Poultry, Fisheries & Wildlife Sciences

Bukola et al., Poult Fish Wildl Sci 2015, 3:2
DOI: 10.4172/2375-446X.1000138

Research Article Open Access

Consequences of Anthropogenic Activities on Fish and the Aquatic Environment

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Abstract

Persistence of pollution into our natural environment has concurrently led to instability, disorder, harm or discomfort to both the physical systems and living organisms inhabiting the ecosystem. Potentially harmful substances such as pesticides, heavy metals, paper mill waste, polychlorinated biphenyl and crude oil are often released into the aquatic environment. When large quantities of these pollutants are released there may be an acute impact as measured by large-scale sudden mortalities of aquatic organisms such as fish kills. Lower levels of discharge may result in an accumulation of the pollutants in body composition of fish. The effects of water pollution on fish species can be classified into acute effects and long term chronic effects, which includes immune-suppression, reduced metabolism, and damage to gills and epithelia. Pollution-related diseases include fin/tail rot, gill disease, hepatic damage and ulceration. Specific examples of fish diseases that reflect the effects of pollution include, fin and tail rot caused by *Amnonas hydrophila* and *Pseudomonas jluorescens*. The polluted water may have undesirable colour, odour, taste, turbidity, harmful chemical contents, toxic and heavy metals, pesticides, industrial waste products, domestic sewage, virus, bacteria, protozoa and worms. Fish species are not only tolerant to severe contaminated waters but show a variety of specific morphological deformities and lesions that appear to reflect the level of water pollution. Assessing morphological deformities is one of the most straightforward methods to study the effects of contamination on fish because of the ease of recognition and examination when compared with other types of biomarkers. The indiscriminate disposal of pollutants without pre-treatment should be discouraged. In order to avoid the effects of water pollution on fish health, effluents discharged from industries and other sources should be properly treated.

Keywords: Pollution; Fish health; Effluents; Biomarkers; Industries; Morphological deformities; Pollutants; Diseases

Introduction

Aquatic systems are considered as suitable sites for disposal and recycling the sewage and toxic wastes and drain off the excess to the sea. However, the increasing pollutant load and the over exploitation of the water resources for potable supplies, irrigation, industries and thermal power plants to meet the requirements of the ever-increasing population, significantly reduces their assimilative capacity. Thus, the dual stress exerted on the watercourses is ultimately faced by the biological communities inhabiting them. Of these, fish is one of the most important aquatic communities concerning man [1].

With exploding population and increasing industrialization and urbanization, water pollution by agricultural, municipal and industrial sources has become a major concern for the welfare of humanity. Water soluble toxicants from industrial and municipal wastes, leached soils and the atmosphere have rapidly transferred to natural bodies of water. While some of the pollutants decompose or volatilize, others form insoluble salts, which precipitate and get incorporated into the sediment. Uptake of such toxicants by aquatic organisms like fish may be followed by metabolism of the toxicants into more toxic derivatives. For example mercury from industrial effluents may be converted by microbial action into highly toxic methyl mercury which can then be taken up by fish. Many aquatic organisms have been known to concentrate toxic solutes from their habitat without any obvious damage to themselves.

They thus act as toxicant amplifiers, making the toxicants available to predators at dangerously high levels. Several cases of the adverse effects of environmental pollution on fish and fish consumers have been reported. The term pollution broadly refers to any undesirable change in the natural quality of environment brought about by physical, chemical, or biological factors [1]. The high rate of increase human population, rapid expansion in the industrial and urban activities and modernization of agriculture has resulted in generation of high volume of waste material causing gradual deterioration of valuable resources of biological productivity [1]. The increased anthropogenic load on our aquatic ecosystem determines the necessity of investigations devoted to adverse effects of pollution and its potential risk for aquatic ecosystems. A deleterious effect of pollution has been detected on populations of different organisms inhabiting the water body through various scientific researches. The decrease of some fish populations and partial loss of commercial fishing importance are among of the huge changes in the ecosystem [2].

It is a well known fact that biochemical, cellular, tissue, and organism modifications underline different types of ecosystem changes; the exposure of fish to chemical contaminants induces a number of modifications in different organs, particularly gills, liver and kidney. Therefore a wide range of histo-cytological alterations in fish have been developed and recommended as biomarkers for monitoring the pollution. This study is concerned with the evaluation of pollution influence on fish health status and establishment relation between

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Received April 24, 2015; **Accepted** August 21, 2015; **Published** August 28, 2015

Citation: Bukola D, Zaid A, Olalekan EI, Falilu A (2015) Consequences of Anthropogenic Activities on Fish and the Aquatic Environment. Poult Fish Wildl Sci 3: 138. doi:10.4172/2375-446X.1000138

fish health and environmental quality on the base of histological examination.

The pressure of increasing population, growth of industries, urbanization, energy intensive life style, loss of forest cover, lack of environmental awareness, lack of implementation of environmental rules and regulations and environment improvement plans, untreated effluent discharge from industries and municipalities leads to aquatic pollution and eventual death of aquatic organisms. The pollutants from industrial discharge and sewage besides finding their way to surface water reservoirs and rivers are also percolating into ground to pollute ground water sources. Pollution can be defined in several ways. Water pollution occurs when energy and other materials are released, degrading the quality of the water for other users.

Aquatic systems are subjected to pollution pressures associated with urbanization and population growth [3,4]. The introduction of these pollutants into aquatic systems constitute a major threat to hydro-chemical and fauna characteristics of the aquatic ecosystems [3,4]. Fish is one of the most valuable sources of high grade protein available to man and knowledge of its composition and nutritional value is essential.

The Lagos lagoon is one of the meandering networks of lagoons and creeks found along the coastline of southern Nigeria. It has continued to be under intensifying pressure from pollution such as sawdust and petrochemical materials [5]; untreated sewage [6]; detergents and industrial effluents [6], petroleum products; sawdust and faecal pollution [6]. Ajao [7] reported that the most obvious effects of pollutants on the populations of sessile and benthic organisms was a total elimination of species from some areas for varying periods in the highly polluted sites. One of the most critical problems of developing countries is improper management of vast amount of wastes generated by various anthropogenic activities. More challenging is the unsafe disposal of these wastes into the ambient environment. Water bodies especially freshwater reservoirs are the most affected. This has often rendered these natural resources unsuitable for both primary and/or secondary usage. This study is a review study concerned with the evaluation of pollution influence on fish health status and establishing relation between fish health and environmental quality on the base of histological examination.

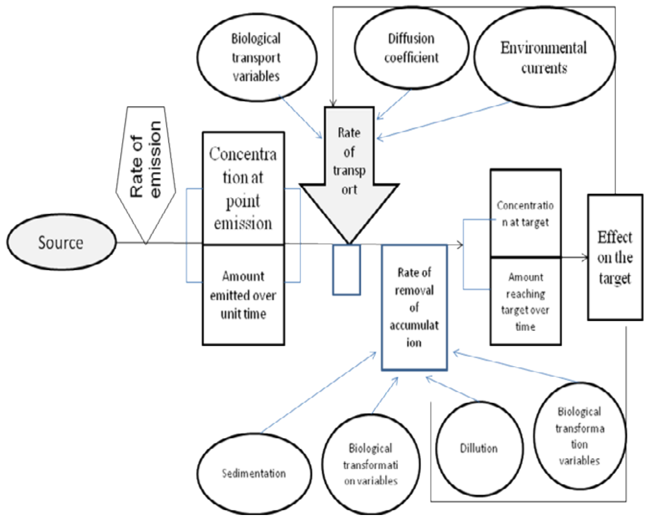


Figure 1: A generalized pollutant pathway [6].

Figure 2: Sewage collected from household septic tanks deposited at IDDO in the Lagos lagoon [8].

Materials and Methods

This paper adopts a review approach and relevant information were gathered from journals, books, technical papers, and other beneficial scholarly materials. Pollutants may enter the aquatic environment as a result of natural occurrences, such as the collapse of algal blooms and/or as a result of human endeavors, leading to adverse water quality. Some pollutants, e.g. pesticides, have been found in the tissues of aquatic animals. High levels of certain pollutants, e.g. from oil spillages, may be directly responsible for deaths of large numbers of aquatic animals. Furthermore, disease may develop long after the pollutant has been removed from the aquatic environment. In this circumstance, it would be difficult to prove that the original pollution led to disease.

Sources of Pollution

The heaviest polluting source for surface water is sewage from cities. Pollution is often classified as Point source or Non-point source (Figure 1).

Point source pollution

Point source pollution refers to contaminants that enter a waterway through a discrete conveyance, such as a pipe or ditch. Examples of sources of this category includes discharges from a sewage treatment plant, a factory etc. A point source pollution is a single identifiable source of air, water, thermal, noise or light pollution. It is negligible to an extent, distinguishing it from other pollution sources [8]. Point source pollution enters a water body at a specific site and is generally readily identified. Potential point sources of pollution includes effluent discharges from sewage treatment works and industrial sites, power stations, landfill sites, fish farms, and oil spillage via a pipeline from industrial sites [8] (Figures 2 and 3).

Non-point source pollution

Non-point source (NPS) pollution refers to diffuse contamination that does not originate from a single discrete source. NPS pollution is often the cumulative effect of small amounts of contaminants gathered from a large area.

The leaching out of nitrogen compounds from agricultural land which has been fertilized is a typical example. Nutrient run off in storm water from "sheet flow" over an agricultural field or a forest are also examples of Non-point source. Contaminated storm water washed off

Figure 3: Okobaba Sawmill waste entering the Lagos lagoon [8].

Figure 4: Runoff of fertilizers from a crop land.

of parking lots, roads and highways, called urban runoff, is sometimes included under the category of NPS pollution. However, this runoff is typically channeled into storm drain systems and discharged through pipes to local surface waters, and is a point source. Although these pollutants have originated from a point source, the long-range transport ability and multiple sources of the pollutant make it a nonpoint source of pollution. Other significant sources of runoff include hydrological and habitat modification, and forestry [8] (Figure 4).

Results

It is well established that at various times pollutants enter the aquatic environment. Examples of pollutants include:

1) Hydrocarbons: e.g. creosote [9], resulting from accidental discharge from tankers or deliberate spillage during wartime [6-8].

2) Pesticides: e.g. organochlorines [10], dioxin [11] and l,l,l-trichloro-2,2-bis-(l)- chlorophenyl) ethane (DDT) [12].

3) (Heavy) metals: e.g. tin, tributyltin and triphenyltin, have been incorporated in anti-fouling paints used extensively to prevent bio attachment and thence fouling of the undersurfaces of ships; arsenic, copper, zinc [9,10]; cadmium, lead and mercury which are discharged in industrial effluents.

4) Pulp mill effluents.

5) Plastics.

6) Organic sewage, including faecal debris, which may contain large populations of bacteria.

7) Inorganic nitrogen, as nitrate, nitrite and ammonia, which may be derived from fish farming (i.e. aquaculture) activities and agricultural run-off.

8) Toxins, such as from the collapse of dinoflagellate blooms.

This runoff may enhance the organic loading of the receiving waters, reduce the salinity, and cause localized temperature changes. However, the extent and longevity of pollutants in the aquatic environment needs to be established, and this will certainly involve effective monitoring programs (Figure 5).

Organic pollutants

Organic pollutants originate from domestic sewage (raw or treated), urban run-off, industrial (trade) effluents and farm wastes. Sewage effluents are the greatest source of organic materials discharged to freshwaters. In England and Wales there are almost 9000 discharges releasing treated sewage effluent to rivers and canals and several hundred more discharges of crude sewage, the great majority of them tot the lower, tidal reaches of rivers or, via long outfalls, to the open sea [8].

The main categories of organic pollutants are:

Polycyclic aromatic hydrocarbons: Polycyclic aromatic hydrocarbons (PAHs) arise from incomplete combustion or pyrolysis of organic substances such as wood, carbon or mineral oil.

Polychlorinated biphenyls (PCBs): There are two main sources of PCBs: Directly manufactured PCBs (by chlorination of biphenyls), used as hydraulic liquids. The other main source of PCBs in the environment is combustion processes, from waste incineration plants, fossil fuel burning and to other incomplete combustion processes.

Sources of other potential organic pollutants are listed below: Organic pollutants can originate from food and household related products, such as long chain fatty acids and their methyl and ethyl esters, originating from faeces, soaps and food oils. Plasticizers and flame retardants, preservatives and antioxidants, solvents fragrance, pesticides and herbicides (Tables 1 and 2).

There has been growing interest to determine heavy metal levels in the marine environment. Levels of contaminants in fish are of

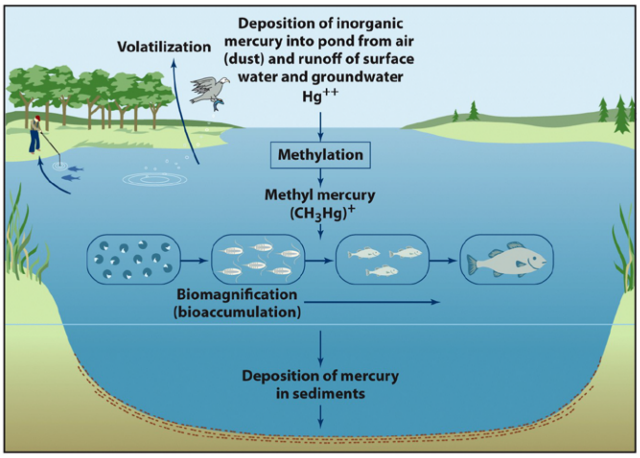


Figure 5: The pathway of mercury deposition inn sediments [5].

