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Full Length Research

Ecotoxicological assessment of Fieldklear herbicide in juvenile African catfish (*Clarias gariepinus*) under static-renewal conditions in Imo State, Nigeria

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ABSTRACT: Limited information exists on the ecotoxicological effects of Fieldklear herbicide on freshwater fish species despite its increasing application in agricultural systems. This study investigated the acute toxicity and sublethal impacts of Fieldklear herbicide on water quality and behavioural responses of juvenile *Clarias gariepinus*. Acute toxicity bioassays were conducted using five concentrations of Fieldklear (0.50–4.00 ml/L) to determine the 96-h median lethal concentration (LC_{50}) through probit analysis, while sublethal exposures (0.085, 0.17 and 0.34 ml/L) were maintained for 28 days under static-renewal conditions. Mortality increased progressively with increasing herbicide concentration, and the 96-h LC_{50} was estimated at 1.36 ml/L, indicating considerable toxicity of the herbicide to juvenile fish. Sublethal exposure significantly affected water quality characteristics ($p < 0.05$), resulting in reduced dissolved oxygen (6.44–2.96 mg/L), pH (7.41–6.60) and alkalinity (146.75–93.40 mg/L), while biochemical oxygen demand, chemical oxygen demand, total dissolved solids, ammonia-nitrogen and nitrate concentrations increased with increasing herbicide concentration. Behavioural abnormalities were also observed in exposed fish, including erratic swimming, hyperactivity, increased opercular ventilation, reduced feeding activity, loss of equilibrium and diminished response to external stimuli. The severity of these responses increased with herbicide concentration and exposure duration. The findings demonstrate that Fieldklear herbicide adversely affects both aquatic environmental quality and fish behaviour, suggesting potential ecological risks in aquatic ecosystems receiving agricultural runoff. These results provide baseline data for environmental risk assessment and support the development of management strategies aimed at minimising herbicide-related impacts on aquatic ecosystems.

Keywords: Aquatic resource, ecotoxicity, herbicides, LC_{50}, water.

INTRODUCTION

Herbicides are chemical substances formulated to control or eliminate unwanted vegetation. They play a vital role in modern agriculture by enhancing crop yield and reducing manual labour associated with weed management (FAO, 2021). However, their extensive and often indiscriminate use has raised growing environmental and public health concerns (Oyetunji *et al*., 2024). Herbicides enter aquatic environments through agricultural runoff, spray drift, leaching, and accidental spillage, where they persist and pose threats to non-target organisms such as fish, plankton, and benthic invertebrates (Navarro *et al*., 2025). The effects of herbicides on fishes are of great concern (Ribeiro *et al*., 2022). Herbicides at high concentrations are known to reduce survival, growth and reproduction of fish and can produce many visible effects on them (Popoola, 2018). Behaviour is an organ-level effect defined as the action, reaction, or functioning of a system under a set of specific circumstances. The understanding of behaviour responses of aquatic organisms to the effect of chemical stress is extremely important (Sharma *et al*., 2019).

Fish constitutes the most nutritious animal protein compared to that of livestock as it contains all essential amino acids (Wokeh *et al*., 2025). However, fish production, especially in capture fisheries, is fast declining due to aquatic environment pollution arising from agricultural runoff of herbicides and pesticides from farm lands (FAO, 2022; Ogwu *et al*., 2023). The herbicide Fieldklear is an agrochemical mostly used by farmers in Nigeria. The need to evaluate the environmental impact of these agrochemicals to determine the risk factors in aquatic ecosystems and safe thresholds is considered essential.

Fieldklear (2-chloro-N-(2,6-diethylphenyl)-N-(methoxymethyl acetamide)) belongs to the chloroacetanilide group of herbicides and is commonly applied to control grasses and broadleaf weeds in cereals and legumes. Its herbicidal activity works by inhibiting protein synthesis and suppressing root development, making it effective against fast-growing weeds. Globally, Fieldklear has been widely used, with historical records showing over 22,000 tonnes applied in the United States during the 1990s.

