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Acute Toxicity Effect of Mulsate (Glyphosate) Herbicide on Behaviour and Haematological Indices of African Catfish (*Clarias gariepinus* Burchell 1822) Juvenile

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Abstract

A semi-static bioassay method was used to study the toxicity effect of acute exposure of a commercial formulation of glyphosate herbicide (Mulsate) on the behaviour and haematological profile of *Clarias gariepinus* juvenile. Sample fish were exposed to lethal concentrations of mulsate at 0.00mg/l, 55.00mg/l, 65.00mg/l, and 75.00mg/l for 96 hours. Behavioural characteristics observed in exposed fish include respiratory distress, erratic swimming, loss of equilibrium, lethargies and sudden fish death. These varied greatly with differences in concentration of the toxicant. Mortality increased with an increase in concentration of the toxicant. The differences observed in the mortalities of *C. gariepinus* at varying concentrations were significant ($P<0.05$), an indication that mortality could be a factor of concentration and time of exposure. After 96 hr of exposure, the LC50 for mulsate glyphosate herbicide was found to be 44.67mg/l. Furthermore, the toxicant led to significant reduction ($P<0.05$) in haematological parameters as the toxicant concentration increased. Mean Red Blood Cells (RBC), Haemoglobin content (Hb), Packed Cell Volume (PCV), reduced as the concentration of toxicant increased. Mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) were significantly different ($P <0.05$) between the treated and control fish. Our results indicate that the commercial formulation of glyphosate herbicide (Mulsate) is toxic to *C. gariepinus*. The herbicide must hence be applied with care in our environment particularly close to water bodies to avoid ecotoxicological consequences.

Keywords: Bioassay; Toxicity; Herbicide; Glyphosate; Biota; Haematology

Abbreviations: RBC: Red Blood Cells; Hb: Haemoglobin; PCV: Packed Cell Volume; MCV: Mean Corpuscular Volume; MCH: Mean Corpuscular Haemoglobin; MCHC: Mean Corpuscular Haemoglobin Concentration; SE: Standard Error; WBC: White Blood Cells.

Introduction

The contamination of freshwater by different pollutants has posed a serious global challenge in recent times owing to its undesirable effects on aquatic organisms [1]. Knowledge on the deleterious effects of fresh water pollution due to toxic pollutants such as heavy metals, industrial and domestic sewage as well as agro-chemicals is on the rise [2]. The flow of agro-wastes such as herbicides in the form of 'run-offs' from farm lands into streams, rivers and lakes is a global occurrence that needs attention. This is because the exposure of fish and other aquatic biota to these chemicals can lead to grievous physiological impairment as well as death of the organisms [3].

As a result of population explosion and industrialization, agrochemicals are employed to boost food production [4]. However, indiscriminate use of these agrochemicals like herbicides by farmers to checkmate weed growth in farms is causing harmful consequences on non-target organisms [5]. Herbicides are blend of chemicals formulated to control the growth of unwanted weeds [6]. They comprise a wide range of pesticides with more than 500 active products in different marketable constitutions [7,8]. After applying herbicides on target organisms, they leach into water bodies far from their originating source where they exert harmful effects on aquatic biota and their surroundings. This is because herbicides are naturally persistent and can be transported through atmospheric exchange or water currents to far-flung locations. Besides, other human activities like washing spray cans and pouring away of spray remnants help to spread the chemicals. Aquatic pollution due to herbicide contamination is of great concern because it rigorously affects fish and other organisms in the aquatic food chain [9,10].

Mulsate is a brand of glyphosate herbicide formulated in a soluble liquid form. Like other varieties of glyphosate, it is a non-selective systemic herbicide. It is readily absorbed by the foliage with rapid translocation through the plant body. Generally, glyphosate is an organophosphorus compound. It is one of the most accepted herbicides used by farmers the world over because of its dynamic action of eliminating weeds without affecting the crops. Due to its low toxicity, it is regarded as being eco-friendly [11]. It can easily dissolve in water, has a low vapour pressure, high water solubility and has a low persistence in the environment [12]. However, studies have revealed that glyphosate use at higher concentrations is lethal and can end in physiological damages or death in organisms. A range of glyphosate concentrations have been found to be poisonous to young catfish species leading to poor growth, low survival and death [5]. Other behavioural changes caused by glyphosate contamination which have been shown to be lethal to the survival of affected species include loss of equilibrium, erratic swimming, jerky movement, hyperactivity, decreased opercula movement and air gulping [13,14]. A good number of surfactants have been detected in the formulation of glyphosate which are noxious and so not suitable for aquatic use [15]. Herbicide residues in the agro-waste may be moved further away into near water bodies where they bioaccumulate in the food chain and non-target organisms like fish are affected [16]. Humans rely on fish as a veritable source of protein food.