Sources	Pollutants	Threats to coastal ecosystems	References
Industrial Waste e.g. Vitamalt Plc	Organic pollutant, alcoholic brewer waste, biodegradable, Zn, Pb,Sulphate, Calcium, Magnesium sulphate,free chloride, caustic soda, hlorinedioxide and Hypochlorite	Low dissolved oxygen, eutrophication, pollutants get clogged in the gills of fish.	Ajao [8]
Soap Factories e.g. Lever Brothers Plc, Lorry Parks/Mechanic	Detergent, caustic soda from washing and cooling water, sulphurnated detergent, oil, grease, engine oil, petrol.	Prevent penetration of light, low dissolved oxygen in water, prolific growth of bluegreen algae and bacteria, eutrophication.	FEPA [49]
Plastic Industries e.g. Lotus Plastic	Hot polymer by-products, calcium, tin and lead.	Increases the temperature and bioaccumulation of metals often result.	FEPA [49]
Food Industries e.g. International Quality Food(Nig) Ltd, Lever Brothers Plc, Nestle Food Plc	Organic pollutants and biodegradables. Elevated water temperature which may affect fish.	Eutrophication, pollutants get clogged in the gills of fish and low dissolved oxygen.	FEPA [49]
Wood Shaving (sawdust) industries e.g. Okobaba sawmill	Biodegradable organic matter	Increased organic load, increased turbidity, reduction in dissolved oxygen content, emission of foul odour of hydrogen sulphide, enhanced fungal and bacterial population, impaction of a blueblack colouring presumably caused by lignin exudates. Sporadic occurrence of opportunistic species.	Okoye [51]
Sand and gravel extraction, dredging activities	Sedimentation, flocculation.	Alteration of bottom conditions, smothering effects, damage to spawning and nursery grounds, marked variation in sediment types, patchy distribution of some organisms.	
Hydrocarbons (waste oil discharge, shipping losses in harbour)	Oil and grease	Undesirable thick black flames of oil in	
Industrial waste waters (complex mixture) e.g. Chemical and Allied Products (Nig) Ltd Thermal pollution	Pollutants, waste heat, various inorganic and organic pollutants, heavy metals such as Cr, Cu, Zn, Fe Waste heat	sheltered waters, reduction in light penetration, loss of plankton, reduced dissolved oxygen, anoxic conditions in bottom sediments, risk to aquatic organisms and fish-eating birds.	

Table 1: Different types of waste pollutants from various industries in Lagos state.

Pollutant	Origin	Domestic usage	Storm runoff	Commercial effluent
Aliphatic hydrocarbons	Fuel	++	++	++
Monocyclic aromatic hydrocarbons	Solvents, phenols	+	+	++
PAHs	By-products of petrol transformation and insecticides	+	+	+
Halogens	Solvents, plastics, chlorination	++	+	++
Chlorophenols and Chlorobenzenes	Solvents, pesticides	+	+	+4-
Chlorinated PAHs	PCB, hydraulic fluids	(+)		++
Pesticides		+		++
Phthalate esters	Plastifler	+	+	+4-
Detergents		++	+	+1-
Nitrosamines	Industrial by-products (rubber)	0	+	++
Note: +++ very likely, ++ likely, + less likely present				

Table 2: Principal sources of organic micropollutants in urban wastewater treatment works.

particular interest because of the potential risk to humans who consume them. In attesting to these, Fin and shell fishes have been widely used as bio-indicators to monitor heavy metals concentrations in the coastal environment, due to their wide range of distribution, and also their important position in the food chain. Pollution studies have revealed elevated levels of Pb, Cr, Ni, V, and Zn in Port Harcourt and Warri sediments and some species of fauna, suggesting inputs from petroleum exploration and exploitation [12].

Persistent organic pollutants

Typical results of the human activities proved to be elevated levels of heavy metals present in fresh waters, and among these microelements lead (Pb), cadmium (Cd), mercury (Hg) and zinc (Zn) are most specific [13]. The arousal of anthropogenic pollution in the environment evoked the necessity to develop the pollution impact management strategies.

The most important factors are: distribution of heavy metals in individual organs and the respective affinity of these organs for metals, uptake kinetics, regulatory mechanisms (especially for essential metals), effects on the metabolism evoked by heavy metals, the synergism of metals and their uptake), the fish as the end consumers in the aquatic food chain and thus their use as an indicator of heavy metal enrichment [13]. Knowledge of biological factors such as age and size, life cycle and life history, seasonal and local variations of heavy metal content in the animal, and the trophic level of the species, as well as of the biological half-life of the metal are essential [13]. No matter how many good health supplements or procedures one takes, heavy metals overload will be a detriment to the natural healing functions of the body [12].

Mercury in fish

Most fish species have mercury levels of approximately 0.15 ppm in muscle tissue. However, recreational fish - Red drum (*Scaenops ocellatus*) also contaminated: up to 3.6 ppm; 95% >0.5 ppm health limit [14]. Toxic effects reported in marine mammals include:

Lesions in the liver and other tissues; decrease nutritional state and fatty degeneration. High mercury (and other heavy metal) levels have also been associated with disease -induced mortality i. e. mercury may damage the immune system, nearly all fish and shellfish contain traces of methyl-mercury.

Other pollutants in fish

Like mercury, other pollutants, including PCBs, accumulate in fish and in the body tissues of people who eat fish regularly. These chemicals also can increase the damage to the brain from mercury [15]. Lead is known to damage the brain, the central nervous system, kidneys, liver and the reproductive system [16]. It is also accumulated in nervous tissue [16].

Changes in the physico-chemical parameters of water due to pollution

Physical parameters

Temperature: Temperature of water may increase due to thermal pollution when water is used to cool power stations and due to waste heat from industries.

Turbidity and colour: Turbidity of water may increase due to soil erosion or heavy algal bloom due to high level of organic and inorganic nutrients from sewage water or agricultural waste. Turbidity, dye and pigment pollutants affect the general colour of water.

Depth and flow: Flow and depth of the water body may be reduced due to heavy siltation of sediments coming from land erosion.

Light: Due to high turbidity and colouration of the water bodies, penetration of light is reduced [1].

Chemical parameters

pH: pH of water may be acidic due to acid rain that originates largely from burning of coal and oil. Acids also originate in large quantities from mines and various industrial processes (waste from DDT factory, battery, vinegar, tanneries). Fish usually live at pH levels between 6.0 and 9.0, although they may not tolerate a sudden change within this range [1].

Dissolved oxygen: Dissolve oxygen level of water is reduced to greater extent when Heavy sewage pollution or other effluents containing high organic matter are discharged into it. These are broken down by the microorganisms, which used up the dissolved O_2 [1].

CO_2: Eutrophication and organic pollutants responsible for depletion of dissolve oxygen increase the CO_2 level in water bodies, due to decomposition of undecomposed or partially decomposed organic matter [1].

Alkalinity: Wastes associated with tanning, wool scouring, the mercerizing of cotton and the manufacture of certain chemicals (in chloro-alkali industries) may contain caustic soda (NaOH), sodium carbonate or lime. Such alkaline effluents may have a pH of 12-14 and lethal to all types of stream life, including bacteria.

Salinity: Excessive amount of salts brought by sewage; and effluents from chloro-alkali industries increase the chloride level thereby salinity of water, which is responsible for increase in the osmotic pressure. Salinity also reduces dissolve oxygen level.

Dissolved solids: These includes the following;

(i) Nitrates and phosphates: Water polluted by agricultural wastes, soil erosion and organic pollutants (sewage and biodegradable synthetic detergents) are rich in nitrates and phosphates.

(ii) Heavy metals: Hg, Zn, Ni, Cd, Pb, Mn, Cu, Fe, Cr, As, Se etc are present in natural water in very trace amount that's why they are called trace elements [1] (Tables 3 and 4).

Other consequences of cadmium exposure are: anemia, yellow discoloration of the teeth, rhinitis, occasional ulceration of the nasal septum, damage to the olfactory nerve, and anosmia [15].

Pollutants, fish and ecology

Eutrophication: Pollution due to domestic sewage increases the organic load and pollution due to agricultural waste (residual fertilizers) and soil erosion containing nutrients such as nitrates; phosphates, potassium etc. fertilize the water and increase the rate of productivity of the aquatic ecosystem. This results in higher growth of phytoplankton. Water becomes turbid due to excessive growth of phytoplankton and soil eroded particles [1].

Aquatic lives face severe oxygen shortage due to;

i) Bacterial Decomposition of untreated sewage into their inorganic components assimilates dissolve oxygen from the water in the process.

ii) High turbidity restricts the penetration of sunlight in deeper layers and benthic plants could not photosynthesize.

iii) When algal bloom die, they sink to the deeper waters and in the

Fish species	Mean concentration fish species of lead (mg/kg)			
	Surrounding water	In muscles	In kidney	In liver
Metacembelus Iconnbergii	0.001 ± 0.00	0.002 ± 0.001	0.012 ± 0.002	0.007 ± 0.001
Clarias lazera	0.002 ± 0.001	0.003 ± 0.001	0.013 ± 0.002	0.006 ± 0.001
Citarinus citharus	0.003 ± 0.001	0.004 ± 0.001	0.010 ± 0.002	0.007 ± 0.001
Tilapia zilli	0.002 ± 0.001	0.002 ± 0.001	0.015 ± 0.003	0.004 ± 0.001
Erpetoichithys	0.005 ± 0.001	ND	0.014 ± 0.001	0.010 ± 0.001
WHO limit for heavy metals in food	0.05	0.05	0.05	0.05
FAO limit for Heavy metals in fish	0.05	0.05	0.05	0.05
All values are mean values of triplicate determinations ± SD.				

Table 3: Concentrations of Lead in some selected species of fish.

Fish species	Mean Concentration Fish species of lead (mg/kg)			
	Surrounding water	In muscles	In kidney	In liver
Metacembelus Iconnbergii	0.001 ± 0.00	0.001 ± 0.00	0.005 ± 0.001	0.003 ± 0.001
Clarias lazera	0.001 ± 0.00	0.001 ± 0.00	0.004 ± 0.001	0.003 ± 0.001
Citarinus citharus	0.001 ± 0.00	0.002 ± 0.00	0.005 ± 0.001	0.003 ± 0.001
Tilapia zilli	0.001 ± 0.00	0.001 ± 0.00	0.004 ± 0.001	0.002 ± 0.001
Erpetoichithys	0.001 ± 0.00	0.002 ± 0.00	0.006 ± 0.001	0.004 ± 0.001
WHO limit for heavy metals in food	0.01	0.01	0.01	0.01
FAO limit for Heavy metals in fish	0.5	0.5	0.5	0.5
All values are mean values of triplicate determinations ± SD.				

Table 4: Concentrations of Cadmium in some selected species of fish.

process of decomposition, all the oxygen can be consumed [1].

Accelerated aging of lakes and ponds

a. Survival of fish

Pollutants may interfere with various physiological processes without necessarily causing death. Toxic substances and suspended sediments on the mucous membrane of fish gills affect the respiration. Heavy metals particularly mercury and lead inhibit the activities of digestive enzymes [1].

b. Factors that affect fish survival

Pollutants might effect a given population without being lethal to adult organisms in many ways.

i) Migration.

ii) Incidence of diseases.

iii) Behaviour.

iv) Physiological processes.

v) Life cycle.

vi) Nutrition and food chain.

vii) Genetic effects Subhendu [1].

Implications of Pollution on Eggs, Spawn, Fry on Breeding Grounds and Feeding Grounds

Effects on Fish Eggs; Spawn and fry

Fish eggs are much more resistant than the adult fish. Toxicity thresholds for lead, zinc and nickel to be about 20, 40 and 2000 ppm respectively, values for higher than those found for about animal. Eggs would develop normally between pH 6 to 9. In water more acid than pH 4.0, the eggs displayed exosmosis and collapsed, in water more alkaline than pH 9.0 there was endosmosis, the eggs swelled and yolk became white. The critical oxygen tensions are about 40 mm Hg for newly fertilized eggs and rises, as the embryo develops, to about 100 mg Hg (about 60% saturation) at the time of hatching. Trout and Salmon lay their eggs in gravel, through which water must percolate while the eggs batch and the fry live on the food from the egg yolk [16]. Survival of larval fish fry and fingerlings (Figure 6).

(a) Food acquisition: Larval fish is able to feed only on the tiniest of zooplankton and phytoplankton, thus early growth and survival of fish depends upon the densities of small cladocerans and rotifers and phytoplankton. Aquatic pollution is toxic to these plankton and pose threat to survival of fish fry.

(b) Predation: Structural complexity, especially aquatic vegetation,

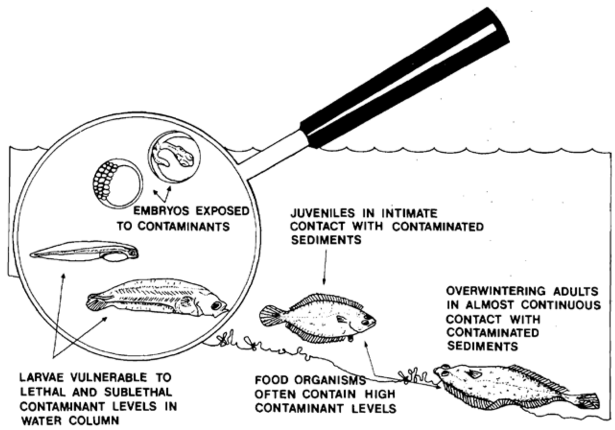


Figure 6: Life history stages of demersal fish that are vulnerable to pollution. A suitable area must not accumulate silt and sand.

while providing refuge for larval and fingerlings fish, may reduce the ability of piscivorous fish to feed on small fish. Fry and fingerlings are more susceptible to pollution than adult fish.

The untreated or partially treated effluent on entering a water body either gets dissolved or lie suspended on river bed, thereby causing the pollution of water body. Varis et al. [17] presented DAVID influence diagram processing system in environmental management. The deterioration in water quality has an adverse on human beings as well as aquatic ecosystem directly or indirectly [18-20] used the Hasse Diagram Technique (ProRank) software for a multi-criteria evaluation of environmental databases. The degradation of surface and groundwater quality due to industrial and urban waste has been recognized for a long time. Filibeli et al. [21] controlled pollution in organized industrial districts in Turkey successfully. Ma analyzed the distribution of industrial pollution sources in U.S. and China. The study found that race and income-the two common lenses used in many U.S. studies played different roles in the Chinese context and rural residents and especially rural migrants were disproportionately exposed to industrial pollution. Kakar and Bhatnagar [22] survived ground water pollution due to industrial effluents in Ludhiana, India. Oketola and Osibanjo [12] estimated sectoral pollution load in Lagos by Industrial Pollution Projection System (IPPS). Magiera et al. [23] used soil magnetometry for mapping particulate pollution loads in urban forests in the Upper Silesia Industrial Region, Poland [24,25].

According to Valipour et al. [26-28] a representation of an Environmental flow diagram was designed based on the reference energy system. In this diagram, all the units are in the specified energy levels and pollutants flow are enumerated according to the environmental source (air, water, soil) of pollution acceptor. In this diagram, the source of production, transmission and conversion processes, and the recipient environmental sources of these pollutants are specified. Generally, the guideline of EFD preparation includes the following steps:

1. Investigating all of the energy levels in RES and PFD of processing units to identify sources of pollutant.

2. Pollutant flow division based on pollution acceptor source (water, air, and soil).

3. Determining a level for produced pollution as the final pollution in the end of diagram and divides it based on pollution acceptor source.