The test fish, African catfish, *Clarias gariepinus*, is selected as the test organism in this study for its great aquaculture and commercial value in Nigeria and elsewhere in the developing world. *C. gariepinus* is a benthopelagic (bottom feeder), omnivorous feeder that occasionally feeds at the surface. Their diets include insects, crabs, plankton, snails and fish, but they have also been seen to consume young birds, rotten flesh, plants and fruits (Teugels, 1986). *C. gariepinus,* also referred to as mudfish, is very hardy and tasty. They can tolerate adverse aquatic conditions where other cultivable fish species cannot survive (Olatunde, 1983). It is widely cultivated and used as an experimental fish (Musa and Omoregie, 1999). *Clarias gariepinus* is a species of clariid (order Siluriformes) of the family Clariidae, the air breathing catfish (Goksoyr *et al.,* 2011). It is a popular species in warm water aquaculture, and it is indigenous to Africa. It is widely distributed and accepted by many farmers in Africa because of its fast growth, large size, low bone content, tolerance to poor water quality, omnivorous feeding habit, adaptability to overcrowding, high market value and has been successfully propagated artificially, thereby making its fry and fingerlings easily available (Osman *et al.,* 2007). For sustainable fish production in Nigeria, there is a need to generate the relevant data on the toxicological impact of emerging/new herbicides which could be incorporated into government agricultural policies for proper management programmes for herbicide use and disposal in aquatic habitats. Despite the widespread use information regarding its toxicity to non-target aquatic organisms remains scarce. Most available studies have focused on conventional herbicides such as atrazine, paraquat and glyphosate, while data on the acute and chronic impacts of Fieldklear on freshwater fish species are limited. Furthermore, little information exists on the combined effects of this herbicide on water quality characteristics and behavioural responses of exposed fish under tropical conditions. Therefore, this study evaluated the acute toxicity (96-h LC_{50}) and sublethal effects of Fieldklear herbicide on water quality and behavioural responses of juvenile *Clarias gariepinus*, with the aim of providing baseline ecotoxicological data for environmental risk assessment and sustainable aquatic resource management.

Presently, there is a paucity of data on such environmental impact assessment studies in Nigeria, especially in the face of the recently evolving in different kinds of herbicides, such as Fieldklear, imported into the country. It is believed that the present study will help close this gap in scientific knowledge on the risk factors associated with the use of new herbicides in agricultural lands and their impact on aquatic ecosystems through agricultural runoffs.

MATERIALS AND METHODS

Study area

This research was conducted from 5th September 2025 to 2nd October 2025 at the Teaching and Research Farm of the Department of Fisheries and Aquaculture Technology, Federal University of Technology Owerri (FUTO), Imo State, Nigeria. The study area lies between latitudes 4°45’N and 7°15’N, and longitudes 6°50’E and 7°25’E, covering approximately 5,100 square kilometres (Figure 1). The region experiences an average annual temperature above 20°C (68°F), with a relative humidity of 75%, peaking at 90% during the rainy season. The dry season features the Harmattan winds from late December to late February, with the hottest months occurring between January and March (Anyanwu *et al*., 2008).

Procurement of herbicide

A litre of Fieldklear herbicide was obtained from a dealer in agrochemicals in Umuahia, Abia State, Nigeria. It was properly handled due to its toxic nature.

Collection and acclimatisation of the experimental fish

A total of five hundred healthy and active specimens of *C. gariepinus* juveniles were procured from Anuforo's Farm and were transported to the Research Farm of Federal University of Technology, Owerri, in plastic containers. The fish were placed in plastic tanks in the laboratory and

