Effects of Oilfield Chemicals, Herbicides, Pesticides and other Pollutants on Fisheries Resources in Nigeria

Abstract

Crude oil exploration and exploitation is the major source of income or revenue generation to the Federal Government of Nigeria. Agriculture also forms a substantial part of the economic stability of the country. However, oil field chemicals used in crude oil exploration, herbicides and pesticides used for agricultural purposes and other anthropogenic pollutants, which are eventually released into the aquatic environment constitute serious sources of threat to the growth, survival and productivity of fisheries resources. This review paper identified the impacts of these substances on fish to include; growth inhibition, increased chromosome aberrations in cell roots, increased fungal biomass and mortality. Recommendations arising from this review include; proper disposal of oilfield chemical wastes, enhanced use of biological and mechanical pesticides/herbicides control methods as against the use of the chemicals, which helps to reduce the amount of these substances released into the aquatic environment and the direct remediation of impacted environment. These recommendations when implemented are expected to ultimately improve fish growth, survival and productivity.

Keywords: Oilfield chemicals, herbicides, pesticides, fisheries resources and pollutants

INTRODUCTION

Nigeria largely depends on the exploration activities of crude oil for her revenue and power generation. Crude oil exploration has been of great benefit as well as causing grave negative impacts on the environment (Uche *et al*., 2015). Oilfield chemicals are different chemicals used throughout the oil and gas exploration and production phases. These chemicals over time enter the aquatic environment. According to Unyimadu *et al*. (2018), the contamination of rivers by chemicals has raised concern around the world and is an increasing challenge facing developing countries. The current practice of urbanization, population density and increase in man-made activities contribute to chemical contamination of surface waters or aquatic bodies in general. The monitoring of chemical pollutant presence in surface water bodies in advanced countries has been used as a yardstick for the formulation of policies and pollution control, thus enhancing safe water bodies.

Adam and Nichole (2017), reported that water is contaminated from oil and gas development through well failure, wastewater storage systems, wastewater transport, disposal wells. Other sources of water contamination from oil and gas development are; the release of wastewater onto roads, lands and waterways as well as the use of oilfield wastewater to irrigate crops. Drilling fluids (water based fluids and non-aqueous drilling fluids) after use are disposed of into pits (temporary or permanent pits) for land-based drilling and into the surrounding water body or swamp-cut for offshore drilling (Ifeadi *et al*., 1985). Saasen *et al*., 2001 and Wills, 2000 reported that the presence of drilling wastes in water body may result in mortality of marine life, smother or suffocate them with plume suspended particles, resulting in potential damage to the population of fish, invertebrates and changes in grounds where organisms feed and spawn. Constituents of drilling fluids hinder the growth of important microbial communities, relevant for some biological cycles present in the ecosystem which may affect the system's productivity (Vincent-Akpu and Sikoki, 2018). Examples of oil field chemicals are hydraulic fracturing fluids, flowback and produced water. According to John (2016), some common hydraulic fracturing fluids (HF), include; proppants, gelling agents, friction reducers, cross-linkers, breakers, biocides, corrosion inhibitors, scale inhibitors, iron control substances, clay stabilizers and surfactants. Examples of flowback and produced water include; production chemicals, dissolved minerals, metals, dissolved and dispersed oil components and produced solids.

Nwaogu *et al*. (2016) reported the scenario of effluents effects on water bodies in Nigeria thus: "Water bodies are the primary means by which waste, especially industrial, municipal, agricultural and sewage effluents are disposed of globally. It has been proven through studies in Nigerian cities that one of the main sources of water pollution is from effluents and less than 10 percent of industries in the country treat their effluents before they are discharged into water bodies. The physical, chemical and biological nature of the water into which the effluents are discharged can be altered leading to the mortality of aquatic organisms such as fish. The discharge of untreated industrial waste into water bodies has led to eutrophication of water bodies as shown by substantial algal bloom, resulting in the depletion of dissolved oxygen and ultimately massive death of fish and other organisms". Although produced water has the potential of being toxic, there is a dearth of information on their actual negative impacts on flora and fauna that are exposed to it in Nigeria. This situation therefore calls for further research to establish the extent of impacts of produced water have on the flora and fauna of impacted water bodies exposed to such effluents of produced water.