4. Removal of non-related terms to environmental pollutions.

5. Adding other sources of pollution which non-related to energy levels such as industrial wastewater Indicators of pollution that are examined in EFD includes greenhouse gases (CO_2, CH_4, and N_2O) and air pollutants (CO, SO_2, NOx, and THC) in atmosphere section and BOD, COD, heavy metals, oil and grease, and total hardness in water and soil sections (Figures 7-9).

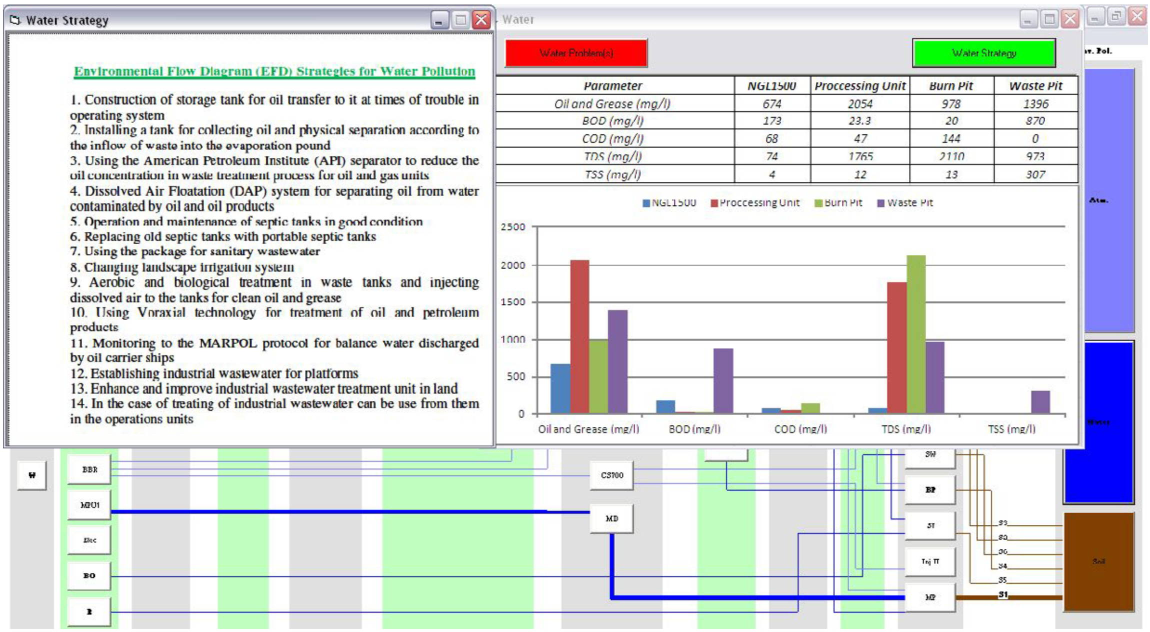


Figure 7: A sample of EFD for a part of NIOC [26,28].

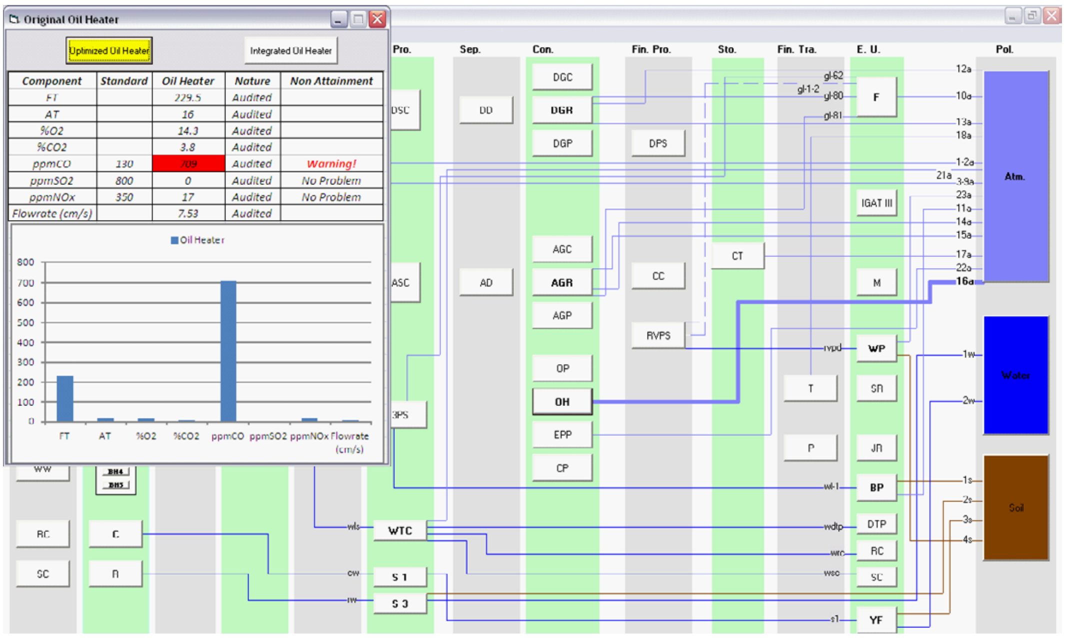


Figure 8: Table and graph related to the a atmosphere pollutant, oil heater (OH), by clicking on it in EFD environment [26,28].

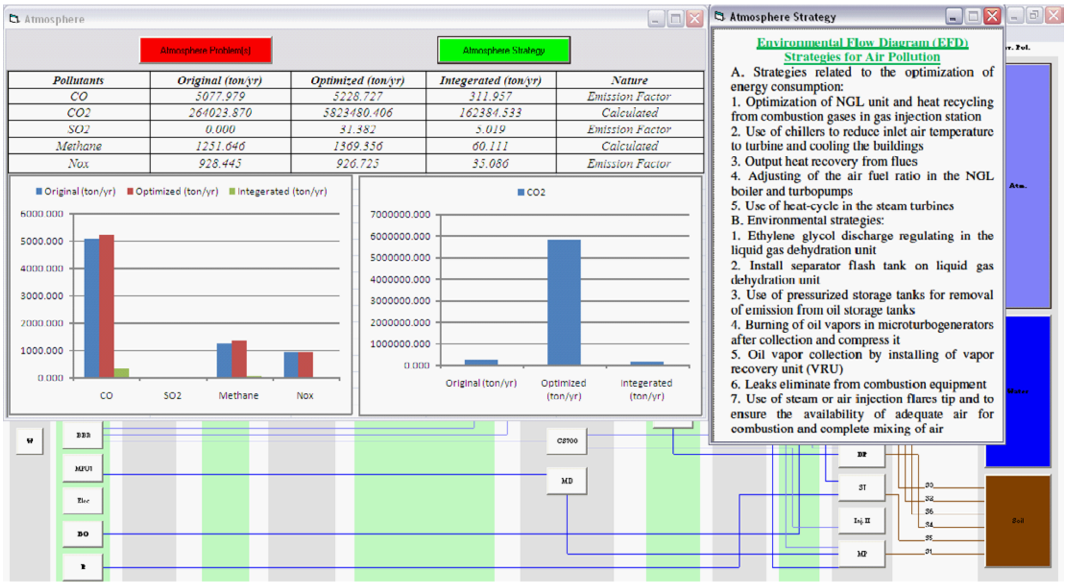


Figure 9: Final pollution in air section with suggested strategies for reducing or removing pollution problems in this section [26,28].

Indicators of pollution that are examined in EFD includes greenhouse gases (CO_2, CH_4, and N_2O) and air pollutants (CO, SO_2, NOx, and THC) in atmosphere section and BOD, COD, heavy metals, oil and grease, and total hardness in water and soil sections. Methods of air pollution estimation in EFD include sampling of emission sources, emission factors available in international resources, engineering calculations, and process simulation. In addition, mode of evaluating water and wastewater in EFD include sampling of industrial wastewater in operational area, comparison with national and international standards, and detecting pollutants that are above environmental standards. According to the Figure 4, high values of coliforms in WWT have been caused which other pollutant was not visible in graph. Figure 5 shows values of atmosphere pollutants in original status and if implementation of scenarios related to the optimization of energy consumption (optimized) and reduction of air pollutions (integrated).

Nature of pollutants estimation for CO, SO_2, and NOx was based on emission factor and for greenhouse gases (CO_2 and CH_4) was calculated.

Destruction of Breeding and Spawning Grounds

For any nest, building fish or any fish in which the eggs attach to a particular substrate the nature of the substrate is important in successful spawning. Aquatic vegetation often provides the very substrate within which or on which eggs are laid and may protect eggs from wave action and erosion. Soil particles due to land erosion carried out run-off water and suspended matter present in sewage and trade wastes gets deposited on the river bed or behind the weirs and cause silting of the bed (Figure 10).

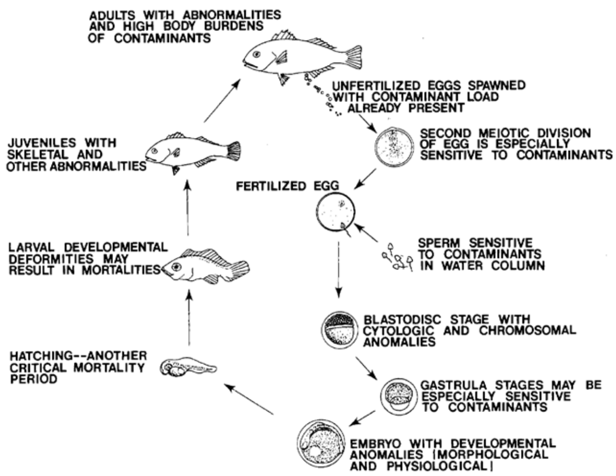


Figure 10: Points in the life cycle when fish are especially sensitive to pollutants [26].

The presence of pollutants in the tissues of aquatic animals

Overtime, many laboratory-based investigations and studies of animals obtained from the aquatic environment have highlighted the presence of pollutants in the tissues of a wide range of aquatic animals.

In-vitro studies: A wide range of pollutants, including creosote fractions [9], thiocyanate [29-31], didecyldimethylammonium chloride [32] and DDI' [12], have been found to be taken up into aquatic organisms via waterborne exposure. However, it is questionable what if any relevance such laboratory data have to occurrences in the aquatic environment.

Investigations using animals obtained from the aquatic environment

There is a good correlation between the presence of pollutants in animals and the levels in the surrounding aquatic environment. For example, heavy metals, including copper and zinc, have been detected in the tissues of rabbitfish *(Siganus oramin)* obtained from the polluted waters around Hong Kong, in a range of invertebrates and vertebrates obtained from Taiwan [33], and cod *(Gadus morhua)* caught from off the coast of Newfoundland, Canada [34]. Cadmium, lead and mercury have been identified in small amounts in fish from the Great Lakes [35-

38]. Interestingly, the levels for cadmium, lead and mercury in cod were below the maximum permitted limit for foods [34], casting some doubt on the significance of the concentrations to the health of the animal.

Similarly, mercury, in concentrations considered to be insufficient to cause human health problems, has been found in apparently healthy fish and shellfish collected from the vicinity of discharges from a chlor-alkali plant in India [39].

Crustaceans, fish and molluscs, obtained from the vicinity of a sewage outfall, have been determined to be contaminated with pesticides, namely chlordane, dieldrin, hexachloro-benzene and DDT. Similarly, DDT and polychlorinated-biphenyls (PCB), organochlorine residues and 2,3,7,8-tetrachlorobenzo-p-dioxin have been found in fish caught from the Vaike Vain Strait in western Estonia [40], from the North Sea [10], and the Great Lakes [11], respectively. Yet, there was not any indication that the compounds were actually causing any harm to the animals.

Sewage

Sewage effluents contain complex mixtures of chemicals such as natural and synthetic hormones, alkylphenols, phthalates, bisphenol A, pharmaceuticals and some pesticides [41-43]. These chemicals disrupt the endocrine system of animals and are known as endocrine disrupting chemicals. Endocrine disrupting chemicals (EDCs) constitute a major group of chemical pollutants in the aquatic environment and they interfere with the hormonal systems of animals [44].

Endocrine disrupting chemicals mimic or antagonize endogenous hormones and alter the synthesis and metabolism of endogenous hormones and hormone receptors [45]. Several adverse health effects in aquatic organisms have been attributed to EDCs, such as developmental, neurological, endocrine and reproductive alterations [46,47]. The aim of the study was to assess the efficiency of the treatment processes at a sewage treatment plant in Sweden with regard to the reduction of some EDCs such as pharmaceuticals and estrogens.

Classification of morphological deformities and their rates of occurrence

Morphological deformities of adult tilapia were separated into 15 categories that described abnormalities on all portions of the fish.

These categories are:

(1) Split fins,

(2) Scale disorientation (including thickened and deformed scales),

(3) Hyperplasia of the surface of the mouth,

(4) Muscle atrophy,

(5) Opercular deformity,

(6) Gill deformity (including gill raker, gill arch, and gill filament deformities),

(7) Eye deformity (including the subcategories of exopthalmia, concave eye, small eye, blindness, lens deformity, and opaque cornea),

(8) Skeleton deformity (including vertebral and skull deformities),

(9) Outward protrusion of the lower lip,

(10) Tumors and other swellings,

(11) Jaw deformity (including one or two sides of the jaw having raised calcifications), (12) head or lower jaw bent to one side,

(13) Protruding mouth or nose part depression,

(14) Fin deformity (including elongated fin, part of the fin missing, and fin ray deformity), and

(15) Miscellaneous items (including body shape deformity and protrusion of the mandibular cartilage) (Figures 11-14).

The exposure of aquatic animals to high concentrations of pollutants may lead rapidly to death. Here, there is a clear association between pollution and mortalities. Yet, exposure to lower quantities of pollutants may lead to chronic darnage, the implications of which need not be manifested for a comparatively long period [48,49]. Exposure to sewage sludge has been implicated with effects on growth and protein synthesis in common dab *(Limanrla iamanda)* [50]. In addition, liver damage in fish has been associated with contamination by components of sewage sludge [51], cadmium [52,53].

Prevention of pollution

1) There should be proper and adequate management of solid and domestic waste.

2) Provision of adequate drainage systems to arrest urban and agricultural runoffs.