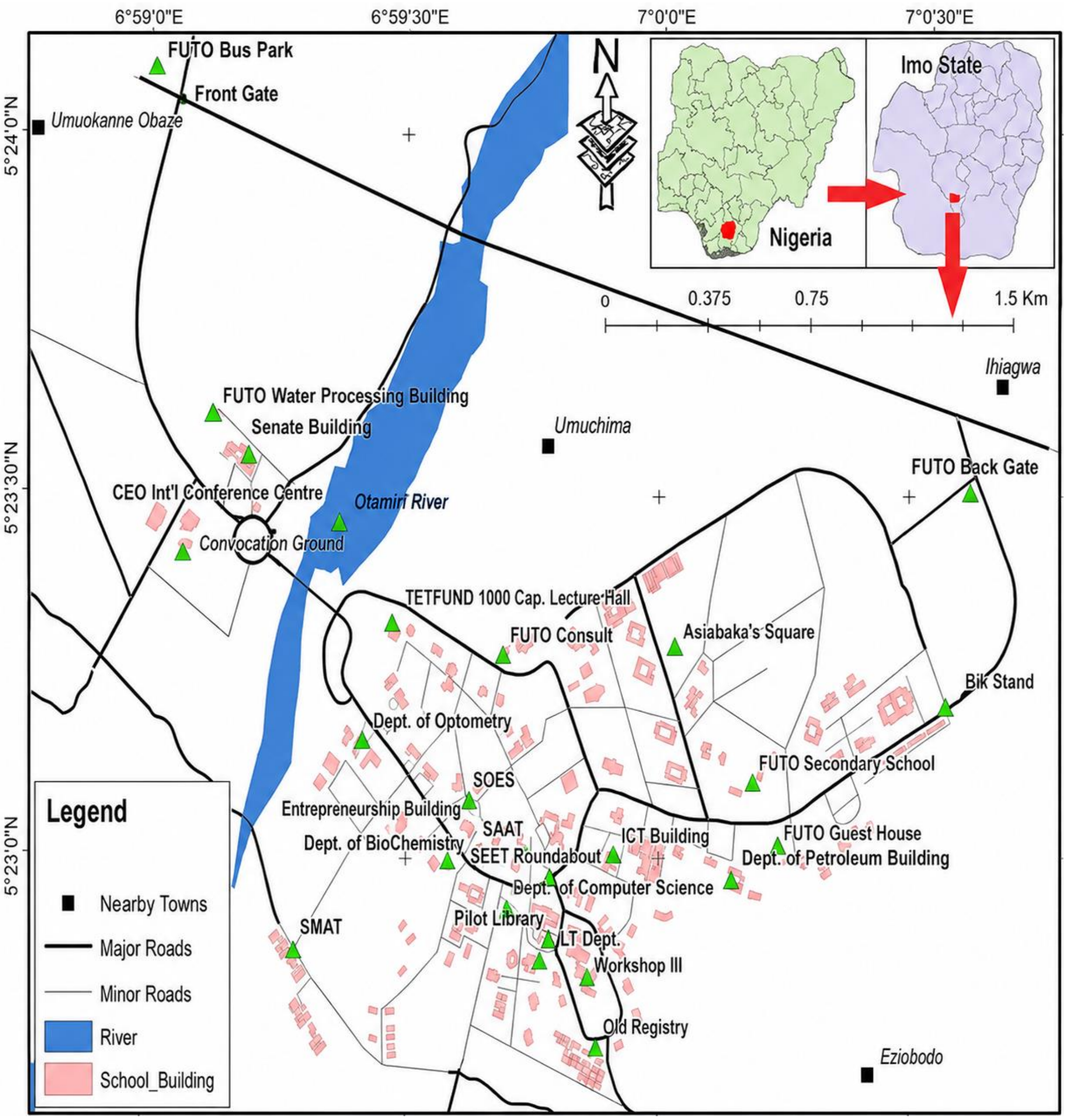

Figure 1. Map of The Federal University of Technology Owerri (Source: Chinaza *et al*., 2023).

were allowed to acclimatise for 14 days in borehole water. During the process of acclimatisation, the fish were fed twice daily (0800hrs and 1800hrs) at 4% of their body weight with a commercial feed with about 35% crude protein of pelleted diet to avoid starvation.

Experimental design and layout

Completely Randomised Design (CRD) was used for the experiment, with four treatment levels and a control, with each treatment having three replicates. The treatment herbicide was bought from a dealer at Ubani Market, Umuahia, Abia State. The treatment herbicide was designed as follows; T0 (µg/L), T1(µg/L), T2 (µg/L), T3 (µg/L), T4 (µg/L), T5 (µg/L) and T6 (µg/L). Each of the six (6) treatments (including the control) was assigned 10 juveniles of *C. gariepinus* and randomly allocated to the three replicates in the 6 (treatments) X 3 (replicates) = 18 experimental units of the toxicological test. Each treatment combination comprises 30 fish juveniles, while each replicate combination consists of a total of 60 fish juveniles. Consequently, a total of 180 fish juveniles were used for the trial, which lasted for 28 days. The design layout of the experiment is shown in Table 1.