Toxicity experiments on aquatic organisms have been utilized over the years to assess the risks that may affect a larger populace man inclusive [17]. So, to establish if a prospective toxicant is hazardous to aquatic life, need arises that the correlation between the toxicant concentrations and their effect on the aquatic organisms be determined. This is done in an aquatic bioassay experiment which is also necessary to control water pollution [18]. Hence, toxicological studies have the capacity to recognize potential hazards in the ecosystem given that pollutants found in aquatic animals may likely affect the whole community where man is on top of the food chain [19]. African catfish *C. gariepinus* was used as a biological model for this ecotoxicological research. This is because the fish is hardy and widespread in Nigeria's natural and manmade water bodies. The fish is an interesting model for toxicological studies because results of the experiment can be applied in order to resolve human and other environmental health concerns [20].

However, glyphosate has been shown from many studies to pose a variety of health and environmental hazards [21]. Portier CJ, et al. [22] and Portier CJ [23] equally reports that glyphosate formulations are probable human carcinogens. Moreover, there is no existing data on the toxicity levels of mulsate brand of glyphosate herbicide. There is therefore the need to investigate the toxicity of commercial formulation of glyphosate herbicide (Mulsate) on *C. gariepinus* juveniles through; observation of the behavioural characteristics of *C. gariepinus* during acute exposure to Mulsate glyphosate; determination of mortality response of *C. gariepinus* at different concentrations; determination of the 96 hours LC50 of *C. gariepinus* juveniles exposed to Mulsate glyphosate and evaluation of the effect of acute exposure of Mulsate glyphosate on the haematological profile of *C. gariepinus*.

Materials and Method

Study Area

The study was carried out in the Water Quality and Toxicology Unit, Wet Laboratory, Department of Fisheries and Aquaculture, Faculty of Agriculture and Natural Resource Management, Ebonyi State University, Abakaliki, Ebonyi State, Nigeria. Ebonyi State is located between Latitude: 6° 15' 18" N, Longitude: 8° 05' 55" E and it has Land Area - 5,533 sq. kms on the South-Eastern part of Nigeria (Figure 1) [24].

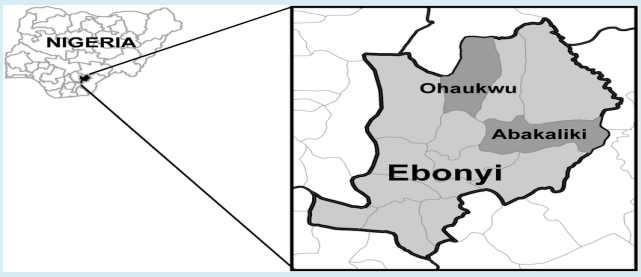

Figure 1: Map of Ebonyi State Showing the Study Area (Source Ebonyigov).

Experimental Fish and Chemical

More than three hundred (300) specimens of *C. gariepinus* juveniles were purchased from Orimori fish farm, Mile 50 in Abakaliki, Ebonyi state. They were transported to the Water Quality and Toxicology unit, Wet Laboratory of the Department of Fisheries and Aquaculture, Ebonyi State University, Abakaliki. The fish were acclimatized in the laboratory condition for two weeks during which they were fed with commercial floating pellets at 5% of their body weight. For the present experiment, a commercial formulation of glyphosate herbicide (Mulsate) is the chemical assessed for its probable toxicity effect on *C. gariepinus* juveniles. Mulsate with the active ingredient isopropylamine salt of glyphosate 41 w/w (400g/l) is produced by Multichem Chemical Industries, China and marketed by Multichem Chemical Industries, Lagos, Nigeria. The herbicide was procured from an agrochemical shop in International market, Abakaliki. Mulsate (Glyphosate) exactly 100ml of the liquid was measured using a measuring cylinder (1000ml). The measured sample was mixed in 200ml of distilled water contained in a conical flask and swirled according to the method of Oti EE, et al. [25]. After 30minutes interval, the mixture was stirred.