3) Measure against pollution must be an intrinsic part of the design

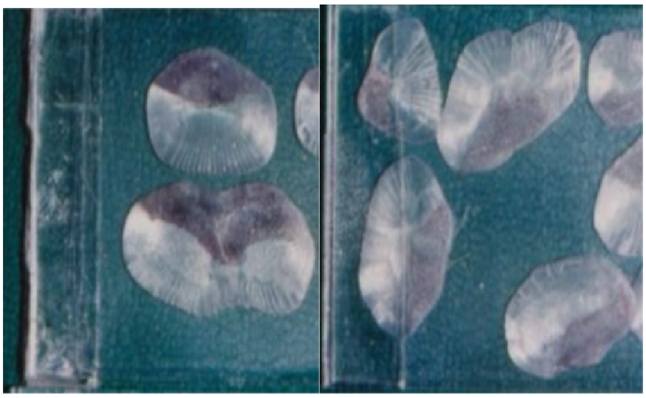


Figure 11: Abnormalities in scales of *Orechromis spp* [19].

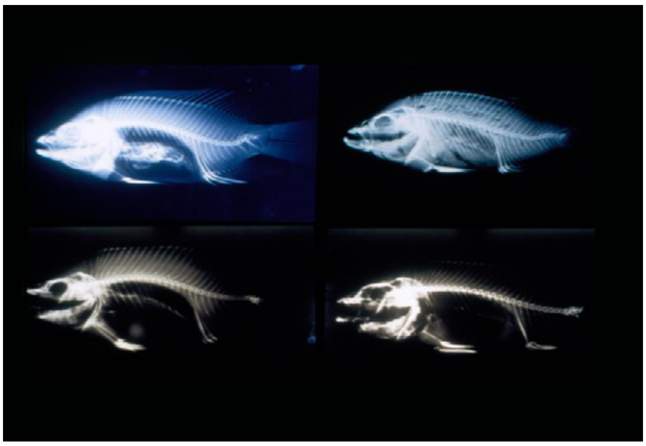
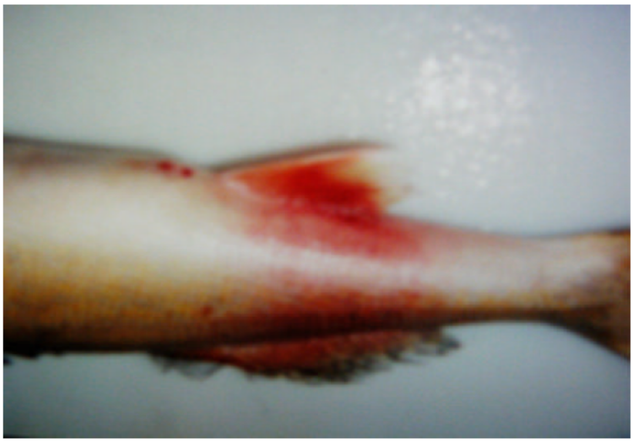


Figure 12: Different Types of Skeletal Deformities in Tilapia [19].

Source: Brown-Peterson.

Figure 13: Gill deformities in *Orechromis spp.*



Source: Timoney.

Figure 14: Reddened fins and skin on walleye; due to a bacterial infection.

and construction of facilities of all industries.

Control measures of pollution

1) Ensuring the primary treatment of municipal sewage discharged into rivers, creeks, lagoons and the sea.

2) Promoting use of environmental impact assessments to help ensure an acceptable level of environment quality.

3) Implementation and enforcement of policies and existing acts and regulation of environmental protection.

Discussions

Overtime, sewage also contains potentially toxic, mutagenic, or carcinogenic compounds [54]. Eutrophication, which may result from organic load on water bodies, is one of the numerous problems created by sewage pollution [55,56]. Even though, water bodies in their natural form contain chemical compounds such as the bicarbonates, nitrates, chlorides, sulphates, various problems however arise with the increase in the amount of these compounds within the water bodies. Water which contains salts is not useful for irrigation either as utilization of such water leads to the salinization of the soil, which in turn leads to soil erosion. The toxins released into the rivers through sewage water are consumed by fishes and other organisms, thus increasing the possibility of these toxins entering the food chain [16,22]. The Lagos lagoon which is the focus of the current research like many coastal lagoons, serves as a seaport, centre for recreational sailing and a sink for disposal of domestic and industrial wastes. A paucity of information exists on the extent of pollution of the lagoon [3].

Conclusively, the discharge of industrial effluents into receiving water bodies invariably results in the presence of high concentrations of pollutant in the water and sediment. Solid waste management policies and enforcement of sanitation laws in various should be practiced. Effluents also have considerable negative effects on the water quality of the receiving water bodies and as such, they are rendered not desirable for fish health and survival. During dietary administration of metals, their concentrations in the digestive tract increase and remain high until the end of exposure, and rapidly decrease during depuration. In case of waterborne exposure, metal levels in the digestive tract are usually low. Liver accumulates high concentrations of metals, irrespectively of the uptake route. Assessing morphological deformities is one of the most straightforward methods to study the effects of contamination on fish because of the ease of recognition and examination when compared with other types of biomarkers. Different types of morphological abnormalities have been reported in fish taken from contaminated waters, including fin erosion [25] skull deformation; jaw deformities; skeletal deformities such as lordosis, scoliosis, and kyphosis [57]; opercular deformity; fin deformity; lower lip protrusion; gill deformity ocular disorders; scale deformity and disorientation; and neo-plasia or hyperplasia [58,59].

In contaminated waters, fish may exhibit whole animal, morphological, histopathological, cellular, organismic, or parasitic aspects of abnormalities, some of which can be used as biomarkers of contamination exposure [60]. The use of abnormalities in fish as biomarkers has become more prevalent in recent years [61]. Biomarkers in fish can provide a chronic indication the environmental condition than can more general and acute indices such as plankton analyses or water quality parameters. However, the cause-and-effect relationships between biomarkers and certain suspected pollutants cannot always be established [62]. Metal concentrations in the kidneys rise slower than in liver, and usually reach slightly lower values, except for such metals as cadmium and zinc that show very high affinity to kidneys, therefore the kidneys may be considered a good indicator of pollution too. Further research is required on the discharge of industrial effluents into receiving water bodies in Nigeria which invariably results in the presence of high concentrations of pollutant in the water and sediment.

Acknowledgments

We appreciate the support of the Marine Science department of the University of Lagos, Akoka, for making this study a success. We extend gratitude to colleagues who contributed positively in to this paper. Our thanks also extend to the editorial board for their restless effort for the peer reviewed process.

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ISSN: 2375-446X

Poultry, Fisheries & Wildlife Sciences

Research Article Open Access

Consequences of Anthropogenic Activities on Fish and the Aquatic Environment

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Received Date: April 24, 2015; **Accepted Date:** August 21, 2015; **Published Date:** August 28, 2015

Citation: Bukola D, Zaid A, Olalekan EI, Falilu A (2015) Consequences of Anthropogenic Activities on Fish and the Aquatic Environment. Poult Fish Wildl Sci 3:138.doi:10.4172/2375-446X.1000138

Keywords

Pollution; Fish health; Effluents; Biomarkers; Industries; Morphological deformities; Pollutants; Diseases

Introduction

Aquatic systems are considered as suitable sites for disposal and recycling the sewage and toxic wastes and drain off the excess to the sea. However, the increasing pollutant load and the over exploitation of the water resources for potable supplies, irrigation, industries and thermal power plants to meet the requirements of the ever-increasing population, significantly reduces their assimilative capacity. Thus, the dual stress exerted on the watercourses is ultimately faced by the biological communities inhabiting them. Of these, fish is one of the most important aquatic communities concerning man [1].

With exploding population and increasing industrialization and urbanization, water pollution by agricultural, municipal and industrial sources has become a major concern for the welfare of humanity. Water soluble toxicants from industrial and municipal wastes, leached soils and the atmosphere have rapidly transferred to natural bodies of water. While some of the pollutants decompose or volatilize, others form insoluble salts, which precipitate and get incorporated into the sediment. Uptake of such toxicants by aquatic organisms like fish may be followed by metabolism of the toxicants into more toxic derivatives. For example mercury from industrial effluents may be converted by microbial action into highly toxic methyl mercury which can then be taken up by fish. Many aquatic organisms have been known to concentrate toxic solutes from their habitat without any obvious damage to themselves.

They thus act as toxicant amplifiers, making the toxicants available to predators at dangerously high levels. Several cases of the adverse effects of environmental pollution on fish and fish consumers have been reported. The term pollution broadly refers to any undesirable change in the natural quality of environment brought about by physical, chemical, or biological factors [1]. The high rate of increase human population, rapid expansion in the industrial and urban activities and modernization of agriculture has resulted in generation of high volume of waste material causing gradual deterioration of valuable resources of biological productivity [1]. The increased anthropogenic load on our aquatic ecosystem determines the necessity of investigations devoted to adverse effects of pollution and its potential risk for aquatic ecosystems. A deleterious effect of pollution has been detected on populations of different organisms inhabiting the water body through various scientific researches. The decrease of some fish populations and partial loss of commercial fishing importance are among of the huge changes in the ecosystem [2].

It is a well known fact that biochemical, cellular, tissue, and organism modifications underline different types of ecosystem changes; the exposure of fish to chemical contaminants induces a number of modifications in different organs, particularly gills, liver and kidney. Therefore a wide range of histo-cytological alterations in fish have been developed and recommended as biomarkers for monitoring the pollution. This study is concerned with the evaluation of pollution influence on fish health status and establishment relation between fish health and environmental quality on the base of histological examination.

The pressure of increasing population, growth of industries, urbanization, energy intensive life style, loss of forest cover, lack of environmental awareness, lack of implementation of environmental rules and regulations and environment improvement plans, untreated effluent discharge from industries and municipalities leads to aquatic pollution and eventual death of aquatic organisms. The pollutants from industrial discharge and sewage besides finding their way to surface water reservoirs and rivers are also percolating into ground to pollute ground water sources. Pollution can be defined in several ways. Water pollution occurs when energy and other materials are released, degrading the quality of the water for other users.

Aquatic systems are subjected to pollution pressures associated with urbanization and population growth [3,4]. The introduction of these pollutants into aquatic systems constitute a major threat to hydro-chemical and fauna characteristics of the aquatic ecosystems [3,4]. Fish is one of the most valuable sources of high grade protein available to man and knowledge of its composition and nutritional value is essential.

The Lagos lagoon is one of the meandering networks of lagoons and creeks found along the coastline of southern Nigeria. It has continued to be under intensifying pressure from pollution such as sawdust and petrochemical materials [5]; untreated sewage [6]; detergents and industrial effluents [6], petroleum products; sawdust and faecal pollution [6]. Ajao [7] reported that the most obvious effects of pollutants on the populations of sessile and benthic organisms was a total elimination of species from some areas for varying periods in the highly polluted sites. One of the most critical problems of developing countries is improper management of vast amount of wastes generated by various anthropogenic activities. More challenging is the unsafe disposal of these wastes into the ambient environment. Water bodies especially freshwater reservoirs are the most affected. This has often rendered these natural resources unsuitable for both primary and/ or secondary usage. This study is a review study concerned with the evaluation of pollution influence on fish health status and establishing relation between fish health and environmental quality on the base of histological examination.

Materials and Methods

This paper adopts a review approach and relevant information were gathered from journals, books, technical papers, and other beneficial scholarly materials. Pollutants may enter the aquatic environment as a result of natural occurrences, such as the collapse of algal blooms and/ or as a result of human endeavors, leading to adverse water quality. Some pollutants, e.g. pesticides, have been found in the tissues of aquatic animals. High levels of certain pollutants, e.g. from oil spillages, may be directly responsible for deaths of large numbers of aquatic animals. Furthermore, disease may develop long after the pollutant has been removed from the aquatic environment. In this circumstance, it would be difficult to prove that the original pollution led to disease.

Sources of Pollution

The heaviest polluting source for surface water is sewage from cities. Pollution is often classified as Point source or Non-point source (**Figure 1**).

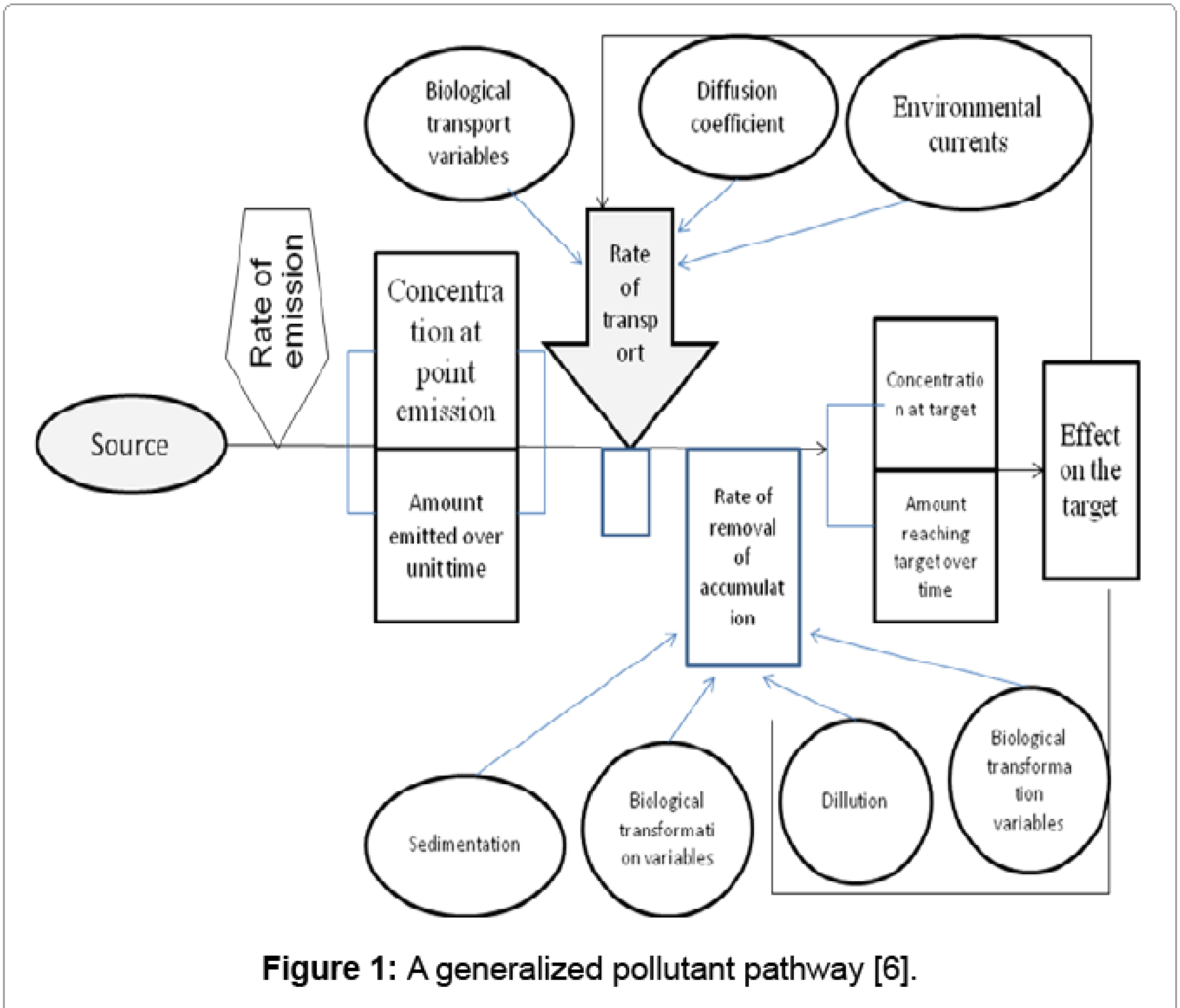

Figure 1: A generalized pollutant pathway [6].