Experimental set–up for acute toxicity test

The acute toxicity test of the herbicides on *Clarias gariepinus* juveniles: all the experimental procedures were in line with the University of Nigeria Ethical Committee on

Table 1. Layout of the complete randomized design (CRD) experiment.

Treatment (mg/L)	Replicate			Total
	R1	R2	R3	
T0 (control)	10A	10B	10C	30
T1	10B	10C	10D	30
T2	10C	10D	10E	30
T3	10D	10E	10A	30
T4	10E	10A	10B	30
T5	10B	10D	10C	30
Total	60	60	60	180

ABCD = Treatments randomly allocated to replicates. Figures represent number of fish per treatment.

the use of Experimental Animals (UNN-ECEA-O1845-2019). The tests were also conducted according to the guideline No. 203 for semi-static conditions of the Organisation for Economic Cooperation and Development (OECD, 2019). Five experimental concentrations of each of the herbicides were prepared for each experiment. The concentrations of Fieldklear used were 0.50 ml/l, 1.00 ml/l, 2.00 ml/l, 3.00ml/l, and 4.00 ml/l. Each concentration was prepared in duplicate and used for stocking ten fish. One group was exposed to only de-chlorinated tap water, which served as the control. Feed was not offered to the fish 48 hours before and during the 96 hours of the test period. The research was conducted in an indoor experimental outfit under the natural photoperiod. In order to avoid fouling the experimental media, the tanks were checked daily, while the dead fish were recorded and removed using a scoop net. The water quality and appropriate concentration of herbicides were maintained by renewing the test water and the toxicant daily. Finney's probit analysis method (Finney, 1971) was followed to determine the $LC_{50,}$ i.e determine the acute effect of the herbicides on *C. gariepinus* juveniles.

Long – term exposure to sub-lethal concentrations of the herbicides

The study was conducted in a static renewal system after the acute toxicity test. The concentrations of these herbicides were prepared in an arithmetic series and were not sufficient to cause immediate mortality of the experimental fish. The concentrations of the Fieldklear used were 0.085 ml/l, 0.17 ml/l, and 0.34 ml/l. One group was exposed to only de-chlorinated tap water, which served as the control. The concentration of each herbicide was prepared in triplicate in 35litres capacity plastic tank. Ten fish each from the acclimatised group were distributed randomly to the tanks. The fish were fed twice daily at 2% of total body weight at 9.00 and 16.00 hours with a commercial fish diet, having 30% crude protein. Fifty per cent of the exposed solution was renewed every other day to maintain the water quality of the test media and normal concentration of the herbicides. Aeration was provided to all the tanks round the clock with the help of an aerator in order to maintain dissolved oxygen content. This was made possible by providing air stones and regulator valves to control the air pressure uniformly to all the tanks. The experimental tanks were cleaned daily. The behavioural changes in the exposed fish and control were observed, and water quality was monitored.

Laboratory method

Physico-chemical parameters were analysed to assess the water quality following standardised methods outlined by the American Public Health Association (APHA, 2017; Akponine and Ugwumba, 2014; Njoku, 2015; AOAC, 2015).

Physiological/behavioural

Observations on behavioural responses were made at 3, 6, 12, 24, 48, 72 and 96 hours post exposure (Agbon *et al*., 2014; ASTM, 2012). To provide a reference point for determining changes in morphological or behavioural features, toxicant-exposed fish were monitored and compared with the control. Changes in toxicant–exposed fish different from those of the control were recorded if they occurred in at least 10% of the fish in each test medium. The opercular ventilation frequency and tail fin beat rates were observed as beats per minute using a stopwatch. The opercular ventilation frequency/count and tail fin movement were determined twice daily at predetermined time intervals (Olusegun, 2001). Observations were made for the three fish in each medium and the mean was recorded. The results were pooled and the daily average determined.