Toxicity studies have tested the negative impacts of Brent crude produced water with oyster larvae, water flea (*Duphnia mugnu*), and shrimp. The study conducted by Somerville *et al*. (1987) on *Salmo guirdneri* revealed that Brent production water was only toxic at dilutions below 20-fold. In other words the toxicity of produced water could be reduced through the dilution effect of sea water in offshore situations. This study seem to establish "that generally produced water can only become toxic to aquatic organisms of interest if it's dilution factor with sea water is at a volumetric ratio of 20:1 for sea water and produced water respectively. Nevertheless, the disposal of such effluents on land during onshore operations could become a threat to exposed flora (Odeigah *et al*., 1997). Although the impact of oil field chemicals can be ascertained under laboratory condition, some shortcomings have been identified with this method of assessing the effect of oil field chemicals. Uche *et al*. (2015), posited that there is lack of ecological realism in laboratory based research on the impacts of oil field chemicals on aquatic organisms. The preceding reports highlighted the disadvantages of impact of oil field chemicals determined under laboratory conditions to include; fluctuation of environmental conditions, chemical accumulation in the sediment and biota, synergistic and/or antagonistic effects of oil field chemicals with other industrial chemicals and effluents, inability to find food, e.t.c. Despite these short comings, laboratory testing for toxicological impacts of oil filed chemicals still remains the best pointer for giving a dependable guide as to what actually occurs in real life situations.

Pesticides are substances used to control pests, including weeds. Herbicides are substances used to control weeds, although, adverse effect can be seen on other organisms, other than the one intended as a result of indiscriminate use of herbicide in the environment, chiefly aquatic organisms (Nwani *et al*., 2011). It is a common practice in Agriculture globally, to use herbicide in the control of weeds, mainly with the view of improving the production of agricultural products. According to George *et al*. (2017), common herbicides include; atrazine, clomazone, dicamba, linuron, metsulfuron, trifluralin and 2, 4-D (Kassio *et al*., 2019). Nwani *et al*., 2013, reported that among these chemicals, atrazine and metalachlor rank as the most hazardous in terms of environmental pollution, because they are very persistent, non-biodegradable and can potentially bio-magnify as they move up in the food chain. The report further indicated that mortality and sub-lethal impacts occur in fish exposed to these compounds. In addition, the unregulated use of herbicides, poor handling, spills from accidents or untreated effluent discharge into natural waterways have harmful effects on the fish population as well as other aquatic organisms and could contribute to long term eco-toxicological effects to inhabiting aquatic organisms.

In Agricultural fielsd, there is the availability of several brands of herbicides for herbs/weeds control. Most of these herbicides have ecological effects on the organisms and humans that unknowingly use substances contaminated by such kind of chemicals (Ogaga and Sylvester, 2018). The use of pesticides at high concentrations has been proven to lower the survival, growth, reproduction and several effects that can be seen on fish (Rahman *et al*., 2002). There is an increasing scientific consensus that several Industrial and Agricultural chemicals have the potential to interfere with endocrine systems and the activities of hormones in all animals (Ogeleka *et al*., 2016). It is obvious that Agricultural chemicals have effects on aquatic organisms, thus concerted efforts should be prioritized in the area of preventing the chemicals inflow into the aquatic habitats as against remediation of their effects.

There has been noticeable increasing trend of aquatic organisms showing signs of stress symptoms associated with the nature of the environment in which they live (Phys, 2014). Additionally, amongst the symptoms reported by this study findings are effects of stress in aquatic organisms; leading to reduced yield and availability of fish for man, gasping for breath, poor quality of flesh, swimming near or around the water surface, or breathing rapidly, loss of appetite with attendant loss of weight, itching disease with symptoms of white spots on the skin of the organism, slow to react to disturbances and stimuli, listless or hibernating at the bottom, abnormal swimming, such as swimming upside down. Furthermore, aquaria organisms impacted by such chemicals especially within experimental tanks has been observed to scratch their bodies against the aquarium/experimental tanks or any other available other surfaces. This behaviour is obviously a symptom of the organism responding to irritation effects as a result of the chemical substances.