Point source pollution

Point source pollution refers to contaminants that enter a waterway through a discrete conveyance, such as a pipe or ditch. Examples of sources of this category includes discharges from a sewage treatment plant, a factory etc. A point source pollution is a single identifiable source of air, water, thermal, noise or light pollution. It is negligible to an extent, distinguishing it from other pollution sources [8]. Point source pollution enters a water body at a specific site and is generally readily identified. Potential point sources of pollution includes effluent discharges from sewage treatment works and industrial sites, power stations, landfill sites, fish farms, and oil spillage via a pipeline from industrial sites [8] (**Figures 2 and 3**).

Figure 2: Sewage collected from household septic tanks deposited at IDDO in the Lagos lagoon [8].

Figure 2: Sewage collected from household septic tanks deposited at IDDO in the Lagos lagoon [8].

Figure 3: Okobaba Sawmill waste entering the Lagos lagoon [8].

Figure 3: Okobaba Sawmill waste entering the Lagos lagoon [8].

Non-point source pollution

Non-point source (NPS) pollution refers to diffuse contamination that does not originate from a single discrete source. NPS pollution is often the cumulative effect of small amounts of contaminants gathered from a large area.

The leaching out of nitrogen compounds from agricultural land which has been fertilized is a typical example. Nutrient run off in storm water from “sheet flow” over an agricultural field or a forest are also examples of Non-point source. Contaminated storm water washed off of parking lots, roads and highways, called urban runoff, is sometimes included under the category of NPS pollution. However, this runoff is typically channeled into storm drain systems and discharged through pipes to local surface waters, and is a point source. Although these pollutants have originated from a point source, the long-range transport ability and multiple sources of the pollutant make it a nonpoint source of pollution. Other significant sources of runoff include hydrological and habitat modification, and forestry [8] (**Figure 4**).

Figure 4: Runoff of fertilizers from a crop land.

Figure 4: Runoff of fertilizers from a crop land.

Results

It is well established that at various times pollutants enter the aquatic environment. Examples of pollutants include:

1) Hydrocarbons: e.g. creosote [9], resulting from accidental discharge from tankers or deliberate spillage during wartime [6-8].

2) Pesticides: e.g. organochlorines [10], dioxin [11] and l,l,ltrichloro- 2,2-bis-(l)- chlorophenyl) ethane (DDT) [12].

3) (Heavy) metals: e.g. tin, tributyltin and triphenyltin, have been incorporated in anti-fouling paints used extensively to prevent bio attachment and thence fouling of the undersurfaces of ships; arsenic, copper, zinc [9,10]; cadmium, lead and mercury which are discharged in industrial effluents.

4) Pulp mill effluents.

5) Plastics.

6) Organic sewage, including faecal debris, which may contain large populations of bacteria.

7) Inorganic nitrogen, as nitrate, nitrite and ammonia, which may be derived from fish farming (i.e. aquaculture) activities and agricultural run-off.

8) Toxins, such as from the collapse of dinoflagellate blooms.

This runoff may enhance the organic loading of the receiving waters, reduce the salinity, and cause localized temperature changes. However, the extent and longevity of pollutants in the aquatic environment needs to be established, and this will certainly involve effective monitoring programs (Figure 5).

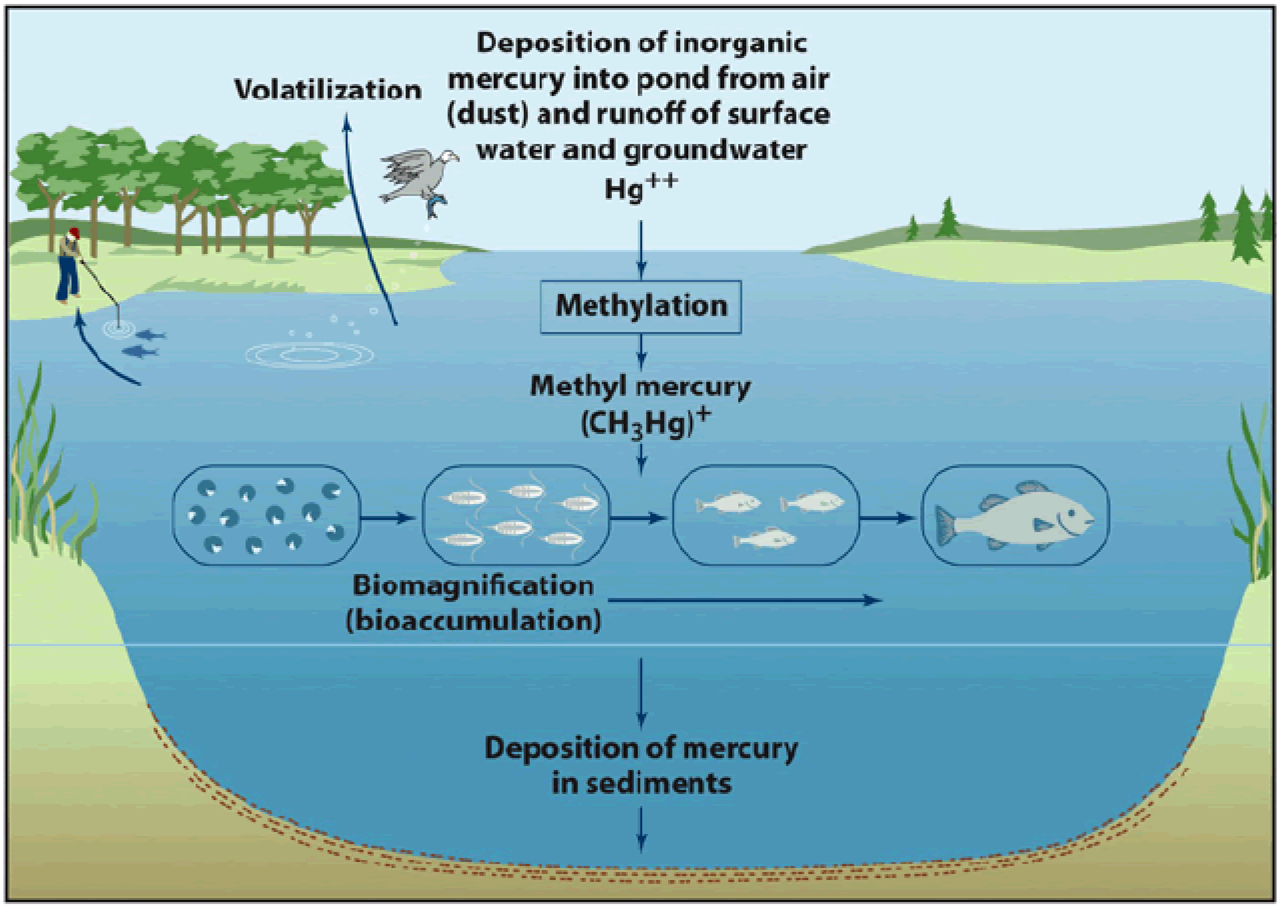

Figure 5: The pathway of mercury deposition inn sediments [5].

Figure 5: The pathway of mercury deposition inn sediments [5].

Organic pollutants

Organic pollutants originate from domestic sewage (raw or treated), urban run-off, industrial (trade) effluents and farm wastes. Sewage effluents are the greatest source of organic materials discharged to freshwaters. In England and Wales there are almost 9000 discharges releasing treated sewage effluent to rivers and canals and several hundred more discharges of crude sewage, the great majority of them tot the lower, tidal reaches of rivers or, via long outfalls, to the open sea [8].

The main categories of organic pollutants are:

Polycyclic aromatic hydrocarbons: Polycyclic aromatic hydrocarbons (PAHs) arise from incomplete combustion or pyrolysis of organic substances such as wood, carbon or mineral oil.

Polychlorinated biphenyls (PCBs): There are two main sources of PCBs: Directly manufactured PCBs (by chlorination of biphenyls), used as hydraulic liquids. The other main source of PCBs in the environment is combustion processes, from waste incineration plants, fossil fuel burning and to other incomplete combustion processes.

Sources of other potential organic pollutants are listed below: Organic pollutants can originate from food and household related products, such as long chain fatty acids and their methyl and ethyl esters, originating from faeces, soaps and food oils. Plasticizers and flame retardants, preservatives and antioxidants, solvents fragrance, pesticides and herbicides (**Tables 1 and 2**).

Sources	Pollutants
Industrial Waste e.g. VitamaltPlc	Organic pollutant, alcoholic brewer waste, biodegradab
Soap Factoriese.g. Lever Brothers Plc, Lorry Parks/Mechanic	Detergent, caustic soda from washing and cooling wate
Plastic Industries e.g. Lotus Plastic	Hot polymer by-products, calcium, tin and lead.
Food Industriese.g. InternationalQuality Food(Nig) Ltd, Lever Brothers Plc, Nestle Food Plc	Organic pollutants and biodegradables. Elevated water temperature which may affect fish.
Wood Shaving (sawdust) industries e.g. Okobaba sawmill	Biodegradable organic matter
Sand and gravel extraction,dredging activities	Sedimentation, flocculation.
Hydrocarbons (waste oil discharge, shipping losses in harbour)	Oil and grease
Industrial waste waters(complex mixture) e.g.Chemical and Allied Products (Nig) Ltd Thermal pollution	Pollutants, waste heat, variousinorganic and organic pc

Table 1: Different types of waste pollutants from various industries in Lagos state.

Pollutant	Origin	Domestic usage	Storm runoff	Commercial effluent
Aliphatic hydrocarbons	Fuel	++	++	++
Monocyclic aromatic hydrocarbons	Solvents, phenols	+	+	++
PAHs	By-products of petroltransformation andinsecticides	+	+	+
Halogens	Solvents, plastics, chlorination	++	+	++
Chlorophenols and Chlorobenzenes	Solvents, pesticides	+	+	+4-
Chlorinated PAHs	PCB, hydraulic fluids	(+)		++
Pesticides		+		++
Phthalate esters	Plastifler	+	+	+4-

Detergents		++	+	+1-
Nitrosamines	Industrial by-products (rubber)	0	+	++

Note: +++ very likely, ++ likely, + less likely present

Table 2: Principal sources of organic micropollutants in urban wastewater treatment works.

There has been growing interest to determine heavy metal levels in the marine environment. Levels of contaminants in fish are of particular interest because of the potential risk to humans who consume them. In attesting to these, Fin and shell fishes have been widely used as bio-indicators to monitor heavy metals concentrations in the coastal environment, due to their wide range of distribution, and also their important position in the food chain. Pollution studies have revealed elevated levels of Pb, Cr, Ni, V, and Zn in Port Harcourt and Warri sediments and some species of fauna, suggesting inputs from petroleum exploration and exploitation [12].

Persistent organic pollutants

Typical results of the human activities proved to be elevated levels of heavy metals present in fresh waters, and among these microelements lead (Pb), cadmium (Cd), mercury (Hg) and zinc (Zn) are most specific [13]. The arousal of anthropogenic pollution in the environment evoked the necessity to develop the pollution impact management strategies.

The most important factors are: distribution of heavy metals in individual organs and the respective affinity of these organs for metals, uptake kinetics, regulatory mechanisms (especially for essential metals), effects on the metabolism evoked by heavy metals, the synergism of metals and their uptake), the fish as the end consumers in the aquatic food chain and thus their use as an indicator of heavy metal enrichment [13]. Knowledge of biological factors such as age and size, life cycle and life history, seasonal and local variations of heavy metal content in the animal, and the trophic level of the species, as well as of the biological half-life of the metal are essential [13]. No matter how many good health supplements or procedures one takes, heavy metals overload will be a detriment to the natural healing functions of the body [12].

Mercury in fish

Most fish species have mercury levels of approximately 0.15 ppm in muscle tissue. However, recreational fish - Red drum (*Scaenops ocellatus*) also contaminated: up to 3.6 ppm; 95% >0.5 ppm health limit [14]. Toxic effects reported in marine mammals include:

Lesions in the liver and other tissues; decrease nutritional state and fatty degeneration. High mercury (and other heavy metal) levels have also been associated with disease -induced mortality i . e . mercury may damage the immune system, nearly all fish and shellfish contain traces of methyl-mercury.

Other pollutants in fish

Like mercury, other pollutants, including PCBs, accumulate in fish and in the body tissues of people who eat fish regularly. These chemicals also can increase the damage to the brain from mercury [15]. Lead is known to damage the brain, the central nervous system, kidneys, liver and the reproductive system [16]. It is also accumulated in nervous tissue [16].

Changes in the physico-chemical parameters of water due to pollution

Physical parameters

Temperature: Temperature of water may increase due to thermal pollution when water is used to cool power stations and due to waste heat from industries.

Turbidity and colour: Turbidity of water may increase due to soil erosion or heavy algal bloom due to high level of organic and inorganic nutrients from sewage water or agricultural waste. Turbidity, dye and pigment pollutants affect the general colour of water.

Depth and flow: Flow and depth of the water body may be reduced due to heavy siltation of sediments coming from land erosion.

Light: Due to high turbidity and colouration of the water bodies, penetration of light is reduced [1].

Chemical parameters

pH: pH of water may be acidic due to acid rain that originates largely from burning of coal and oil. Acids also originate in large quantities from mines and various industrial processes (waste from DDT factory, battery, vinegar, tanneries). Fish usually live at pH levels between 6.0 and 9.0, although they may not tolerate a sudden change within this range [1].

Dissolved oxygen: Dissolve oxygen level of water is reduced to greater extent when Heavy sewage pollution or other effluents containing high organic matter are discharged into it. These are broken down by the microorganisms, which used up the dissolved O_2 [1].

CO_2: Eutrophication and organic pollutants responsible for depletion of dissolve oxygen increase the CO_2 level in water bodies, due to decomposition of undecomposed or partially decomposed organic matter [1].