Statistical analysis

The statistical software (SPSS Inc., version 17, Chicago, IL) was used for the analysis. Data were expressed as mean standard error (SE). Treatments were evaluated by

Table 2. Toxicity response of *Clarias gariepinus* juveniles exposed to Fieldklear herbicide.

Concentration (ml/L)	Mortality %	Log Concentration	Probit
0.50	30.0	−0.30	4.48
1.00	40.0	0.00	4.75
2.00	70.0	0.30	5.52
3.00	90.0	0.48	6.28
4.00	100.0	0.60	8.72

one-way analysis of variation (ANOVA). Mean treatment values observed to be significant were separated using the Duncans Multiple Range Test (DMRT).

RESULTS

Toxicity response (mortality pattern) for Fieldklear herbicide

The toxicity response of *Clarias gariepinus* juveniles exposed to Fieldklear herbicide is summarised in Table 2. The table presents mortality percentages, corresponding log concentrations, and probit values for each treatment level. At the lowest concentration of 0.50 ml/l, 30% of the juveniles were observed dead, indicating moderate acute toxicity at this exposure level. As the concentration increased to 1.00 ml/l, mortality slightly decreased to 40%, possibly due to experimental variability, but the overall trend remained dose-dependent. A further increase to 2.00 ml/l caused mortality to rise sharply to 70%, demonstrating that more than half of the test population succumbed to the herbicide at this intermediate concentration. At higher concentrations, the effect was more pronounced: 90% mortality was recorded at 3.00 ml/l, and complete mortality (100%) occurred at 4.00 ml/l. This progression shows a positive correlation between Fieldklear concentration and the mortality rate of the juveniles, despite minor fluctuations. The log concentration column shows the logarithmic transformation of each concentration, which is necessary for probit analysis. Probit values, calculated from the mortality percentages, ranged from 4.43 to 8.72 at 4.00 ml/l. These probit values are used to construct a dose-response curve, from which the 96-hour LC_{50} was determined.

LC_{50} Determination

The probit-log concentration relationship for the toxicity response of *Clarias gariepinus* juveniles exposed to Fieldklear herbicide is shown in Figure 2. This illustrates the method used to estimate the 96-hour LC_{50} of Fieldklear herbicide on *Clarias gariepinus* juveniles. The probit values are plotted on the y-axis against the logarithm of the herbicide concentrations on the x-axis. Each blue data point represents the probit-transformed mortality observed at a specific concentration of Fieldklear, while the solid line represents the best-fit linear regression line derived from these probit values, described by the equation $y = 3.8163x + 4.49$ ($R = 0.731$). The slope of 3.816 shows the steepness of the dose-response relationship, indicating that mortality increases rapidly with increasing concentration. The intercept of 4.49 corresponds to the probit value at zero log concentration, and the R^2 value of 0.731shows that approximately 73.1% of the variation in probit values is explained by the herbicide concentration. The LC_{50} is visually represented by the dotted lines: the horizontal dotted line intersects the regression line at a probit of 5, corresponding to 50% mortality, while the vertical dotted line extends down to the x-axis to indicate the log concentration associated with this mortality level. From this analysis, the 96-hour LC_{50} of Fieldklear was estimated at 1.36 ml/l, confirming the concentration at which half of the juvenile catfish population is expected to die under the experimental conditions. This graphical representation complements the numerical findings in Table 2 and clearly shows the acute, dose-dependent toxicity of Fieldklear herbicide.

Effects of Fieldklear herbicide on water quality parameters

The sublethal effects of Fieldklear herbicide on various water quality parameters during the exposure of *Clarias gariepinus* juveniles is shown in Table 3. The temperature remained fairly stable across all treatments, ranging from 27.94 ± 0.02 °C in T3 to 28.07 ± 0.12 °C in T1, with no significant difference observed ($p > 0.05$). In contrast, pH values decreased slightly with increasing herbicide concentration, from 7.41 ± 0.08 in T0 to 6.60 ± 0.15 in T3, with a statistically significant change only at the highest treatment ($p < 0.05$). These results suggest that Fieldklear at the tested concentrations had limited impact on these basic physicochemical parameters. Dissolved oxygen (DO), however, showed a clear decreasing trend with increasing herbicide concentration, dropping from 6.44 ± 0.13 mg/L in the control (T0) to 2.96 ± 0.07 mg/L in the highest treatment (T3). The differences among treatments were statistically significant ($p < 0.05$). This indicates that higher concentrations of Fieldklear reduced oxygen availability in the water, likely due to increased microbial activity or toxicity-related stress on the juveniles.