Acute Toxicity Bioassay

Acute toxicity bioassay to find out the 96 h LC50 values of commercial formulation of glyphosate (Mulsate) herbicide was conducted with definitive test in a semi-static system in the laboratory according to the standard methods prescribed [26]. The range finding test was carried out earlier to determine the concentrations of the test solution for definitive test. This research was carried out using a Complete Randomized Experimental Design. *C. gariepinus* juveniles with average mean weight 3.5±0.20 g and 5.9±0.31 cm mean total length were randomly distributed into four 50 x 80 x 50 cm plastic aquaria tanks (100L) containing 40L of borehole water and replicated thrice. In the definitive test, a set of 30 test fish specimens were randomly exposed to glyphosate (Mulsate) herbicide (55.0, 65.00 and 75.0mg/l) concentrations. Another set of 30 fish were concurrently maintained in borehole water, with no test chemical, and considered as control (0.00mg/l). Feeding of the test fishes was ended 24 hours prior to acute toxicity testing to avoid fecal interference. After being measured, the stock solution was added to the test tanks. The solutions were stirred for homogenous mixing before each aquarium was randomly stocked with the fish. The test solution was changed on every alternate day to counter-balance the decreasing herbicide concentrations. During the treatment, fish behaviour was observed daily. The 24, 48, 72, and 96-hour survival and mortality rates were noted. The LC50 of Mulsate glyphosate herbicide was determined following the prohibit analysis method described by Finney DJ [27].

Biochemical and Haematological Analysis

Blood samples were collected from each treatment for haematological analysis. Blood samples were collected at the beginning and at the end of the experiment. Blood was drawn from the caudal peduncle of the fish using a disposable needle and syringe into an EDTA sample bottle to avoid clotting. Packed cell volume (PCV) was analyzed with microhaematocrit by means of heparinized 25mm capillary tubes. Red and white blood cell counts were analyzed as described by Blaxhall PC, et al. [28]. While, haemoglobin concentration (Hb) was estimated using the method outlined by Wedemeyer GT, et al. [29]. Other haematological indices like mean cell haemoglobin (MCH), mean cell volume (MCV) and mean cell haemoglobin concentration (MCHC) were determined using the formular put forward by Dacie JV et al. [30] thus:

MCH (pg) = [Hb (g dl-1) x 10]/ RBC (106µl-1)
MCV (fl) = Hct/RBC (106 µl-1)
MCHC (g l-1) = (Hb (g dl-1) x 10]/Hct x 100

Physicochemical Parameters of the Test Water

The physicochemical properties of test water, namely temperature, pH, dissolved oxygen, alkalinity, conductivity and total hardness were analyzed using standard methods according to APHA, AWWA, and WPCF [26].

Statistical Analysis

The probit method of Finney DJ [27] was applied to estimate the 96 hour LC50. Results were reported as mean ± standard error (SE) where appropriate. The averages were compared with one-way analysis of variance (ANOVA) and considerable variations amongst sets were determined by Duncan multiple range test using SPSS for windows version 20. The degree of significance was set at $P<0.05$.

Results

Physico-chemical parameters of the Test Water

The physico-chemical parameters of the test water are shown in Table 1. During the experiment water temperature ranged from 26.06 to 26.55°C. The pH of the water ranged from 5.80 to 6.78. Dissolved oxygen varied from 5.15 to 8.19 mg/l. Alkalinity ranged from 37.4 to 38.4 mg/l. The conductivity value ranged from 254 to 287 µS/cm whereas total hardness varied from 158 to 176 mgl/l.

Parameters	Unit	Mean	Range
Temperature	°C	26.31	26.06 - 26.55
Dissolved oxygen	mg/l	6.67	5.15 - 8.19
pH	-	6.29	5.80 - 6.78
Alkalinity (mg/l)	mg/l	37.9	37.4-38.4
Conductivity	µS/cm	271	254 – 287
Total hardness (mg/l)	mg/l	167	158 – 176

Table 1: Physico-chemical Parameter of the Test Water.

