presented at the 1st certificate course on environmentally sound technologies (EST) for the management of wastes and toxic chemicals in the foods, beverages, breweries and bottling industries in Nigeria, organized by the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria. November 9-13, 1998. 13pp.

Akeredolu, F. A. and Badejo, M. A. (2000). An appraisal of air pollution problems in Nigeria and the relative contribution by industrial sources. In: Badejo, M. A. and Van Straalen (eds.). *Pollutants and their effects on terrestrial and aquatic ecosystems.* College Press Ltd., Ibadan. 19-30.

Akeredolu, F. A., Adeniyi, I. F., Isichei, A. O. and Oluwole, A. F. (1994). Precipitation and aerosol chemistry measurements in Nigeria. *Proceedings of IGAC/DEBITS Workshop, INSET*. Yamoussoukro, Ivory Coast, December 5-8, 1994, 15pp.

Akeredolu, F.A. and Sonibare, J.A (2001) Modeling of Volatile Organic Compounds (VOCs) Emissions from a Nigerian Refinery. *Ife Journal of Technology*. Vol. 10**,** No. 1. pp. 49 – 54.

Amusan, A. A. (1998). Land treatment and bioremediation of sites and contaminated areas. A paper presented at the 1st certificate course on environmentally sound technologies (EST) for the management of wastes and toxic chemicals in the foods, beverages, breweries and bottling industries in Nigeria, organized by the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria. November 9-13, 1998. 11pp.

Anderson, G. K. and Prescod, M. B. (1992). Degradation of organic wastes. In: Bradshaw, A. D., Southword, R. and Warner, F. (eds.). *The treatment and handling of wastes.* Chapman and Hall, London. 167-189.

Badejo, M. A. (2000). Pesticide pollution in aquatic ecosystems in Nigeria and some African countries. In: Badejo, M. A. and Van Straalen (eds.). *Pollutants and their effects on terrestrial and aquatic ecosystems.* College Press Ltd., Ibadan. 43-51.

Bradshaw, A. D. (1992). Pollution and ecosystems. In: Bradshaw, A. D., Southword, R. and Warner, F. (eds.). *The treatment and handling of wastes.* Chapman and Hall, London. 7-25.

BMA (1991). *Hazardous waste and human health.* British Medical Association, Oxford University Press, Oxford. 242pp.

Bull, A. T. (1992). Degradation of hazardous wastes. In: Bradshaw, A. D., Southword, R. and Warner, F. (eds.). *The treatment and handling of wastes.* Chapman and Hall, London. 155-166.

DH (1995). *Quantification of the Effects of Air Pollution on Health in the United Kingdom*. Department of Health, United Kingdom.

DOE (1997). *Waste Treatment*. U.S. Department of Energy, Washington, DC 20585

DOE (2001). *Analysis of Strategies for Reducing Multiple Emissions from Electric Power Plants: Sulfur dioxide, Nitrogen Oxides, Carbon Dioxide, and Mercury and a Renewable Portfolio Standard*. U.S. Department of Energy, Washington, DC 20585. pp.299.

EPA (2002). Industrial Waste Air Model (IWAIR) User's Guide. Office of Solid Waste, US Environmental Protection Agency, Washington DC 20460. August 2002.

Faboya, O. O. P. (1997). Industrial pollution and waste management. In: Osuntokun, A. (ed.) *Dimensions of environmental problems in Nigeria*. Davidson Press, Ibadan. 26-35.

FEPA (1991). *National Interim Guidelines and Standards for Industrial Effluents, Gaseous Emissions and Hazardous Waste Management in Nigeria.* Federal Environmental Protection Agency. 238pp.

Forster, B. A. (1984). Economic impact of acid precipitation: A Canadian perspective. In: Crocker, T. D. (ed.). *Economic perspectives on acid deposition control.* Ann Arbor Science, Ann Arbor, 97-121.

Francis, B. M. (1994). *Toxic substances in the environment*. A Wiley Interscience Publications, New York. 362pp.

Gilpin, A. (1996). *Environmental impact assessment: Cutting edge for the 21st Century.* Cambridge University Press, Cambridge. 182pp.

Gloyna, E. F. (1971). *Waste stabilization ponds.* WHO monograph series No. 60. World Health Organization, Geneva. 175pp.

Horan, N. J. (1993). *Biological wastewater treatment systems: Theory and operation.* John Wiley and Sons Inc., New York. 298pp.

Ikamaise, V. C., Obioh, I. B., Ofoezie, I.E**.** and Akeredolu, F. A. (2001). Monitoring of total suspended air particulate in the ambient air of welding, car painting and battery workshops in Ile-Ife, Nigeria. *Journal of Pure and Applied Sciences,* **7:** 743-748.