In aquatic toxicological studies, some of the terms commonly used are bioconcentration, biomagnifications and bioaccumulation. According to Kassio *et al*. (2019), bioconcentration and biomagnification is the direct capture of pollutants present in water, through the gills, skin, and oral route and the consumption of contaminated prey, associated with different trophic levels respectively, while bioaccumulation is the entry of xenobiotic molecules into organs of living organisms, over the time of exposure. Physicochemical parameters such as turbidity, dissolved oxygen, temperature, alkalinity, pH and conductivity influence the rate of reaction of the pollutants that enter the water or the lethal effects on the inhabiting aquatic organisms (Ani *et al*., 2017). Therefore adequate monitoring and data gathering research of physio-chemical parameters in relation to s toxicological effects of chemical pollutants on aquatic organisms within the Niger Delta should be pursued vigorously to ensure a better understanding of how the latter influences the former.

Several studies have identified the lack of implementation of environmental laws in Nigeria, as one of the reasons for the large scale environmental pollution (Osuji, 2002; Aniefiok *et al*., 2013 and Uche *et al*., 2015). The studies reported that the Federal Government of Nigeria has enacted laws and regulations with the aim of ensuring that the exploration and production operations of oil and gas, on both offshore and onshore fields, could be regulated in different ways with aim of minimizing their associated environmental impacts. These studies further revealed that most of these laws and regulations are not as effective as desired and in some cases, the penalty associated with defaulting is cheaper than the cost of doing it right for example, the "Associated Gas Re–injection Act (1979)".

The application of environmental toxicology bioassays on non-mammalian vertebrates is expanding rapidly and for aquatic system, fish is an indicator for noxious compounds effects evaluation (Ervnest, 2004). Fishes are very important tools for the assessment of the effect of pollution in aquatic environments because of their mobile nature (Van der Oost *et al*. 2003) and other physiological responses from the kidney, liver, gills and heart act as biomarkers that indicate alterations in biological response for example molecular, cellular and physiological as well as behavioral changes, as a result of exposure to toxic effect of environmental chemicals (Sribanjam *et al*. 2018). Biochemical markers are quantifiable responses of an organism's exposure to a pollutant and the use of various factors is more beneficial than using single biomarker (Kanchan *et al*. 2011). Analysis of these biochemical changes is usually used for the determination of the effect of pollutants on different organs in the field or in experimental studies (Fontainhas-Fernandes *et al*. 2008). Fishes can serve as bioindicators of the environment in which they live because their growth, survival and reproduction are a direct reflection of the prevailing quality of the environment.

According to Rahman *et al*. (2002), the contamination of water with recalcitrant chemicals in most cases results in bioaccumulation in fish and other fauna, at other times to biologically active levels. The study further revealed that there have been suspicions of these chemicals being carcinogenic in fish and other aquatic organisms (GESAMP, 1991); remains of these toxic chemicals in water, fish, sediment and other aquatic fauna constitute risk to organisms, predators and human beings. Laboratory experiment has also revealed that paraquat, which is an herbicide commonly used in farms can lead to mortality in exposed fish (Nkeeh and Jamabo, 2019).

Table 1 highlights some studies carried out between 1997 and 2020, to evaluate the effect of various toxicants on different fish species. Some of the toxic substances were lethal; while others were sub lethal, under conditions of either acute or chronic exposure. All the studies revealed various degrees of toxicity, depending on the toxic chemicals under investigation and the time of exposure to the toxicant.

Table 1: Effects some oilfield chemicals, herbicides, pesticides and other pollutants on fisheries resources in Nigeria recorded from some empirical studies