Behavioural and Morphological Response of Fish to Different Test Concentrations of Mulsate (glyphosate) Herbicide

Behavioural response of the test fish was observed in the exposed fish as well as in the control. In this investigation, behavioural and morphological changes were observed on the test fish at 24 to 96 h durations of exposure. The control group showed active swimming, static equilibrium, normal skin colouration and no deaths during the bioassay. Conversely, fish exposed to the varying concentrations of Mulsate glyphosate herbicide displayed various abnormal behavioural responses and morphological changes such as loss of equilibrium, hyperactivity, erratic swimming, loss of reflex and jerky movements. Morphological changes noticed include skin corrosion and increased mucus secretion at the snout and gill areas. Afterward, fish became lethargic, lost consciousness and finally settled down inactively at the bottom of the tank with the operculum wide open and eventually died. These behavioural changes were dose-dependent as shown in Table 2.

Conc. (mg/l).	Loss of equilibrium	Hyperactivity	Erratic Swimming	Loss of reflex	Jerky movement	Corrosion of skin	Mucus secretion
24 hrs							
Control	-	-	-	-	-	-	-
55	++	+	+	+	++	+	+
65	++	++	++	++	++	++	++
75	+++	+++	++	+++	++	+++	+++
48 hrs							
Control	-	-	-	-	-	-	-
55	++	++	+	++	++	+	++
65	++	+++	+++	+++	++	+++	+++
75	+++	+	+++	+++	+++	+++	+++
72 hrs							
Control	-	-	-	-	-	-	-
55	+	++	++	+++	+++	++	++
65	++	+	++	+++	+++	+++	++
75	-	-	-	-	++	-	-
96 hrs							
Control	-	-	-	-	-	-	-
55	++	+++	+++	+++	++	+++	+++
65	++	++	++	++	++	+++	+++
75	-	-	-	-	-	-	-

Key: - None; + mild; ++ moderate; +++ strong.
Source: field survey 2022

Table 2: Behavioral and morphological characteristics of *Clarias gariepinus* exposed to different concentrations of Mulsate glyphosate herbicide.

Fish Survival and Mortality at Different Test Concentrations and Time Intervals in *Clarias gariepinus* Exposed to Mulsate (glyphosate) Herbicide

Table 3 shows the effect of mulsate glyphosate herbicide on survival and mortality of *C. gariepinus*. The numbers of survived and dead fish were examined depending on the duration of exposure (24, 48, 72 and 96 h) in *C. gariepinus*. The herbicide concentration of 75.0 ml/l showed the highest fish mortality of 90% and lowest survival of 3% while no mortality was recorded in the control group throughout the experiment. This shows that increase in mortality rate results to decrease in survival rate of fish.

Conc. ml/l	No of fish exposed	Periods (Hours)				% Survival	% Mortality
		24	48	72	96		
Control 0.00	30	0	0	0	0	30	0
55	30	0	3	6	12	18	40
65	30	6	9	15	21	9	70
75	30	9	15	21	27	3	90

Table 3: Fish survival and mortality at different test concentrations and time intervals in *Clarias gariepinus* exposed to Mulsate glyphosate herbicide.

Acute Toxicity (96hr LC50) for Mulsate (glyphosate) Herbicide

Table 4 show the effect of acute concentrations of Mulsate herbicide on the mortality and probit values of juveniles of *C. gariepinus*. Mortality and probit values increased with increasing concentrations of the test herbicide with the highest mortality recorded in the highest concentration. The 96 h LC50 value for mulsate herbicide was calculated based on these values and was found to be 44.67 mg/L.

Conc. ml/l	Log conc.	No of fish exposed	Periods (Hours)				% Mortality	Probit kill
			24	48	72	96		
Control 0.00	0	30	0	0	0	0	0	-
55	1.74	30	0	3	6	12	40	4.76
65	1.813	30	6	9	15	21	70	5.52
75	1.875	30	9	15	21	27	90	6.28

Table 4: Mortality and probit values of *Clarias gariepinus* exposed to acute concentrations of Mulsate glyphosate herbicide for 96 h.

