# 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 for 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 that 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, including 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 direct remediation of the impacted environment. When implemented, these recommendations are expected to ultimately improve fish growth, survival, and productivity.



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




## 1. INTRODUCTION

Nigeria largely depends on the exploration activities of crude oil for its revenue and power generation. Crude oil exploration has been of great benefit as well as caused grave negative impacts on the environment [1]. 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 [2], 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 man-made activities contributes to the 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.

[3] reported that water is contaminated by oil and gas development through well failure, wastewater storage systems, wastewater transport, and 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 [4]. [5] and [6] reported that the presence of drilling wastes in bodies of water may result in the mortality of marine life by smothering or suffocating them with suspended particles, resulting in potential damage to the population of fish and invertebrates and changes in the grounds where organisms feed and spawn. Constituents of drilling fluids hinder the growth of important microbial communities, relevant to some biological cycles present in the ecosystem which may affect the system's productivity [7].Examples of oil field chemicals are hydraulic fracturing fluids, flowback and produced water. According to John [8], 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.

## 2. EFFLUENT DISPOSAL IN WATER BODIES

[9] reported the scenario of effluent effects on water bodies in Nigeria thus: "Water bodies are the primary means by which waste, especially industrial, municipal, agricultural, and sewage effluents, is disposed of globally. It has been proven through studies in Nigerian cities that one of the main sources of water pollution is 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 blooms, resulting in the depletion of dissolved oxygen and ultimately the massive death of fish and other organisms. Although produced water has the potential to be toxic, there is a dearth of information on its actual negative impacts on the flora and fauna that are exposed to it in Nigeria. This situation therefore calls for further research to establish the extent of the impacts of produced water on the flora and fauna of impacted water bodies exposed to such effluents.

Toxicity studies have tested the negative impacts of Brent crude on produced water with oyster larvae, water fleas (*Duphnia mugnu*), and shrimp. The study conducted by [10] 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 seems to establish that generally produced water can only become toxic to aquatic organisms of interest if its 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 [11]. Although the impact of oil field chemicals can be ascertained under laboratory conditions, some shortcomings have been identified with this method of assessing the effect of oil field chemicals. [1], posited that there is a 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 the 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 field chemicals still remains the best pointer for giving a dependable guide as to what actually occurs in real-life situations.

## 3. PESTICIDES AND HERBICIDES INTRODUCTION INTO THE AQUATIC ENVIRONMENT

Pesticides are substances used to control pests, including weeds. Herbicides are substances used to control weeds, although adverse effects can be seen on other organisms other than the ones intended as a result of indiscriminate use of herbicides in the environment, chiefly aquatic organisms [12]. It is common practice in agriculture globally to use herbicides for the control of weeds, mainly with the view of improving the production of agricultural products. According to [13], common herbicides include atrazine, clomazone, dicamba, linuron, metsulfuron, trifluralin, and 2,4-D [14]. [15], 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 on inhabiting aquatic organisms.

In agricultural fields, there is the availability of several brands of herbicides for the control of herbs and weeds. Most of these herbicides have ecological effects on organisms and humans that unknowingly use substances contaminated by such kinds of chemicals [16]. The use of pesticides at high concentrations has been proven to lower the survival, growth, reproduction, and several other effects that can be seen on fish [17]. 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 [18]. 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 aquatic habitats as against remediation of their effects.

There has been a noticeable increasing trend of aquatic organisms showing signs of stress symptoms associated with the nature of the environment in which they live [19]. Additionally, amongst the symptoms reported by these 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, have been observed to scratch their bodies against the aquarium/experimental tanks or any other available surface. This behaviour is obviously a symptom of the organism's responding to irritation effects as a result of the chemical substances.

## 4. TOXICANT BIOCONCENTRATION, BIOMAGNIFICATION, AND BIOACCUMULATION

In aquatic toxicological studies, some of the terms commonly used are bioconcentration, biomagnification, and bioaccumulation. According to [14], bioconcentration and biomagnification are the direct capture of pollutants present in water through the gills, skin, and oral routes and the consumption of contaminated prey, associated with different trophic levels, respectively, while bioaccumulation is the entry of xenobiotic molecules into the 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 their lethal effects on the inhabiting aquatic organisms [20]. Therefore, adequate monitoring and data-gathering research of physio-chemical parameters in relation to the 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 of environmental pollution [21; 22; and 1]. 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, can be regulated in different ways with the 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 the aquatic system, fish is an indicator for noxious compound effects evaluation [23]. Fishes are very important tools for the assessment of the effect of pollution in aquatic environments because of their mobile nature [24] 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 effects of environmental chemicals [25]. Biochemical markers are quantifiable responses of an organism's exposure to a pollutant, and the use of various factors is more beneficial than using a single biomarker [26]. 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 [27]. 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 [17], 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 [28]. Remains of these toxic chemicals in water, fish, sediment and other aquatic fauna constitute a risk to organisms, predators and human beings. Laboratory experiments have also revealed that paraquat, which is an herbicide commonly used on farms, can lead to mortality in exposed fish [29].