S/N	Author(s)	Publication Titles	Key Findings
1	Avoaja and Oti, 1997	Effects of sublethal concentrations of some pesticides on the growth and survival of the fingerlings of the African catfish-Heteroclarias (Hybrid)	The growth rate of "Heteroclarias" was drastically reduced on exposure to thiodon pesticides
2	Odeigah *et al*., 1997	Genotoxicity of oil field wastewater in Nigeria	Wastewater increased significantly the frequency of chromosome aberrations in root cells
3	Ezemonye and Ogbomidae, 2010	Histological effects of gammalin 20 on African catfish (*Clarias gariepinus*)	The test organism showed gill distortion and fusion of adjacent secondary lamella
4	Nwani *et al*., 2013	Investigation on acute toxicity and behavioural changes in *Tilapia zilli* to glyphosphate-based herbicide, forceup	Commercial formulation of glyphosphate (Forceup) if mildly toxic to *T. zilli*
5	Vincent-Akpu and Sikoki, 2013	Toxicity of drilling fluid parateq on microbial load and survival of Oreochromis niloticus fingerlings	The relationship between fungal biomass and mud concentration was inversely proportional
6	Uche *et al*., 2015	Biological and chemical changes associated with exposure of cyprinid fishes to some oil field chemicals in the Niger-Benue River system, Nigeria (A review)	A research that incorporates both field and laboratory studies is better
7	Ogeleka *et al*., 2016	Impacts of acute exposure of industrial chemicals and of fish (*Tilapia guinensis*) pesticides on the survival of fish and earthworms	The use and disposal of hazardous chemicals should follow standard safety limits
8	Nwaogu *et al*., 2016	Pollution of Nigerian aquatic ecosystems by industrial effluents: effects on fish productivity	Pollutants affect the biological growth and reproduction of fishes in the aquatic ecosystem thereby reducing the amount of captured fishes
9	George *et al*., 2017	Haematological changes in African catfish (*Clarias gariepinus*) exposed to mixture of atrazine and metolachlor in the laboratory	The haematological parameters in fish exposed to the pesticides were significantly ($p<0.05$) higher than that of the control
10	Ani *et al*., 2017	Acute toxicity of glyphosphate-based herbicide glycot on juvenile African catfish *Clarias gariepinus* (Burchell 1822)	The safe level for the herbicide varied from 2.46×10-1 to 2.46×10-4 mgL^{-1}
11	Unyimadu *et al*., 2018	Levels of organochlorine pesticides in brackish water fish	The concentration of total organochlorine pesticides (OCPs) compounds varied markedly

		from Niger River, Nigeria	amongst the different fish species
12	Ogaga and Sylvester, 2018	Toxicity of glyphosphate based herbicides to fingerlings of *Heterobranchus bidorsalis*	The LC_{50} values of glyphosphate on *Heterobranchus bidorsalis* were 20.88ppm, 22.91ppm, 22.39ppm and 19.50ppm at 24hours, 48hours, 72hours and 96hours, respectively
13	Nkeeh and Jamabo, 2019	Effect of paraquat on Tilapia fingerlings under laboratory condition	The test established the LC_{50} (10mg/L) of paraquat on fingerlings of *T. guinensis*
14	Ugbomeh *et al*., 2019	Biochemical toxicity of Corexit 9500 dispersant on the gills, liver and kidney of juvenile *Clarias gariepinus*	Corexi 9500 (toxicant) interfered with transamination and metabolic functions of the fish
15	Adeogun, 2020	How we learnt more about dangerous pollutants in Lagos lagoon	The complex combination of pollutants in Lagos lagoon interferes with fish and mammal biology-especially their endocrine systems-and is potentially harmful to humans

The studies chronicled in table 1 shows the various degrees of adverse impacts that different toxicants have on fisheries resources in Nigeria. From the reviewed studies above, exposure of test organisms to herbicides such as forceup, atrazine and metolachlor as well as glycot were mildly toxic to *T. zilli*, increased hematological parameters in fish and as well established the safe levels in *Clarias gariepinus* respectively. Some of the studies established the LC_{50} of glyphosphate and paraquat on *Heterobranchus bidorsalis* and fingerlings of *Tilapia guinensis* respectively. Similarly, thiodon pesticides reduced the growth rate of *Heteroclarias* Spp, wastewater increased chromosome aberrations frequency, while Gammalin 20 distorted gills of the test organisms. Also, corexi 9500 chemical affected the transamination and metabolic functions of fish. Generally, the most of the pollutants were observed to have disrupted the with most species endocrine systems.

Effects of Oil Field Chemical toxicants on Fishes

Several studies have been conducted to assess the effects of different toxicants on aquatic fauna and flora. For example; sub lethal effect of gammalin 20, genotoxicity of oil field wastewater and lethal effect of drilling fluid on different biota has been investigated (Ezemonye and Ogomidae, 2010; Odeigah *et al*., 1997 and Vincent-Akpu and Sikoki, 2018).