Haematological response of *Clarias gariepinus* juvenile exposed to Mulsate (glyphosate) Herbicide

Variations in mean values of haematological parameters of *C. gariepinus* juvenile exposed to acute toxicity of mulsate (glyphosate) herbicide are shown in Figures 2-5. There was significant ($P<0.05$) reduction in the volume of packed cell volume (PCV), haemoglobin (Hb), white blood cells (WBC) and red blood cell (RBC) with increase in Mulsate concentration when compared with the control. The results indicated that the value of PCV reduced significantly ($P<0.05$) from 32.33±1.20 to 23.67±0.88, Hb values also reduced significantly ($P<0.05$) from 11.00±0.12 to 8.20±0.12 g/l, WBC reduced from 6466.67±88.19 to 5133.33±176.38 while RBC count also reduced from 4.47±0.20 to 3.27±0.39 with increase in concentration of mulsate (glyphosate) herbicide. Also Mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) were significantly different ($P <0.05$) between the treated and control fish. The decrease in these values was observed to be both a factor of time and the concentration of the toxicant (Table 5).

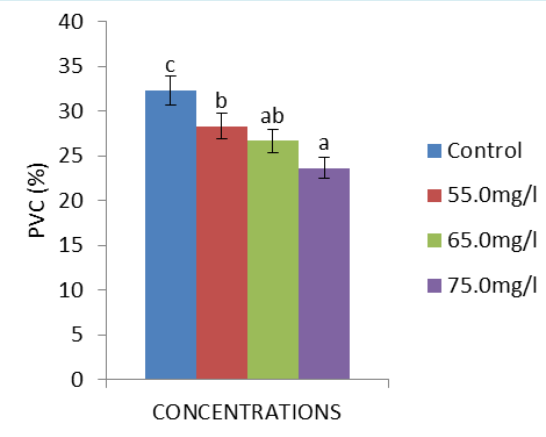

Figure 2: Effect of different acute concentrations of Mulsate glyphosate herbicide on the PCV of *C. gariepinus*. Mean values with different alphabetic superscripts are significantly different ($p<0.05$).

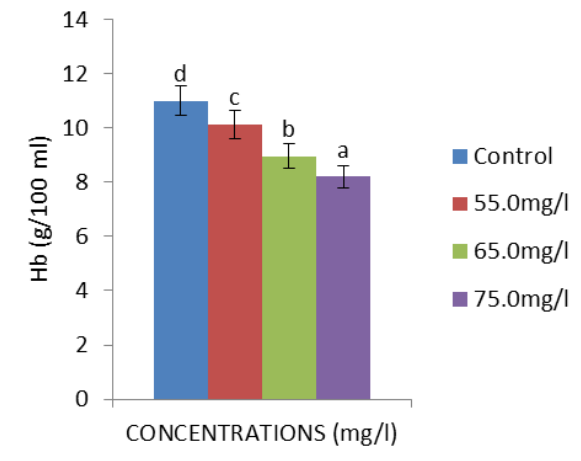

Figure 3: Effect of different acute concentrations of Mulsate glyphosate herbicide on the Hb of *C. gariepinus*. Mean values with different alphabetic superscripts are significantly different ($p<0.05$).

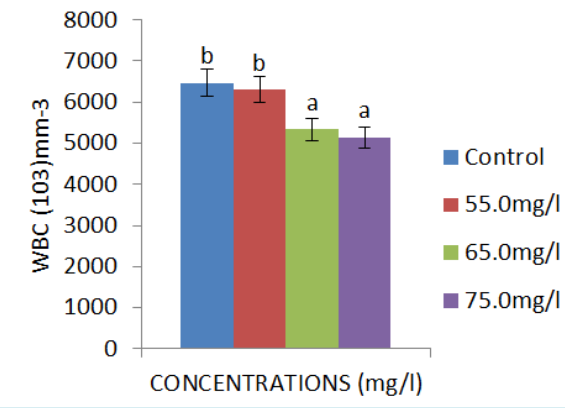

Figure 4: Effect of different acute concentrations of Mulsate glyphosate herbicide on the WBC of *C. gariepinus*. Mean values with different alphabetic superscripts are significantly different ($p<0.05$).