Table 1 highlights some studies carried out between 1997 and 2020 to evaluate the effects 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 | [30] | 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 | [11] | Genotoxicity of oil field wastewater in Nigeria | Wastewater increased significantly the frequency of chromosome aberrations in root cells |
| 3 | [31] | Histological effects of gammalin 20 on African catfish (*Clarias gariepinus*) | The test organism showed gill distortion and fusion of adjacent secondary lamella |
| 4 | [15] | 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 | [7] | 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 | [1] | 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 | [18] | 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 | [9] | 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 | [13] | 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 |

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|---|---|---|---|
| 10 | [20] | 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 | [2] | Levels of organochlorine pesticides in brackish water fish from Niger River, Nigeria | The concentration of total organochlorine pesticides (OCPs) compounds varied markedly amongst the different fish species |
| 12 | [16] | 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 | [29] | 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 | [32] | 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 | [33] | 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 show 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 was 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 aberration frequency, and Gammalin 20 distorted the gills of the test organisms. Also, the corexi 9500 chemical affected the transamination and metabolic functions of fish. Generally, most of the pollutants were observed to have disrupted most species' endocrine systems.

## 5. EFFECTS OF OIL FIELD CHEMICAL TOXICANTS ON FISH

Several studies have been conducted to assess the effects of different toxicants on aquatic fauna and flora. For example, the sublethal effect of gammalin 20, the genotoxicity of oil field wastewater, and the lethal effect of drilling fluid on different biota have been investigated [31; 11 and 7].

Different oil field chemicals have been proven to be toxic to fish. Oil field wastewater can inhibit growth. Exposure to drilling fluid and industrial chemicals has the potential to be toxic and even lethal to fish. When they are exposed to dispersants, there is also the possibility of electrolyte and enzyme activity alteration in fish. The geneotoxicity of oil field wastewater in Nigeria has been evaluated by [11].In the study, allium tests (small bulbs of *Allium cepa*) were used to investigate the general and genotoxicity of oil field wastewater. The study revealed that the treatment with wastewater led 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. [7], 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 96-h $LC_{50}$ was 2210 $mgL^{-1}$. There was a direct proportional relationship between mortality and concentration, while the relationship between lethal times and concentration was inversely proportional. The study noted an increase in fungal biomass with an increase in mud concentration and a decrease in bacterial biomass with an increase in mud concentration. There was a review by [1] 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 research that incorporates both field and laboratory studies to investigate the effects of oil field chemicals in the natural environment would provide holistic data for scientists.

A study by [18] 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 a significant difference compared to the control group. The sensitivity of the organisms to the chemicals indicates that adherence to standard safety limits and measures should be maintained during use and disposal of hazardous chemicals. [32] investigated the biochemical toxicity of the dispersant Corext 9500 on the gills, liver, and kidney of juvenile Clarias gariepinus.They reported that in the 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.

## 6. HERBICIDES AND PESTICIDES' EFFECTS ON FISH

Through studies, pesticides and herbicides have been implicated in growth rate and hematological parameter reduction. They are also known to cause gill distortion, uncoordinated behavior, and mortality in exposed fish. [30], 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 and conversion of food, as well as an 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 content of the gill, liver muscle, and the intestine of the test organism. The study concluded that the growth rate of the test organism was drastically reduced upon exposure to thiodon pesticides, compared to malathion and carbryl. A study by [31] assessed the histopathological effects of gammalin 20 on African catfish (*Clarias gariepinus*). In a renewable static bioassay, the fingerlings of the test organisms were exposed to both lethal and sub-lethal concentrations of gammalin 20. The study listed the symptoms of gammalin 20 lethal poisoning as including increased physical activity, respiratory distress, erratic swimming, convulsions, increased breathing activity, and loss of equilibrium. The 96-hour $LC_{50}$ was 30 ppb. 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 96-h semi-static acute toxicity bioassay study was conducted by [15] to investigate the acute toxicity and behavioral changes in *Tilapia zilli* to the glyphosphate-based herbicide, forceup. The study revealed that the $LC_{50}$ value at the 5% probability limit, estimated by probit analysis within 24 h, was 477.79 (43.9101-358.23) $mgl^{-1}$. 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 $2.11810^{-3}$ $mgl^{-1}$. Test organisms exposed to higher concentrations of the test chemical showed uncoordinated behavior, including erratic and jerking swimming, attempts to jump out of water, frequent surfacing and gulping of air, a 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 a mixture of atrazine and metolachlor in the laboratory were investigated by [13]. The test organisms were exposed to different concentrations of the test chemicals for 14 days. The study showed a significant (p 0.05) reduction with increased concentrations of the hematological parameters.