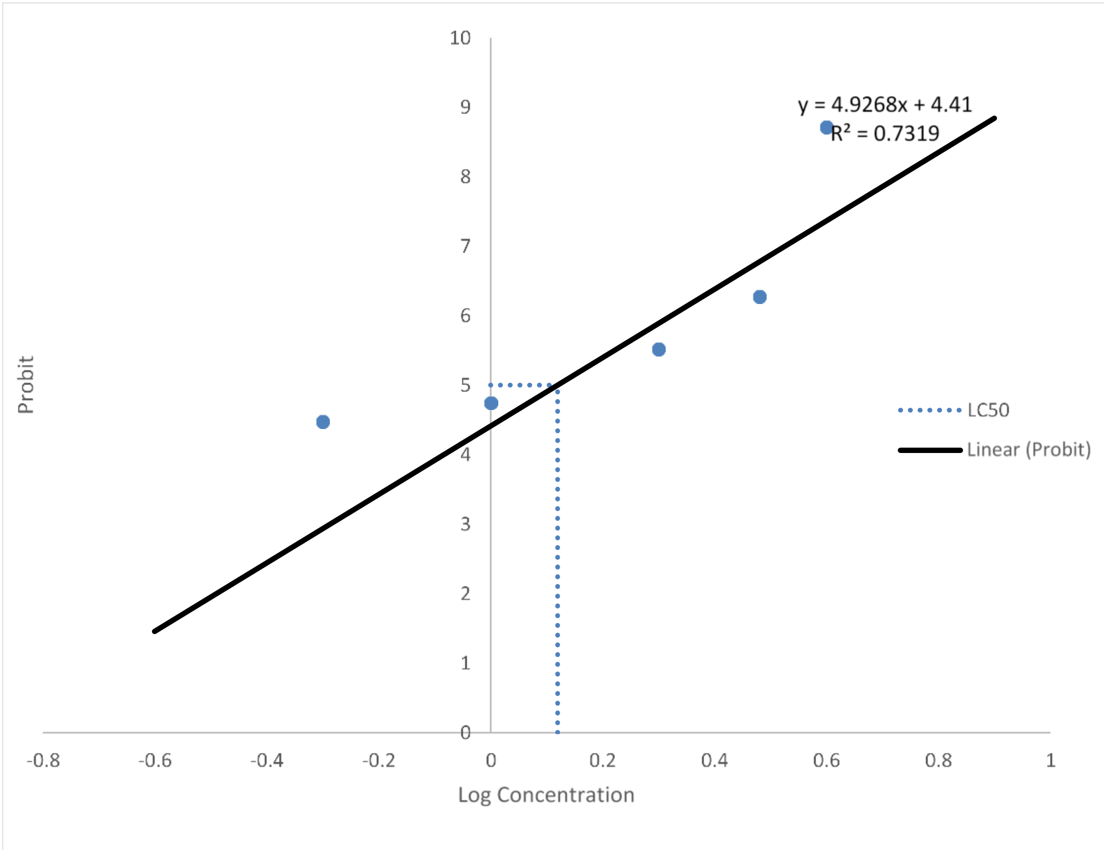

Figure 2. Probit Analysis Showing LC_{50} (1.36 ml/L) of Fieldklear Herbicide on Juveniles.

Table 3. Sublethal effects of Fieldklear herbicide on water quality parameters in *Clarias gariepinus* juveniles.