Different oil filed chemicals has been proven to be toxic to fish. Oil field wastewater can inhibit growth, exposure to drilling fluid and industrial chemicals have the potential to be toxic, and even lethal on fish. There is also the possibility of electrolyte and enzyme activity alteration in fish, when they are exposed to dispersants. The geneotoxicity of oil field wastewater in Nigeria has been evaluated by Odeigah *et al*. (1997). In the study, allium test (small bulbs of *Allium cepa*) was used to investigate the general and genotoxicity of an oil field wastewater. The study revealed that the treatment with wastewater lead to a significant growth inhibition that was dependent on dose. The study also showed that the effect concentration, EC_{50} (96h) was 28.5 percent, while the undiluted sample induced a total phytotoxic effect. The study further stated that the wastewater is mitodepressive and thus significantly increased the frequency of chromosome aberrations in the cell roots; and c-mitosis was the most common aberration at low concentrations. Vincent-Akpu and Sikoki (2013), investigated the toxicity of drilling fluid parateq on microbial load and survival of *Oreochromis niloticus* fingerlings, by exposing the test organisms to different concentrations of drilling fluid. The study revealed that the 96h LC_{50} was $2210mgL^{-1}$. There was a direct proportional relationship between the mortality and concentration, while the relationship between the lethal times and concentration was inversely proportional. The study noted an increase in fungal biomass with increase in mud concentration and a decrease in bacterial biomass with increase in mud concentration. There was a review by Uche *et al*. (2015) on the biological and chemical changes associated with exposure of cyprinid fishes to some oil field chemicals in the Niger-Benue River system, Nigeria. The review recommended that a research that incorporates both field and laboratory studies to investigate the effects of oil field chemicals in the natural environment would provide a holistic data for scientists.

A study by Ogeleka *et al*. (2016), to investigate the impacts of acute exposure of industrial chemicals on the survival of fish and earthworms was conducted following the Organization for Economic Cooperation and Development (OECD) #203 and 207 protocols. The study established that the test chemicals were toxic to the test organisms. The organisms exposed to the test chemicals showed significant difference compared to the control group. The sensitivity of the organisms to the chemicals indicates that adherence to standard safety limits/measures should be maintained during use and disposal of hazardous chemicals. Ugbomeh *et al*. (2019), investigated the biochemical toxicity of Corext 9500 dispersant on the gills, liver and kidney of juvenile *Clarias gariepinus.* They reported that in kidney, creatinine was significantly higher in the fish exposed to the test chemical. Similarly, alkaline phosphate (ALP) increased in the test organism while there was a decrease in urea. There were alterations in the activities of electrolytes and enzymes indicating that the test chemical interfered with transamination and metabolic functions of the fish.

Effects of Herbicides and Pesticides on Fish

Pesticides and herbicides through studies have been implicated in growth rate and hematological parameters reduction. They are also known to cause gill distortion, uncoordinated behavior and mortality in exposed fish. Avoaja and Oti (1997), worked on the effect of sub lethal concentrations of some pesticides on the growth and survival of the fingerlings of the African catfish-*Heteroclarias* (Hybrid). In their study, the fingerlings of the test organisms (*Heteroclarias* hybrid) were exposed to sub lethal concentrations of organophosphates (thiodon and melathio) and organocarbamide (carbryl). The exposure period was three weeks in a static bioassay. The study noted that there was a decreased rate of feeding, conversion of food as well as the efficiency of absorption and conversion as the concentrations of the pesticides increased. Upon exposure of the fish to maximum sub lethal concentrations of the toxicants, there was a decrease in protein, lipid and carbohydrate contents of gill, liver muscle and the intestine of the test organism. The study concluded that the growth rate of the test organism was reduced drastically upon exposure to thiodon pesticides, compared to malathion and carbryl. A study by Ezemonye and Ogomida (2010) assessed the histopathological effects of gammalin 20 on African catfish (*Clarias gariepinus*). The fingerlings of the test organisms were exposed to both lethal and sub lethal concentrations of gammalin 20 in a renewable static bioassay. The study listed the symptoms of gammalin 20 lethal poisoning to include increased physical activity, respiratory distress, erratic swimming, convulsions, increased breathing activity and loss of equilibrium. The 96-hour LC_{50} was 30ppb. Observed histopathological changes in fish include gill distortion as well as the fusion of adjacent secondary lamella following hyperplasia and the excessive accumulation of mucus.