Alkalinity: Wastes associated with tanning, wool scouring, the mercerizing of cotton and the manufacture of certain chemicals (in chloro-alkali industries) may contain caustic soda (NaOH), sodium carbonate or lime. Such alkaline effluents may have a pH of 12-14 and lethal to all types of stream life, including bacteria.

Salinity: Excessive amount of salts brought by sewage; and effluents from chloro-alkali industries increase the chloride level thereby salinity of water, which is responsible for increase in the osmotic pressure. Salinity also reduces dissolve oxygen level.

Dissolved solids: These includes the following;

(i) Nitrates and phosphates: Water polluted by agricultural wastes, soil erosion and organic pollutants (sewage and biodegradable synthetic detergents) are rich in nitrates and phosphates.

(ii) Heavy metals: Hg, Zn, Ni, Cd, Pb, Mn, Cu, Fe, Cr, As, Se etc are present in natural water in very trace amount that's why they are called trace elements [1] (**Tables 3 and 4**).

	Mean concentration fish species of lead (mg/kg)			
Fish species	**Surrounding water**	**In muscles**	**In kidney**	**In liver**
MetacembelusIconnbergii	0.001 ± 0.00	0.002 ± 0.001	0.012 ± 0.002	0.007 ± 0.001
Clariaslazera	0.002 ± 0.001	0.003 ± 0.001	0.013 ± 0.002	0.006 ± 0.001
Citarinuscitharus	0.003 ± 0.001	0.004 ± 0.001	0.010 ± 0.002	0.007 ± 0.001
Tilapia zilli	0.002 ± 0.001	0.002 ± 0.001	0.015 ± 0.003	0.004 ± 0.001

Erpetoichithys	0.005 ± 0.001	ND	0.014 ± 0.001	0.010 ± 0.001
WHO limit for heavy metals in food	0.05	0.05	0.05	0.05
FAO limit for Heavy metals in fish	0.05	0.05	0.05	0.05

All values are mean values of triplicate determinations ± SD.

Table 3: Concentrations of Lead in some selected species of fish.

	Mean Concentration Fish species of lead (mg/kg)			
Fish species	**Surrounding water**	**In muscles**	**In kidney**	**In liver**
MetacembelusIconnbergii	0.001 ± 0.00	0.001 ± 0.00	0.005 ± 0.001	0.003 ± 0.001
Clariaslazera	0.001 ± 0.00	0.001 ± 0.00	0.004 ± 0.001	0.003 ± 0.001
Citarinuscitharus	0.001 ± 0.00	0.002 ± 0.00	0.005 ± 0.001	0.003 ± 0.001
Tilapia zilli	0.001 ± 0.00	0.001 ± 0.00	0.004 ± 0.001	0.002 ± 0.001
Erpetoichithys	0.001 ±0.00	0.002 ± 0.00	0.006 ± 0.001	0.004 ± 0.001
WHO limit for heavy metals in food	0.01	0.01	0.01	0.01
FAO limit for Heavy metals in fish	0.5	0.5	0.5	0.5

All values are mean values of triplicate determinations ± SD.

Table 4: Concentrations of Cadmium in some selected species of fish.

Other consequences of cadmium exposure are: anemia, yellow discoloration of the teeth, rhinitis, occasional ulceration of the nasal septum, damage to the olfactory nerve, and anosmia [15].

Pollutants, fish and ecology

Eutrophication: Pollution due to domestic sewage increases the organic load and pollution due to agricultural waste (residual fertilizers) and soil erosion containing nutrients such as nitrates; phosphates, potassium etc. fertilize the water and increase the rate of productivity of the aquatic ecosystem. This results in higher growth of phytoplankton. Water becomes turbid due to excessive growth of phytoplankton and soil eroded particles [1].

Aquatic lives face severe oxygen shortage due to;

i) Bacterial Decomposition of untreated sewage into their inorganic components assimilates dissolve oxygen from the water in the process.

ii) High turbidity restricts the penetration of sunlight in deeper layers and benthic plants could not photosynthesize.

iii) When algal bloom die, they sink to the deeper waters and in the process of decomposition, all the oxygen can be consumed [1].

Accelerated aging of lakes and ponds

a. Survival of fish

Pollutants may interfere with various physiological processes without necessarily causing death. Toxic substances and suspended sediments on the mucous membrane of fish gills affect the respiration. Heavy metals particularly mercury and lead inhibit the activities of digestive enzymes [1].

b. Factors that affect fish survival

Pollutants might effect a given population without being lethal to adult organisms in many ways.

i) Migration.

ii) Incidence of diseases.

iii) Behaviour.

iv) Physiological processes.

v) Life cycle.

vi) Nutrition and food chain.

vii) Genetic effects Subhendu [1].

Implications of Pollution on Eggs, Spawn, Fry on Breeding Grounds and Feeding Grounds

Effects on Fish Eggs; Spawn and fry

Fish eggs are much more resistant than the adult fish. Toxicity thresholds for lead, zinc and nickel to be about 20, 40 and 2000 ppm respectively, values for higher than those found for about animal. Eggs would develop normally between pH 6 to 9. In water more acid than pH 4.0, the eggs displayed exosmosis and collapsed, in water more alkaline than pH 9.0 there was endosmosis, the eggs swelled and yolk became white. The critical oxygen tensions are about 40 mm Hg for newly fertilized eggs and rises, as the embryo develops, to about 100 mg Hg (about 60% saturation) at the time of hatching. Trout and Salmon lay their eggs in gravel, through which water must percolate while the eggs batch and the fry live on the food from the egg yolk [16]. Survival of larval fish fry and fingerlings (**Figure 6**).

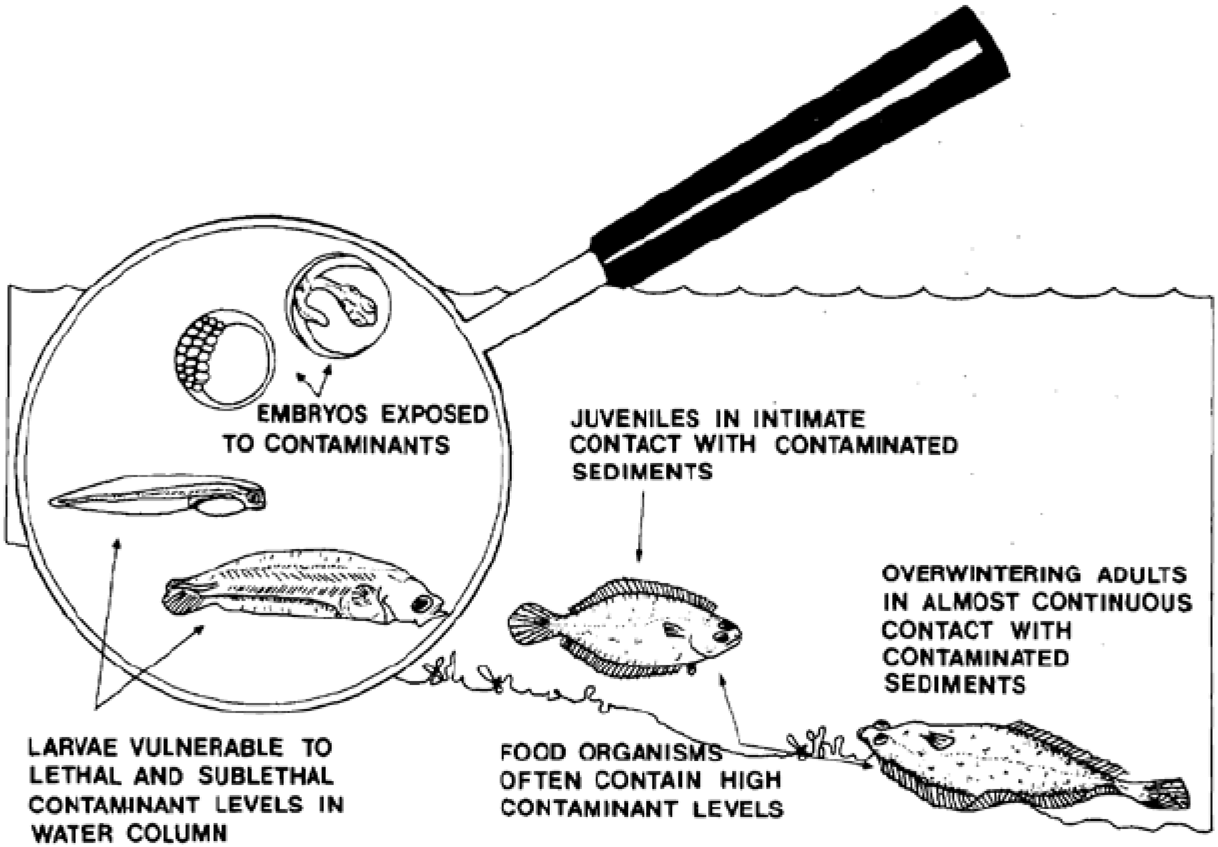

Figure 6: Life history stages of demersal fish that are vulnerable to pollution. A suitable area must not accumulate silt and sand.

Figure 6: Life history stages of demersal fish that are vulnerable to pollution. A suitable area must not accumulate silt and sand.

(a) Food acquisition: Larval fish is able to feed only on the tiniest of zooplankton and phytoplankton, thus early growth and survival of fish depends upon the densities of small cladocerans and rotifers and phytoplankton. Aquatic pollution is toxic to these plankton and pose threat to survival of fish fry.

(b) Predation: Structural complexity, especially aquatic vegetation, while providing refuge for larval and fingerlings fish, may reduce the ability of piscivorous fish to feed on small fish. Fry and fingerlings are more susceptible to pollution than adult fish.

The untreated or partially treated effluent on entering a water body either gets dissolved or lie suspended on river bed, thereby causing the pollution of water body. Varis et al. [17] presented DAVID influence diagram processing system in environmental management. The deterioration in water quality has an adverse on human beings as well as aquatic ecosystem directly or indirectly [18-20] used the Hasse Diagram Technique (ProRank) software for a multi-criteria evaluation of environmental databases. The degradation of surface and groundwater quality due to industrial and urban waste has been recognized for a long time. Filibeli et al. [21] controlled pollution in organized industrial districts in Turkey successfully. Ma analyzed the distribution of industrial pollution sources in U.S. and China. The study found that race and income-the two common lenses used in many U.S. studies played different roles in the Chinese context and rural residents and especially rural migrants were disproportionately exposed to industrial pollution. Kakar and Bhatnagar [22] survived ground water pollution due to industrial effluents in Ludhiana, India. Oketola and Osibanjo [12] estimated sectoral pollution load in Lagos by Industrial Pollution Projection System (IPPS). Magiera et al. [23] used soil magnetometry for mapping particulate pollution loads in urban forests in the Upper Silesia Industrial Region, Poland [24,25].

According to Valipour et al. [26-28] a representation of an Environmental flow diagram was designed based on the reference energy system. In this diagram, all the units are in the specified energy levels and pollutants flow are enumerated according to the environmental source (air, water, soil) of pollution acceptor. In this diagram, the source of production, transmission and conversion processes, and the recipient environmental sources of these pollutants are specified. Generally, the guideline of EFD preparation includes the following steps:

1. Investigating all of the energy levels in RES and PFD of processing units to identify sources of pollutant.

2. Pollutant flow division based on pollution acceptor source (water, air, and soil).

3. Determining a level for produced pollution as the final pollution in the end of diagram and divides it based on pollution acceptor source.

4. Removal of non-related terms to environmental pollutions.

5. Adding other sources of pollution which non-related to energy levels such as industrial wastewater Indicators of pollution that are examined in EFD includes greenhouse gases (CO_2, CH_4, and N_2O) and air pollutants (CO, SO_2, NOx, and THC) in atmosphere section and BOD, COD, heavy metals, oil and grease, and total hardness in water and soil sections (**Figures 7-9**).

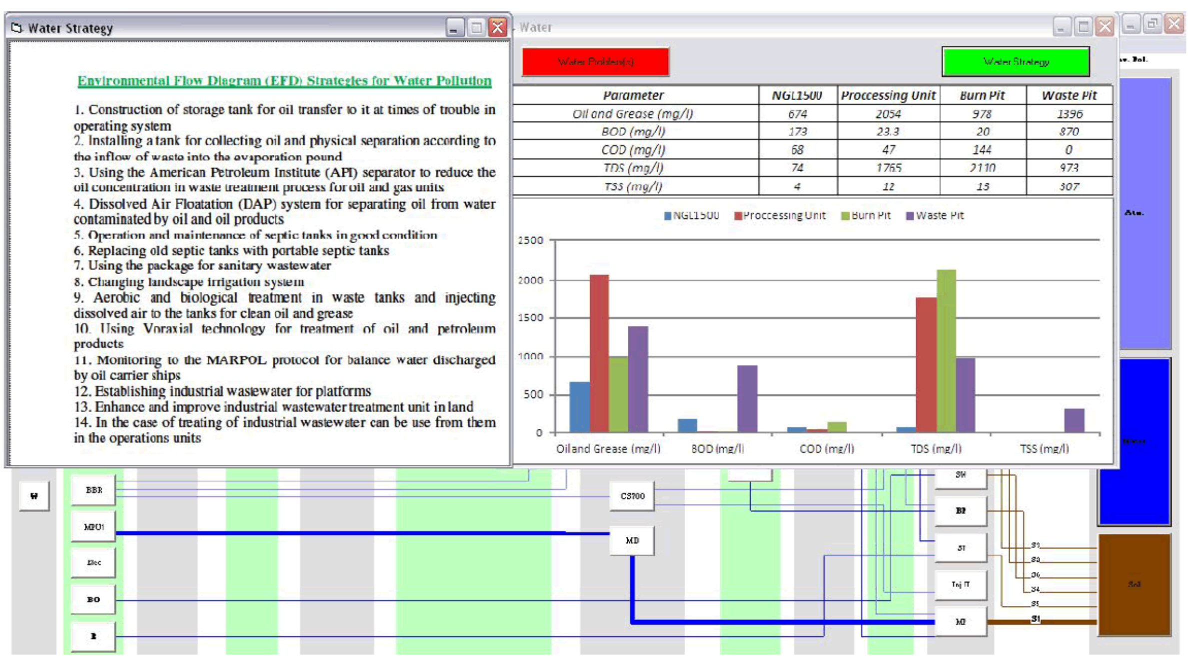

Figure 7: A sample of EFD for a part of NIOC [26,28].