Ikhamaise, V and Kassik, M (2003). Assessment of urban air quality in south Estonia by simple measures. *Environmental Modeling and Assessment***.** Vol. 8 pp. 47 – 53.

Kornhauser, A., Vrtacnik, M. and DaSilva, E. (1997). Information support for toxic waste management. *Nature Resources*, 33, 2-17.

Mara, D. D. (1977). Wastewater treatment in hot climates. In: Feachem R., McGarry, M. and Mara, D.D. (eds.). Water, wastes and health in hot climates. John Wiley and Sons, New York, 98pp.

Obioh, I. B. (1998). Criteria for choice of waste management techniques. A paper presented at the 1st certificate course on environmentally sound technologies (EST) for the management of wastes and toxic chemicals in the foods, beverages, breweries and bottling industries in Nigeria, organized by the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria. November 9-13, 1998. 9pp.

Obioh, I. B., Oluwole, A. F., Akeredolu, F. A. and Asubiojo, O. I. (1994). *National inventory of air pollutants in Nigeria: Emissions for 1998.* SEEMS Nig. Ltd. Lagos, 338pp.

Ogedengbe, M. O. (1998). Technologies for industrial waste management. A paper presented at the 1st certificate course on environmentally sound technologies (EST) for the management of wastes and toxic chemicals in the foods, beverages, breweries and bottling industries in Nigeria, organized by the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria. November 9-13, 1998. 10pp.

Ogunfowokan, A. O. and Fakankun, O. A. (1998). Physico-chemical characterization of effluents from beverage processing plants in Ibadan, Nigeria. *International Journal of Environmental Studies,* 54, 145-152.

Ojanuga, A. G., Lekwa, G. and Akamigbo, F. R. O. (1981). Survey, classification and genesis of acid sands. In: Udo and Sobulo (eds.). *Acid sands of southern Nigeria.* Soil Science Society of Nigeria special publication monograph 1: 1-18.

Rosendahl, K.E. (1998). Health Effects and Social Costs of Particulate Pollution – A Case Study of Oslo. Environmental Modeling & Assessment, 3: 47-61.

Ross, D., Stroo, H. F. and Bourguin, A. W. (1988). Bioremediation of hazardous waste sites in the USA. In: Wolf, N. J., Van den Brink and Colon, F. J.(eds). *Contaminated Soil*. Klemer Academic Publisher, Dordrecht. 717-726.

Samara, C., Koulmitz, Th., Tsitouridou, R., Kanias, g., and Simeonov, V (2003). Chemical Mass Balance Source Apportionment of PM_{10} in an Industrialized Urban Area of Northern Greece. *Atmospheric Environment,* Vol. 37**.** pp. 41 – 54.

Solomon, B. O. (1998). Application of genetic engineering and other biotechnologies in environmental management. A paper presented at the 1st certificate course on environmentally sound technologies (EST) for the management of wastes and toxic chemicals in the foods, beverages, breweries and bottling industries in Nigeria, organized by the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria. November 9-13, 1998. 14pp.

Sozco, E. R. and Straps, J. J. M. (1988). Reviewing of biological soil treatment techniques in the Netherlands. In: Wolf, N. J., Van den Brink and Colon, F. J.(eds). *Contaminated Soil*. Klemer Academic Publisher, Dordrecht. 663-670.

Stone, D.K., Lynch, S.K., Pandullo, R.F., Evans, L.B., and Vatavic, W.M (1992), "Flares Part 1: Flaring Technologies for Controlling VOC – Containing Waste Streams" *Air & Waste Management Association* Vol. 42., No. 3, pp. 333 – 340.

Tyler, G., (2002). Public and Private Electricity Provision as a Barrier to Manufacturing Competitiveness. *Findings 221*, World Bank, December 2002. pp. 4

UNEP (1991). Urban air pollution. United Nations Environment Programme , UNEP/GEMS Environment Library No. 4. 36pp.

Van Straalen, N. M. (2000). Physiological and ecological factors determining variability of ecotoxicological responses in animals. In: Badejo, M. A. and Van Straalen (eds.). *Pollutants and their effects on terrestrial and aquatic ecosystems.* College Press Ltd., Ibadan. 111-127.

World Bank (1984). World Bank Report 1984. Oxford University Press, Oxford. 286pp.

World Health Organization (1976). Environmental health criteria 2: Polychlorinated biphenyls and triphenyls. World Health Organization, Geneva, 85pp.