A 96h semi-static acute toxicity bioassay study was conducted by Nwani *et al*. (2013) to investigate the acute toxicity and behavioral changes in *Tilapia zilli* to glyphosphate based herbicide, forceup. The study revealed that the LC_{50} value at 5% probability limit estimated by probit analysis within 24h was 477.79 (43.101-358.23) mgl^{-1}. The 48h LC_{50} was 296.43 (265.45-325.52) mgl^{-1}, LC_{50} value within 72h was 253.21 (222.58-281.02) mgl^{-1}. The 96h LC_{50} value was 211.80 (122.27-293.55) mgl^{-1}. The safe level for the herbicide was between 2.118 and 2.118×10^{-3} mgl^{-1}. Test organisms exposed to higher concentration of the test chemical showed uncoordinated behavior including erratic and jerking swimming, attempt to jump out of water, frequent surfacing and gulping of air, decrease in the movement of the opercula and mucus secretion on the body and gills as a result of exhaustion and death. Hematological changes in African catfish (*Clarias gariepinus*) exposed to mixture of atrazine and metolachlor in the laboratory was investigated by George *et al*. (2017). The test organisms were exposed to different concentrations of the test chemicals for 14days. The study showed a significant ($p<0.05$) reduction with increased concentrations of the hematological parameters.

Ani *et al*. (2017) carried out a study on the acute toxicity of glyphosphate-based herbicide glycot on juvenile African catfish *Clarias gariepinus* (Burchell 1822). The 24, 48, 72 and 96h LC_{50} values (with 5% probability limits) estimated by probit analysis were 34.72 (31.02-37.20), 31.90 (28.12-33.89), 27.40 (24.98-29.30), 24.60 (21.95-26.54) mgl^{-1} respectively. The safe level of the herbicide varied between 2.46×10^{-1} and 2.46×10^{-4} mgl^{-1}. Fish exposed to the test chemical showed uncoordinated behavior for example erratic and jerking swimming, gulping of air, jumping out of water, hyperactivity, loss of equilibrium, decreased opercula movement and ultimately mortality. Similarly, the levels of organochlorin pesticides (OCPs) in brackish water from Niger River, Nigeria was evaluated by Unyimadu *et al* . (2018), to investigate the OCPs levels in *Drapane africana, Mochokus niloticus, Chrysichthys nigrodigitatus,Pristipoma jubelini, Vomer septapinis, Pseudotolithus senegalensis, Mugil cephalus, Pseudotolithus elongatus, Sphyraena piscatorum,* and *Lutjanus goreensis.* The study observed that the test chemical could be potentially harmful to humans because the guideline value of 2000µg/kg fresh weight by WHO/FAO was exceeded. In another study by Ogaga and Sylvester (2018), fingerlings of *Heterobanchus bidorsalis* was subjected to glyphosphate based herbicides in order to assess the toxicity of the test chemical. A renewal bioassay technique was used for the experiment. The LC_{50} values from the study were 20.88ppm, 22.91ppm, 22.39ppm and 19.50ppm at 24h, 48h, 72h and 96h, respectively. The effect of paraquat on Tilapia fingerlings under laboratory condition was assessed by Nkeeh and Jamabo (2019). A static bioassay was used for the experiment. The LC_{50} of the test chemical was $10mgl^{-1}$. From the study, $5mgl^{-1}$, $2.5mgl^{-1}$ and $1mgl^{-1}$ were sub lethal, while $120mgl^{-1}$, $60mgl^{-1}$, $30mgl^{-1}$, $15mgl^{-1}$ and $10mgl^{-1}$ were lethal; and mortality increased with increase in concentration.

Effects of Industrial Effluents on Fish

Industrial effluents and other hazardous pollutants have the potential of interfering with the biology of fish and as well lead to aquatic eutrophication. Nwaogu *et al*. (2016) conducted a study on the pollution of Nigerian aquatic ecosystems by industrial effluents and its effects on fish productivity. It was reported from the study that untreated waste from industry directly discharged into water bodies results in aquatic ecosystem eutrophication as can be seen by substantial algal bloom resulting in the depletion of dissolved oxygen and eventually massive mortality of fish and other organisms. In a study on dangerous pollutants in Lagos lagoon by Adeogun (2020), it was reported that the complex combination of pollutants in the study area interferes with the biology of fish and mammal, especially their endocrine systems and thus have the potential to harm humans.

Increasing industrial effluent has been reported to decrease the activation of enzyme activity which would ultimately lead to low fish yield or productivity and even mortality in exposed fish. According to Mnkandia *et al.* (2016), an investigation of the effects of industrial effluent on aquatic organisms using Zebra fish showed that activation of enzyme activity was highest in fish exposed to the lowest concentration of industrial effluent. The study further revealed that activation of enzyme activity decreased with increase in the concentration of industrial effluent. Also, Soumitra (2016) evaluated the effect of paper mill effluents on morphological and hematological indices of *Amblyceps mangois*. The study revealed that the exposure of fish to paper mill effluents resulted in unusual swimming patterns, movements of opercula and other physiological responses. Hematological studies on the effluent treated fishes showed increase in white blood cell (WBC) count and decrease in red blood cell (RBC) count, implying the disturbance of blood balance and infection in fishes. The study further reported that some fishes exposed to effluent were also found to be anemic. Exposing fish to paper mill effluent is a source of stress to fish. A stressed fish would lead to low fish yield and productivity. In the long run, fishermen who depend solely on fishing as their source of livelihood would experience a drop in their income, leading to poverty and hunger.