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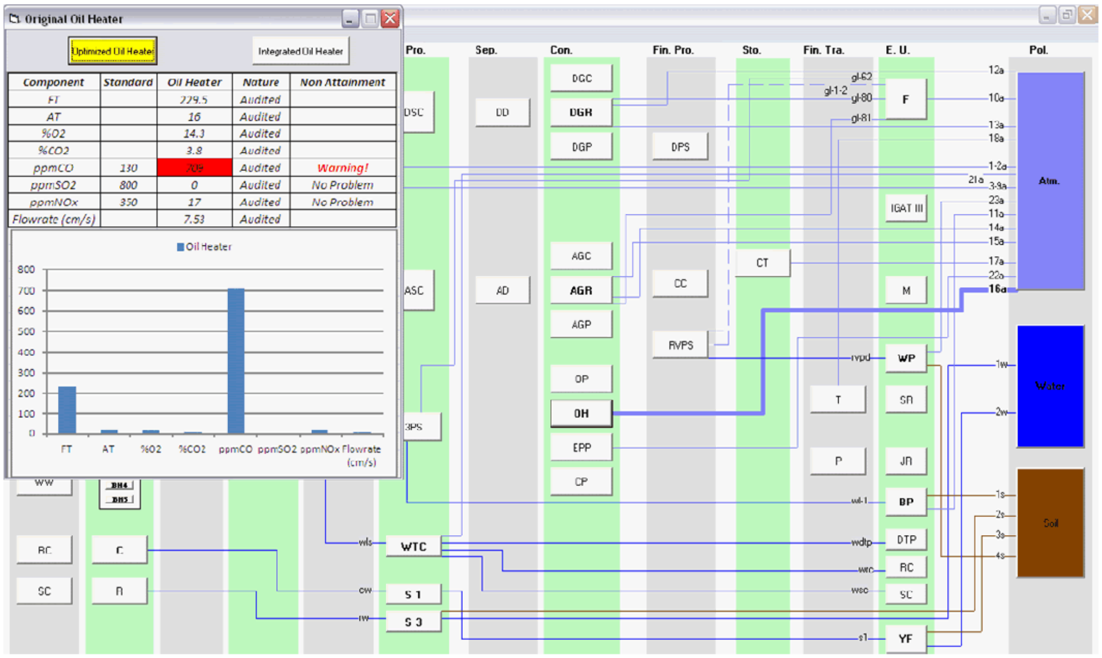


Figure 8: Table and graph related to the a atmosphere pollutant, oil heater (OH), by clicking on it in EFD environment [26,28].

Figure 8: Table and graph related to the a atmosphere pollutant, oil heater (OH), by clicking on it in EFD environment [26,28].

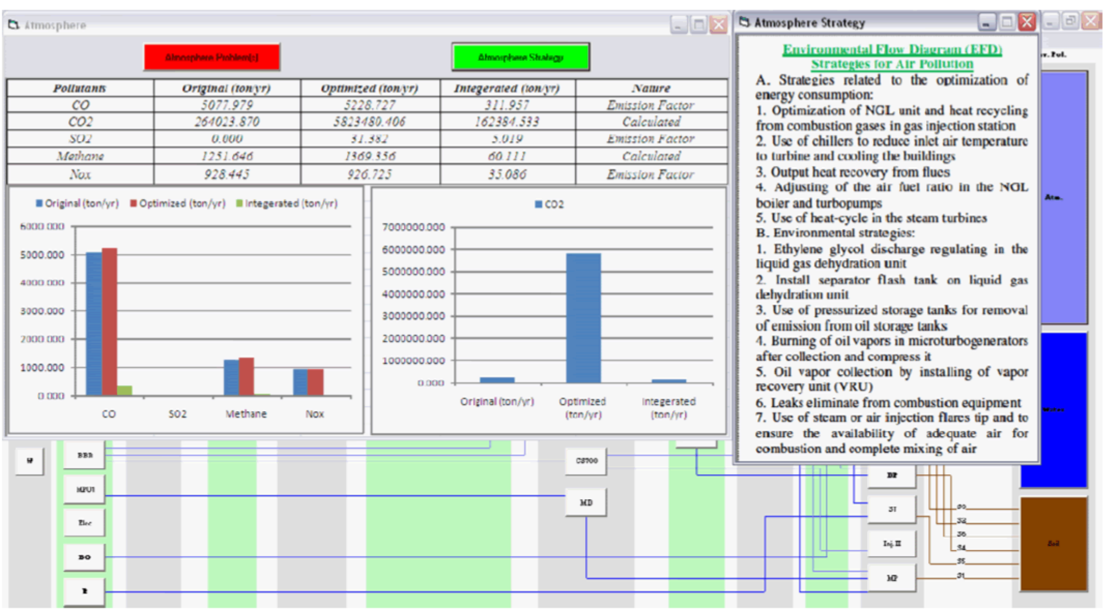


Figure 9: Final pollution in air section with suggested strategies for reducing or removing pollution problems in this section [26,28].

Figure 9: Final pollution in air section with suggested strategies for reducing or removing pollution problems in this section [26,28].

Indicators of pollution that are examined in EFD includes greenhouse gases (CO_2, CH_4, and N_2O) and air pollutants (CO, SO_2, NOx, and THC) in atmosphere section and BOD, COD, heavy metals, oil and grease, and total hardness in water and soil sections. Methods of air pollution estimation in EFD include sampling of emission sources, emission factors available in international resources, engineering calculations, and process simulation. In addition, mode of evaluating water and wastewater in EFD include sampling of industrial wastewater in operational area, comparison with national and international standards, and detecting pollutants that are above environmental standards. According to the **Figure 4**, high values of coliforms in WWT have been caused which other pollutant was not visible in graph. **Figure 5** shows values of atmosphere pollutants in original status and if implementation of scenarios related to the optimization of energy consumption (optimized) and reduction of air pollutions (integrated).

Nature of pollutants estimation for CO, SO_2, and NOx was based on emission factor and for greenhouse gases (CO_2 and CH_4) was calculated.

Destruction of Breeding and Spawning Grounds

For any nest, building fish or any fish in which the eggs attach to a particular substrate the nature of the substrate is important in successful spawning. Aquatic vegetation often provides the very substrate within which or on which eggs are laid and may protect eggs from wave action and erosion. Soil particles due to land erosion carried out run-off water and suspended matter present in sewage and trade wastes gets deposited on the river bed or behind the weirs and cause silting of the bed (**Figure 10**).

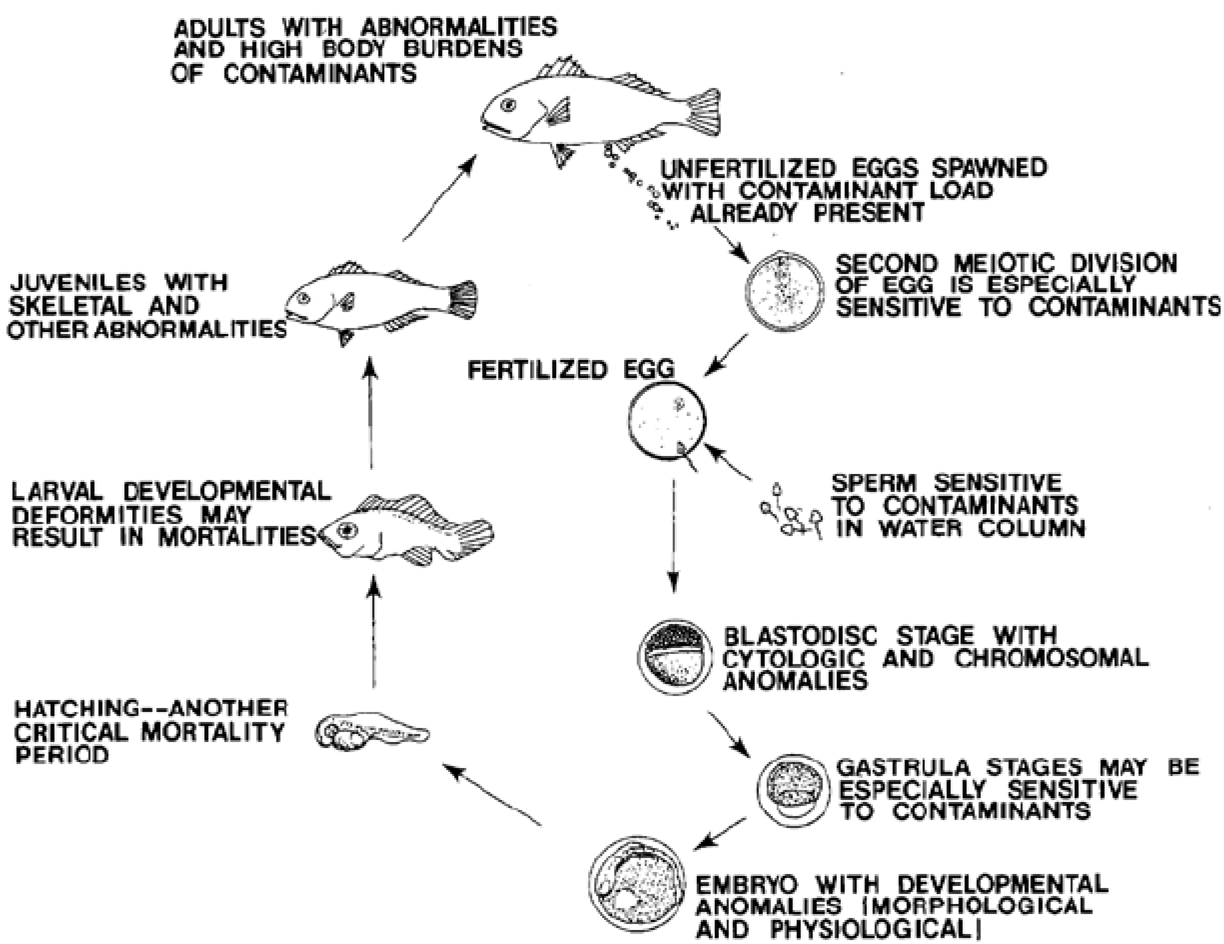


Figure 10: Points in the life cycle when fish are especially sensitive to pollutants [26].

Figure 10: Points in the life cycle when fish are especially sensitive to pollutants [26].

The presence of pollutants in the tissues of aquatic animals

Overtime, many laboratory-based investigations and studies of animals obtained from the aquatic environment have highlighted the presence of pollutants in the tissues of a wide range of aquatic animals.

In-vitro studies: A wide range of pollutants, including creosote fractions [9], thiocyanate [29-31], didecyldimethylammonium chloride [32] and DDI' [12], have been found to be taken up into aquatic organisms via waterborne exposure. However, it is questionable what if any relevance such laboratory data have to occurrences in the aquatic environment.

Investigations using animals obtained from the aquatic environment

There is a good correlation between the presence of pollutants in animals and the levels in the surrounding aquatic environment. For example, heavy metals, including copper and zinc, have been detected in the tissues of rabbitfish (*Siganus oramin*) obtained from the polluted waters around Hong Kong, in a range of invertebrates and vertebrates obtained from Taiwan [33], and cod (*Gadus morhua*) caught from off the coast of Newfoundland, Canada [34]. Cadmium, lead and mercury have been identified in small amounts in fish from the Great Lakes [35-38]. Interestingly, the levels for cadmium, lead and mercury in cod were below the maximum permitted limit for foods [34], casting some doubt on the significance of the concentrations to the health of the animal.

Similarly, mercury, in concentrations considered to be insufficient to cause human health problems, has been found in apparently healthy fish and shellfish collected from the vicinity of discharges from a chloralkali plant in India [39].

Crustaceans, fish and molluscs, obtained from the vicinity of a sewage outfall, have been determined to be contaminated with pesticides, namely chlordane, dieldrin, hexachloro-benzene and DDT. Similarly, DDT and polychlorinated-biphenyls (PCB), organochlorine residues and 2,3,7,8-tetrachlorobenzo-p-dioxin have been found in fish caught from the Vaike Vain Strait in western Estonia [40], from the North Sea [10], and the Great Lakes [11], respectively. Yet, there was not any indication that the compounds were actually causing any harm to the animals.

Sewage

Sewage effluents contain complex mixtures of chemicals such as natural and synthetic hormones, alkylphenols, phthalates, bisphenol A, pharmaceuticals and some pesticides [41-43]. These chemicals disrupt the endocrine system of animals and are known as endocrine disrupting chemicals. Endocrine disrupting chemicals (EDCs) constitute a major group of chemical pollutants in the aquatic environment and they interfere with the hormonal systems of animals [44].

Endocrine disrupting chemicals mimic or antagonize endogenous hormones and alter the synthesis and metabolism of endogenous hormones and hormone receptors [45]. Several adverse health effects in aquatic organisms have been attributed to EDCs, such as developmental, neurological, endocrine and reproductive alterations [46,47]. The aim of the study was to assess the efficiency of the treatment processes at a sewage treatment plant in Sweden with regard to the reduction of some EDCs such as pharmaceuticals and estrogens.

Classification of morphological deformities and their rates of occurrence

Morphological deformities of adult tilapia were separated into 15 categories that described abnormalities on all portions of the fish.

These categories are:

(1) Split fins,

(2) Scale disorientation (including thickened and deformed scales),

(3) Hyperplasia of the surface of the mouth,

(4) Muscle atrophy,

(5) Opercular deformity,

(6) Gill deformity (including gill raker, gill arch, and gill filament deformities),

(7) Eye deformity (including the subcategories of exopthalmia, concave eye, small eye, blindness, lens deformity, and opaque cornea),

(8) Skeleton deformity (including vertebral and skull deformities),

(9) Outward protrusion of the lower lip,

(10) Tumors and other swellings,

(11) Jaw deformity (including one or two sides of the jaw having raised calcifications), (12) head or lower jaw bent to one side,

(13) Protruding mouth or nose part depression,

(14) Fin deformity (including elongated fin, part of the fin missing, and fin ray deformity), and

(15) Miscellaneous items (including body shape deformity and protrusion of the mandibular cartilage) (**Figures 11-14**).