[20] 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), and 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 the Niger River, Nigeria were evaluated by [2], to investigate the OCP levels in *Drapane africana*, *Mochokus niloticus*, *Chrysichthys nigrodigitatus*, *Pristipoma jubelini*, *Vomer septapinis*, *Pseudotolithus senegalensis*, *Mugil cephalus*, *Pseudotolithus*, *Sphyraena piscatorum*, and *Lutjanus goreensis.* The study observed that the test chemical could be potentially harmful to humans because the guideline value of 2000 g/kg fresh weight by WHO/FAO was exceeded. In another study [16], fingerlings of *Heterobanchus bidorsalis* were 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 20.88 ppm, 22.91 ppm, 22.39 ppm, and 19.50 ppm at 24 h, 48 h, 72 h, and 96 h, respectively. [29]: [30] evaluated the effect of paraquat on Tilapia fingerlings in the laboratory.A static bioassay was used for the experiment. The $LC_{50}$ of the test chemical was 10 $mgl^{-1}$. From the study, 5$mgl^{-1}$, 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 an increase in concentration.

## 7. EFFECTS OF INDUSTRIAL EFFLUENTS ON FISH

Industrial effluents and other hazardous pollutants have the potential to interfere with the biology of fish and also lead to aquatic eutrophication. [9] conducted a study on the pollution of Nigerian aquatic ecosystems by industrial effluents and its effects on fish productivity. It was reported in the study that untreated waste from industry directly discharged into water bodies results in aquatic ecosystem eutrophication, as can be seen by substantial algal blooms 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 [33], it was reported that the complex combination of pollutants in the study area interferes with the biology of fish and mammals, especially their endocrine systems, and thus has 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 [34], 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 enzyme activation decreased with an increase in the concentration of industrial effluent. Also, [35] 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 an increase in white blood cell (WBC) count and a decrease in red blood cell (RBC) count, implying the disturbance of blood balance and infection in fishes. The study further reported that some fish exposed to effluent were also found to be anemic. Exposing fish to paper mill effluent is a source of stress for 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.

## 8. OILFIELD CHEMICALS, PESTICIDES, HERBICIDES, AND OTHER HAZARDOUS POLLUTANTS IMPACT ABATEMENT MEASURES.

The importance of oil field chemicals to oil and gas production and the value of herbicides and pesticides to agricultural practices cannot be overemphasized. However, these and other chemicals have had several negative impacts on fish. It is therefore important to consciously put measures in place to protect the aquatic ecosystem. According to [13], although the aquatic environment is not the target pesticide, its widespread use has resulted in very serious problems in aquatic biota. Therefore, restrictions should be placed on the discharge of pesticides into the aquatic environment. Similarly, [15] has advised the cautious application of glyphosphate (Foreup) in the environment, particularly near water bodies, because their study revealed that the commercial formulation of the pesticide is mildly toxic to *T. zillii*.

[29] stated that it is preferable to use mechanical and biological methods of weed control instead of the use of herbicides such as paraquat, since the former would pose little or no threat to the life of fish. According to [20], 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 of and caution should be exercised during its application near aquatic ecosystems [16]. [32] had earlier advised that the concentrations of dispersants used in oil spills be assessed properly and that they should not be used near fish breeding grounds. Water quality should be maintained since the contamination of fish samples is an indication of a contaminated river [2].

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 the aquatic environment [9]. Also, there should be constant adherence to standard safety limits and measures during hazardous chemical use and disposal [18]. [33] 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 [36]. 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 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 the application of empirical research findings as a scientific guide for the 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 on the aquatic environment and biota will be greatly minimized.

## 9. 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 the aquatic environment would usually go unnoticed, because mortality is not recorded. However, long-term exposure of fish to even sub-lethal concentrations of any toxicant could pose very serious adverse effects on aquatic resources, including fish.

## 10. 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 a deterrent to others. Finally, research into the production of marine environmental (marine life) tolerant oil field chemicals should be encouraged.

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