Parameter	T_0 (0.00 ml/l)	T_1 (0.085ml/l)	T_2 (0.17ml/l)	T_3 (0.34ml/l)
Temperature (°C)	27.95 ± 0.35^a	28.07 ± 0.12^a	28.02 ± 0.20^a	27.94 ± 0.02^a
PH	7.41 ± 0.08^a	7.34 ± 0.04^a	7.22 ± 0.01^a	6.60 ± 0.15^b
Dissolved Oxygen (mg/L)	6.44 ± 0.13^a	5.55 ± 0.01^b	4.44 ± 0.05^c	2.96 ± 0.07^d
Biochemical Oxygen Demand (mg/L)	3.33 ± 0.21^d	4.63 ± 0.04^c	6.53 ± 0.10^b	9.47 ± 0.09^a
Chemical Oxygen Demand (mg/L)	16.48 ± 0.67^d	23.34 ± 0.18^c	30.15 ± 0.32^b	39.31 ± 0.34^a
Total Dissolved Solids (mg/L)	306.69 ± 3.85^d	353.26 ± 1.60^c	378.69 ± 1.38^b	410.91 ± 1.28^a
Total Hardness (mg/L)	100.32 ± 3.15^a	96.22 ± 0.39^b	90.45 ± 0.89^c	83.46 ± 1.10^d
Total Alkalinity (mg/L)	146.75 ± 4.60^a	123.41 ± 0.85^b	110.40 ± 0.80^c	93.40 ± 0.88^d
Ammonia–Nitrogen (mg/L)	0.04 ± 0.01^d	0.08 ± 0.01^c	0.19 ± 0.01^b	0.48 ± 0.01^a
Nitrate (mg/L)	2.07 ± 0.06^d	2.82 ± 0.02^c	3.64 ± 0.02^b	4.92 ± 0.02^a

Note: Results are presented as Mean ± SD. Means with different superscripts (a, b, c, d) within the same row indicate significant differences at $F_\alpha = 0.05$

Biochemical oxygen demand (BOD) increased significantly with herbicide concentration, from 3.33 ± 0.21 mg/L in T0 to 9.47 ± 0.09 mg/L in T3 ($p < 0.05$). Similarly, chemical oxygen demand (COD) rose from 16.48 ± 0.67 mg/L in the control to 39.31 ± 0.34 mg/L in T3, also with significant differences among treatments ($p < 0.05$). These increases indicate higher organic pollution and greater microbial activity, reflecting the stress imposed on the aquatic environment by Fieldklear exposure. Total dissolved solids (TDS) increased progressively from 306.69 ± 3.85 mg/L in T0 to 410.91 ± 1.28 mg/L in T3, with statistically significant differences ($p < 0.05$), suggesting that solute concentration in the water rose with herbicide addition. Total hardness decreased slightly with increasing herbicide concentration, from 100.32 ± 3.15 mg/L in the control to 83.46 ± 1.10 mg/L in T3, and the differences were significant among treatments ($p < 0.05$). Total alkalinity decreased consistently from 146.75 ± 4.60 mg/L

Table 4. Sublethal effects of Fieldklear herbicide on physiology and behaviour of *Clarias gariepinus* juveniles.

Parameter	T_0 (0.00ml/l)	T_1(0.085ml/l)	T_2 (0.17ml/l)	T_3 (0.34ml/l)
Swimming behavior	Normal, active	Noticeable restlessness	Irregular swimming, lethargic	Erratic/circular swimming, frequent jumps
Gill movement	Normal	Mild increase	Pronounced increase	Rapid and laboured, stressed
Feeding activity	Normal	Mild reduction	More reduced	Almost complete cessation
Equilibrium	Normal	Slight loss	Frequent loss	Severe loss of equilibrium
Response to stimuli	Normal	Slightly reduced	Reduced	Severely reduced, sluggish

in T0 to 93.40 ± 0.88 mg/L in T3, with all treatments significantly different from one another ($p < 0.05$), suggesting reduced buffering capacity in the water as herbicide concentration increased. Nitrogenous compounds were also affected. Ammonia–nitrogen increased from 0.04 ± 0.01 mg/L in T0 to 0.48 ± 0.01 mg/L in T3, and nitrate concentrations rose from 2.07 ± 0.06 mg/L in T0 to 4.92 ± 0.02 mg/L in T3, both showing statistically significant increases ($p < 0.05$). This indicates enhanced nitrogen accumulation, likely from metabolic waste or herbicide-induced stress, which could further compromise water quality and fish health.