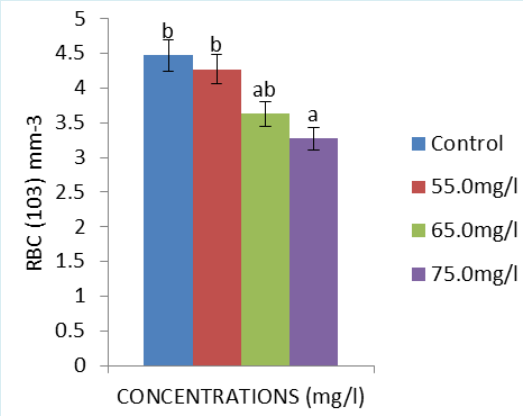

Figure 5: Effect of different acute concentrations of Mulsate glyphosate herbicide on the RBC of *C. gariepinus*. Mean values with different alphabetic superscripts are significantly different ($p<0.05$).

Parameters	Control	55.0mg/l	65.0mg/l	75.0mg/l
MCH (pg)	89.7 ± 0.18^{d}	69.3 ± 0.71^{a}	51.2 ± 0.41^{c}	68.9 ± 0.37^{a}
MCV (fl)	493 ± 0.65^{d}	128.1 ± 1.34^{c}	104.3 ± 0.39^{b}	91.8 ± 1.33^{a}
MCHC (%)	28.5 ± 3.13^{b}	28.7 ± 0.76^{b}	26.3 ± 0.09^{b}	24.2 ± 0.57^{a}

MCV- Mean Corpusular volume, MCH- Mean cell hemoglobin, MCHC- Mean cell hemoglobin concentration.
*Means within rows with different superscripts are significantly different ($P<0.05$).
Table 5: Effects of exposure to acute mulsate glyphosate herbicide concentrations on red blood cell indices in *Clarias gariepinus* juveniles.

Discussion

Aquatic pollution owing to agricultural practices has become a global concern. This is because of the quantum of harm done to the aquatic ecosystem and consequent disruption of the normal food chain. There are a lot of research works on the degree of harm caused by some agricultural activities such as the use of pesticides and herbicides, industrial activities like mining and oil exploration.

Acute toxicity experiments are exceedingly required in the determination of water quality requirements of fish [9]. The present investigation was done to assess the effect of acute toxicity of commercial formulations of Mulsate glyphosate herbicide on *C. gariepinus* juveniles. Findings from the study showed that exposure of juvenile *C. gariepinus* to glyphosate (Mulsate) herbicide resulted in increased mortality rate and decreased survival rate at different level of concentrations. The result is in conformity with the assertion of Nikinmma M, et al. [3] that fish and other aquatic biota are debilitated by herbicide polluted water. Observed behavioural changes caused by the toxicant (Mulsate) glyphosate on the test fish are in harmony with earlier reports on glyphosate based herbicides [31-33,20,11]. Fish treated with large doses of glyphosate displayed behavioural characteristics like loss of equilibrium, hyperactivity, erratic swimming, loss of reflex, jerky movement, and morphological changes such as corrosion of skin and secretion of mucus at the snout and gill areas. It eventually led to the death of the test fishes when compared with the control group. These behavioural and morphological alterations are direct responses of the fish to the herbicide and other allied chemicals [9]. Therefore, the behavioural activities of organisms represent the final integrated result of diversified biochemical and physiological processes [34]. These behavioural alterations noted may be credited to the neurotoxic consequence of Mulsate glyphosate toxicity. The toxicant may have caused the body to accumulate acetycholine at synaptic junctions which inhibited the functions of the enzyme acetycholinerase (AChE) [2,35]. As Miron D, et al. [36] posited this type of constraint impedes normal neurotransmission in cholinergic synapses and neuromuscular junctions of the nervous system thereby influencing the standard functioning of the nerves. The observed corrosion of the outer epithelial cells (hydroedema) of *C. gariepinus* in higher acute concentrations of glyphosate may be because of COX-1 inhibition that also results in the significant release of endothelin-1, which is a very potent vasoconstrictor that may have caused the deterioration of the skin [19]. The mucus secretion noted on the mouth and gills of fish is a protective mechanism against the toxicant. According to mucus cells enclose mucins and polyanions made up of glycoprotein that entraps toxicants

and block their entry into the gill epithelium. However, the mucus in the gill area may lead to respiratory impairments in the fish.