Oilfield Chemicals, Pesticides, Herbicides and Other Hazardous Pollutants Impacts Abatement Measures

The importance of oil field chemicals to the oil and gas and the value of herbicides and pesticides to agricultural practices cannot be overemphasized. However, these and other chemicals have led to several negative impacts on fish. It is therefore important to consciously put measures in place to protect the aquatic ecosystem. According to George *et al*. (2017), although the aquatic environment is not the target pesticide but the widespread use has resulted in very serious problems in aquatic biota. Therefore, restriction should be placed on the discharge of pesticide in aquatic environment. Similarly, Nwani *et al*. (2013) has advised the cautious application of glyphosphate (Foreup) in the environment, particularly near water bodies, because their study revealed that commercial formulation of the pesticide is mildly toxic to *T. zillii*.

Nkeeh and Jamabo (2019), stated that it is preferable to use mechanical and biological methods of weed control, instead of the use of herbicide such as paraquat; since the former would pose little or no threat to the life of fish. According to Ani *et al*. (2017), there should be a prudent use of herbicide in both aquatic and terrestrial ecosystems in order to avoid ecotoxicological hazards.

Empty herbicide cans should be properly disposed and caution should be as well exercised during its application near aquatic ecosystem (Ogaga and Sylvester, 2018). Ugbomeh *et al*. (2019), had earlier advised that the concentrations of dispersants used in oil spills assessed properly and they should not be used near fish breeding grounds. Water quality should be maintained, since the contamination of fish sample is an indication of contaminated river (Uyimadu *et al*., 2018).

Industrial wastes and effluents should be minimized through the use of non-waste and low waste technologies; while proper treatment of effluents should be carried out before they are discharged into aquatic environment (Nwaogu *et el*., 2016). Also, there should be constant adherence to standard safety limits/measures during hazardous chemicals use and disposal (Ogeleka *et al* ., 2016). Adeogun (2020) encouraged more research in order to develop and enforce water and food safety regulations. Some protocols developed for the treatment of industrial effluent include; biological treatment, vacuum evaporation and physico-chemical treatment (Condorchem, 2020). There should also be synergy between the government and industrial facilities to come up with measures to reduce pollution before effluents get into any water body. Finally, there should be environmental monitoring by the government from time to time, in order to assess the response of species in the environment.

Going by the preceding proposed abatement measures, it is obvious that a cocktail/combo approach is required to be able to achieve a holistic and considerably effective minimization of the impacts of these chemicals on fish and other aquatic biota in Nigeria. Some of these measures should include application of empirical research findings as a scientific guide for application of standards on a case by case basis, consideration of the peculiarities of each recipient environment and biota and their level of sensitivity to the potential impacts of such chemicals (sensitivity index mapping), the anthropological and socio-economic implications of the deployment of such chemicals etc. With this combo approach, it is believed that the associated adverse impacts of these chemicals to the aquatic environment and biota will be greatly minimized.

CONCLUSION

More often than not, the release of sub lethal doses of herbicides, pesticides, oil field chemicals and other pollutants into fish rearing facilities and aquatic environment would usually go unnoticed, because mortality is not recorded. However, long-term exposure of fish to even a sub lethal concentrations of any toxicant, could pose very serious adverse effects on aquatic resources, including fish.

RECOMMENDATIONS

Biological and mechanical methods of weed control should be encouraged. The use of oilfield chemicals and disposal of their wastes should be according to recommended guidelines. Also, there should be proper regulation of the activities of Oil Multinationals and Commercial Farms, especially as it regards their operations waste and effluent disposal into both onshore and offshore environment, since these discharges eventually find their way into the aquatic environment. Erring farmers, industries and oil and gas companies should be appropriately sanctioned and fined where necessary, to serve as deterrent to others. Finally, research into the production of marine environment (marine life) tolerant oil field chemicals should be encouraged.

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