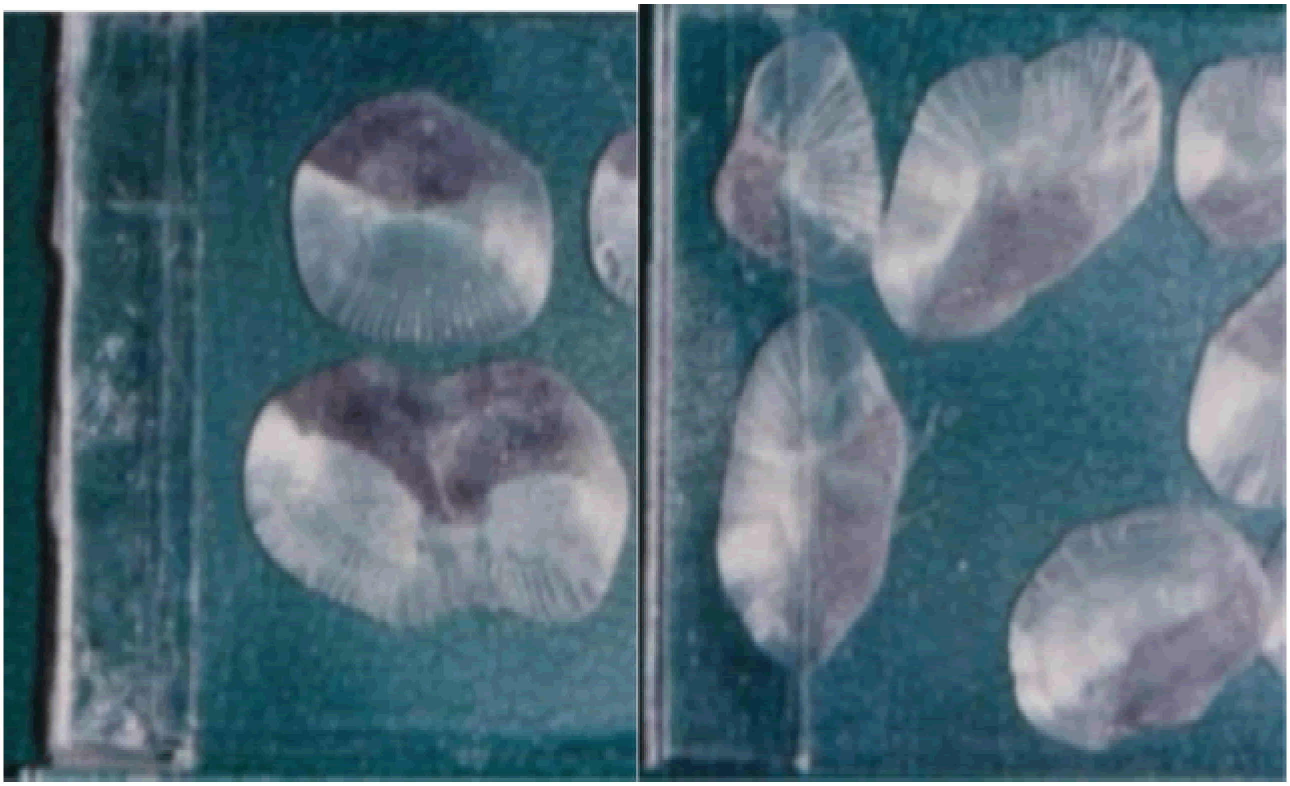


Figure 11: Abnormalities in scales of *Orechromis spp* [19].

Figure 11: Abnormalities in scales of Orechromis spp [19].

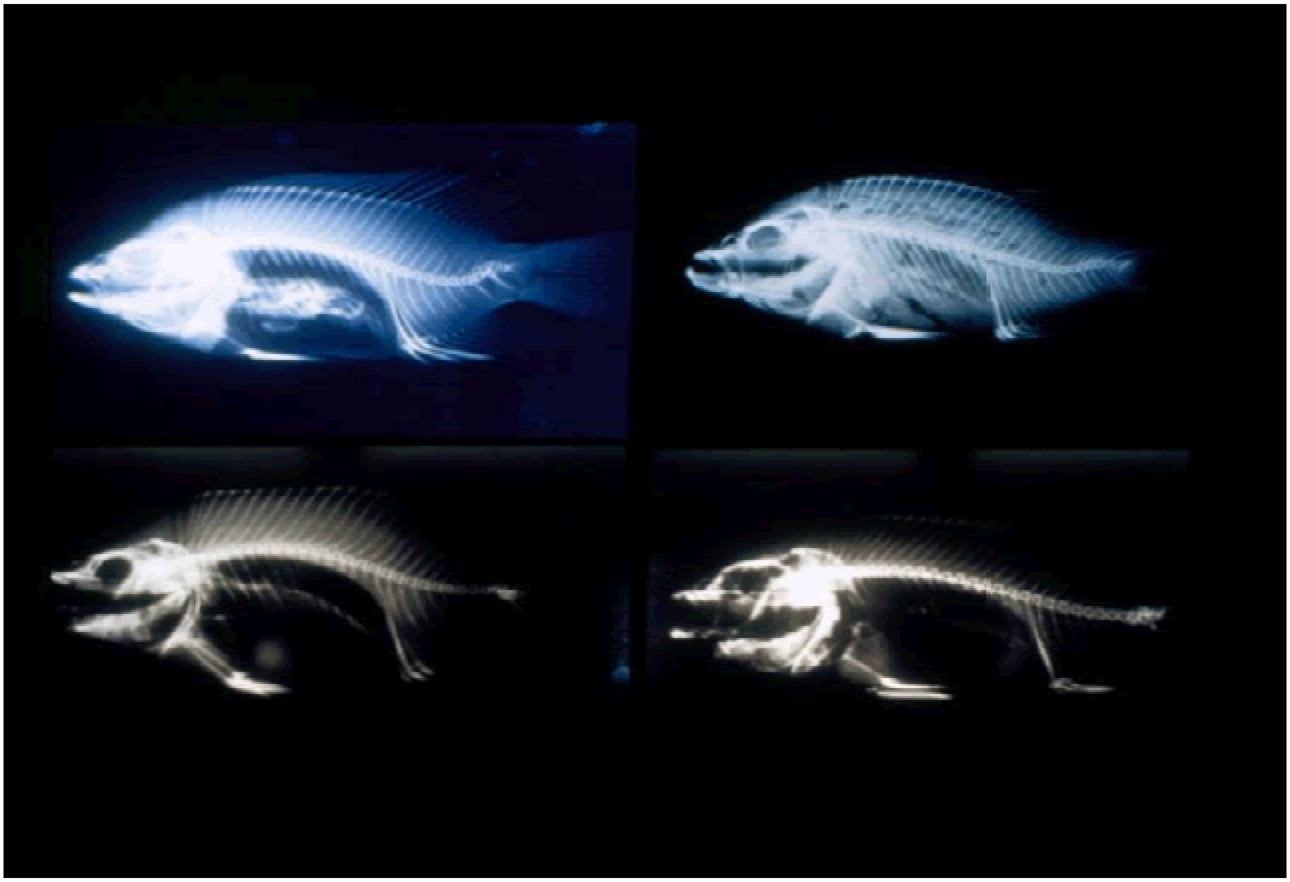


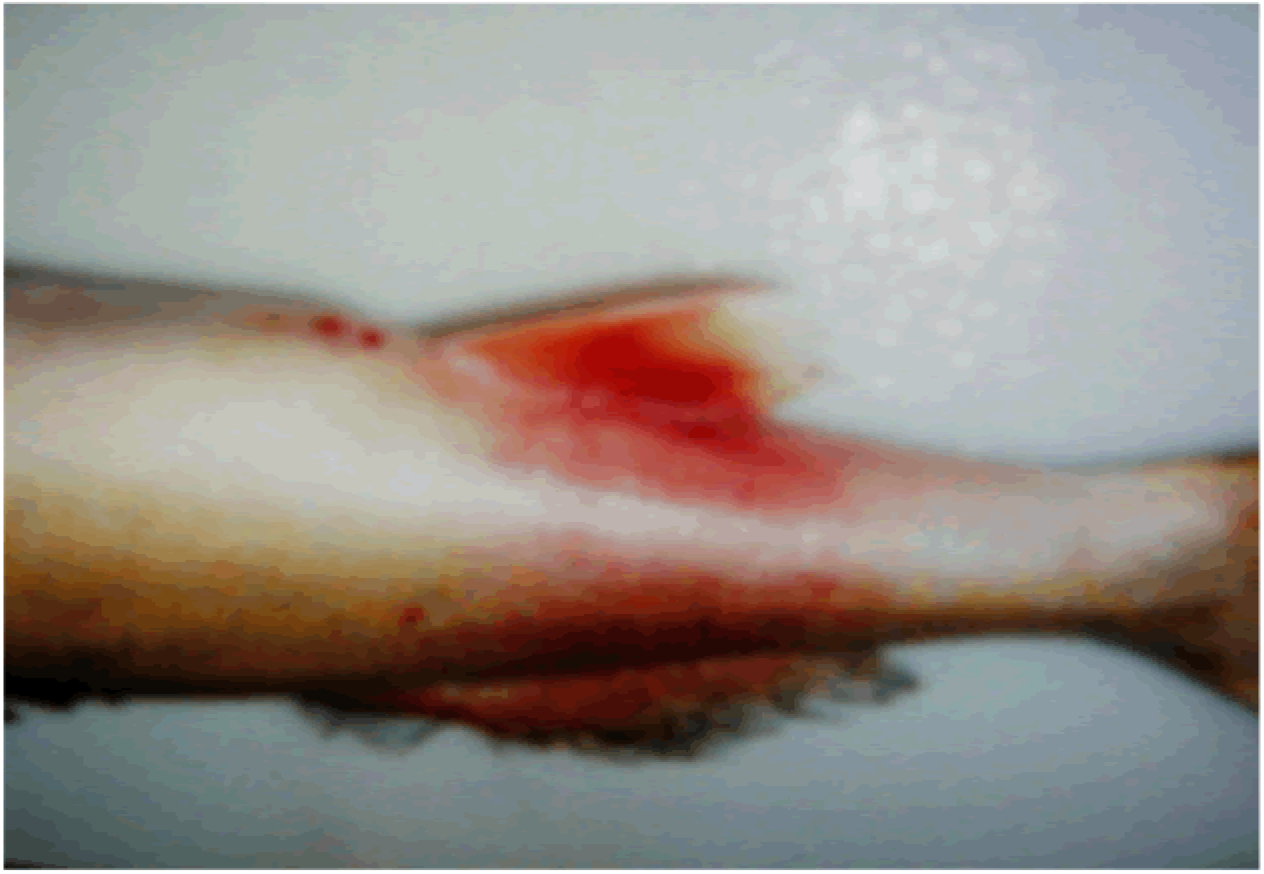
Figure 12: Different Types of Skeletal Deformities in Tilapia [19].

Figure 12: Different Types of Skeletal Deformities in Tilapia [19].

Source: Brown-Peterson.

Figure 13: Gill deformities in *Orechromis spp.*

Figure 13: Gill deformities in Orechromis spp.



Source: Timoney.

Figure 14: Reddened fins and skin on walleye; due to a bacterial infection.

Figure 14: Reddened fins and skin on walleye; due to a bacterial infection.

The exposure of aquatic animals to high concentrations of pollutants may lead rapidly to death. Here, there is a clear association between pollution and mortalities. Yet, exposure to lower quantities of pollutants may lead to chronic darnage, the implications of which need not be manifested for a comparatively long period [48,49]. Exposure to sewage sludge has been implicated with effects on growth and protein synthesis in common dab (*Limanrla iamanda*) [50]. In addition, liver damage in fish has been associated with contamination by components of sewage sludge [51], cadmium [52,53].

Prevention of pollution

1) There should be proper and adequate management of solid and domestic waste.

2) Provision of adequate drainage systems to arrest urban and agricultural runoffs.

3) Measure against pollution must be an intrinsic part of the design and construction of facilities of all industries.

Control measures of pollution

1) Ensuring the primary treatment of municipal sewage discharged into rivers, creeks, lagoons and the sea.

2) Promoting use of environmental impact assessments to help ensure an acceptable level of environment quality.

3) Implementation and enforcement of policies and existing acts and regulation of environmental protection.

Discussions

Overtime, sewage also contains potentially toxic, mutagenic, or carcinogenic compounds [54]. Eutrophication, which may result from organic load on water bodies, is one of the numerous problems created by sewage pollution [55,56]. Even though, water bodies in their natural form contain chemical compounds such as the bicarbonates, nitrates, chlorides, sulphates, various problems however arise with the increase in the amount of these compounds within the water bodies. Water which contains salts is not useful for irrigation either as utilization of such water leads to the salinization of the soil, which in turn leads to soil erosion. The toxins released into the rivers through sewage water are consumed by fishes and other organisms, thus increasing the possibility of these toxins entering the food chain [16,22]. The Lagos lagoon which is the focus of the current research like many coastal lagoons, serves as a seaport, centre for recreational sailing and a sink for disposal of domestic and industrial wastes. A paucity of information exists on the extent of pollution of the lagoon [3].

Conclusively, the discharge of industrial effluents into receiving water bodies invariably results in the presence of high concentrations of pollutant in the water and sediment. Solid waste management policies and enforcement of sanitation laws in various should be practiced. Effluents also have considerable negative effects on the water quality of the receiving water bodies and as such, they are rendered not desirable for fish health and survival. During dietary administration of metals, their concentrations in the digestive tract increase and remain high until the end of exposure, and rapidly decrease during depuration. In case of waterborne exposure, metal levels in the digestive tract are usually low. Liver accumulates high concentrations of metals, irrespectively of the uptake route. Assessing morphological deformities is one of the most straightforward methods to study the effects of contamination on fish because of the ease of recognition and examination when compared with other types of biomarkers. Different types of morphological abnormalities have been reported in fish taken from contaminated waters, including fin erosion [25] skull deformation; jaw deformities; skeletal deformities such as lordosis, scoliosis, and kyphosis [57]; opercular deformity; fin deformity; lower lip protrusion; gill deformity ocular disorders; scale deformity and disorientation; and neo-plasia or hyperplasia [58,59].

In contaminated waters, fish may exhibit whole animal, morphological, histopathological, cellular, organismic, or parasitic aspects of abnormalities, some of which can be used as biomarkers of contamination exposure [60]. The use of abnormalities in fish as biomarkers has become more prevalent in recent years [61]. Biomarkers in fish can provide a chronic indication the environmental condition than can more general and acute indices such as plankton analyses or water quality parameters. However, the cause-and-effect relationships between biomarkers and certain suspected pollutants cannot always be established [62]. Metal concentrations in the kidneys rise slower than in liver, and usually reach slightly lower values, except for such metals as cadmium and zinc that show very high affinity to kidneys, therefore the kidneys may be considered a good indicator of pollution too. Further research is required on the discharge of industrial effluents into receiving water bodies in Nigeria which invariably results in the presence of high concentrations of pollutant in the water and sediment.

Acknowledgements

We appreciate the support of the Marine Science department of the University of Lagos, Akoka, for making this study a success. We extend gratitude to colleagues who contributed positively in to this paper. Our thanks also extend to the editorial board for their restless effort for the peer reviewed process.

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