After 96hr of exposure of the test fish to glyphosate (Mulsate) herbicide, the LC50 recorded was 44.67mg/l which indicated that Mulsate is extremely toxic. The value obtained was greater than 17.5mg/l, 43.65mg/l, 24.6mg/l, 8.098mg/l and 1.50mg/l recorded for *C. gariepinus* treated with glyphosate based herbicide by Ani LC, et al. [11], Nafiu SA, et al. [12], Edeh IC, et al. [19], Akinsorotan AM, et al. [32] and Okomoda VT, et al. [37] respectively. In this study LC50 value however is lower than the 86mg/l reported by Deivasigamani S [38] for *Cyprinus carpio* treated witb glyphosate herbicide and 300mg/l reported by Erhunmwunse NO, et al. [33] when *C. gariepinus* was exposed to glyphosate. It is also lower than 975mg/l reported by Shiogiri NS, et al. [39] when she treated *Phalloceros caudimaculatu*s with Aterbane glyphosate [40]. The LC50 recorded in this present investigation is also lower than 211.80mg/l documented by Nwani CD, et al. [41] when he exposed *Tilapia zillii* to glyphosate herbicide Forceup. This result shows that Mulsate glyphosate is less toxic than some of the earlier reported formulations of glyphosate. More so, earlier literature show that toxicity of glyphosate based herbicides fluctuates from species to species. It may also vary in organisms of the same species. Besides, toxicity of chemicals to aquatic biota has been reported to be influenced by temperature, pH, dissolved oxygen, size and age, type of species, water quality, concentration and formulation of test chemicals [40,41]. WHO [42] equally affirms that the LC50 value of glyphosate based herbicides vary broadly due to the prevailing test conditions and the active ingredient present in the herbicide.

Study of haematological indices is very important to the diagnoses of fish health especially under different strenuous situations [43]. The constituents of blood are very vulnerable to chemicals and if there is a variation physiologically, it will be manifested in the standards of some blood characteristics [44]. In the present experiment, exposure of *C. gariepinus* juveniles to acute concentrations of Mulsate (glyphosate) caused a significant ($P<0.05$) decrease in Packed cell volume (PCV), Haemoglobin (Hb), white blood cell (WBC) and red blood cell (RBC) counts of the fish (Figure 2-5). There was also a decrease in mean cell haemoglobin (MCH), mean cell volume (MCV) and mean cell haemoglobin concentration (MCHC). The decrease was noted to be time and dose dependent. The reduction in these haematological indices may be as a result of hemolysis of red blood cells, haemodilution owing to weakened osmoregulation across the gill epithelial cells. It may also be as a result of significant deterioration in hematopoiesis [45]. This physiological change can be attributed to the effect of Mulsate glyphosate toxicity. A similar drop in these haematological parameters was reported in *C. gariepinus* exposed to different concentrations of glyphosate [19,46-48]. Acute exposure of *C. gariepinus* to Mulsate glyphosate as well resulted in a non- significant increase in MCHC. The reduction in MCH, MCV and MCHC is an affirmative signal of a malfunctioned Hb biosynthesis in the fish. Similar decline in MCV, MCH, and MCHC have been reported in fish treated to different doses of herbicides [48,49].

Conclusion

The present study shows that the LC50 of Mulsate is 44.67mgl1, which implies that the herbicide is toxic to *C. gariepinus*. Exposure of the fish to acute concentrations of the herbicide resulted in behavioural, morphological and haematological modifications that is likely be detrimental to the survival and general well being of the fish. The use of Mulsate herbicide has been found to be on the rise in recently. Based on the results presented, we conclude that the use of the herbicide for weed eradication and control in our farms and fields should be regulated. This is because the toxicant has the capability to seep into water bodies. We therefore recommend the establishment of environmental monitoring agency to monitor the cautious use of mulsate glyphosate in our environment. This will help mitigate the ecotoxicological consequences associated with herbicide use and prevent the risk of contamination by humans.

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