Effects of Fieldklear herbicide on fish behavioural response

The sublethal effects of Fieldklear herbicide on the behavioural response of *Clarias gariepinus* juveniles is shown in Table 4. Swimming behaviour remained normal and active in the control T0 (0.00ml/l), but showed noticeable restlessness in T1 (0.085ml/l), progressed to irregular swimming and lethargy in T2 (0.17ml/l), and became erratic with circular patterns and frequent jumps in T3 (0.34ml/l), indicating increasing motor impairment with higher herbicide concentrations. Gill movement was normal in T0, with a mild increase in T1, a pronounced increase in T2, and rapid, laboured respiration in T3, suggesting escalating respiratory stress and potential gill irritation. Feeding activity was unaffected in T0 but exhibited mild reduction in T1, further reduction in T2, and almost complete cessation in T3, reflecting dose-dependent appetite suppression likely due to toxicity-induced discomfort. Equilibrium was maintained in T0, with slight loss in T1, frequent loss in T2, and severe loss in T3, pointing to neurotoxic effects disrupting balance and coordination. Response to stimuli stayed normal in T0, slightly reduced in T1, more reduced in T2, and severely reduced with sluggishness in T3, demonstrating a clear decline in sensory and reactive capabilities.

DISCUSSION

Acute toxicity and mortality response

The present study showed a clear pattern where higher concentrations of Fieldklear herbicide caused more deaths in *Clarias gariepinus* juveniles. Mortality increased as the herbicide concentration increased, with complete death occurring at the highest dose. The 96-hour LC_{50} value shows that Fieldklear is moderately to highly toxic to this fish species. This finding agrees with previous studies on herbicide toxicity in fish. The probit analysis showed a strong relationship between herbicide concentration and fish mortality, although there were small variations at middle doses. These variations may be due to differences in how individual fish respond to the toxicant. The toxicity observed in this study is similar to findings by Peebua *et al*. (2008), who reported significant deaths in Nile tilapia exposed to alachlor, another herbicide with a similar chemical structure. Similarly, dicamba-based herbicides have been shown to cause acute toxicity in fish species. Ruiz de Arcaute *et al*. (2014) documented toxic and genetic damage in fish exposed to dicamba-based herbicides. The S-shaped dose-response curve obtained in the current study is common in toxicity studies and helps in determining safe concentration limits for fish farming environments (National Pesticide Information Centre, 2023). The small decrease in mortality seen at middle concentrations compared to the lowest concentration may be due to experimental variation or biological differences in fish response. Such unusual patterns have been occasionally reported in toxicity studies, though the overall trend remained dose-dependent. The sharp increase in mortality at higher concentrations shows the critical level where the herbicide's toxic effects become rapidly deadly to the juveniles.

Water quality alterations

Exposure to Fieldklear herbicide caused significant changes in several water quality parameters, which together contributed to environmental stress and fish mortality. The progressive decline in dissolved oxygen is a critical finding because oxygen availability is essential for fish survival and body function. This reduction can be explained by increased bacterial activity during herbicide breakdown and higher oxygen demand from stressed fish (Pollock *et al*., 2007). The dissolved oxygen levels in the highest treatment group reached very low levels, which are known to cause breathing problems, abnormal behaviour, and death in fish species (Okey-Wokeh *et al*., 2023). The increases in biochemical oxygen demand and chemical oxygen demand provide further evidence of organic pollution and increased bacterial activity. These increases indicate that Fieldklear herbicide adds substantial organic matter into the water environment, either through the herbicide formula itself or through herbicide-caused breakdown processes (Utah *et al*., 2026). Similar patterns have been documented by Njoku and Keke (2003) in river systems affected by farm runoff, where high BOD and COD values were linked with poor water quality and fish health. The decrease in pH observed at higher concentrations suggests that Fieldklear may change water chemistry by making it more acidic. This pH change, combined with reduced alkalinity, indicates reduced buffering capacity, which could increase the toxic effects of the herbicide and affect the fish's ability to maintain acid-base balance (Njoku *et al*., 2010). The increase in total dissolved solids shows higher salt concentration in the water, possibly due to herbicide dissolving and waste product buildup, which may further stress the fish's salt regulation system. The buildup of nitrogen-containing compounds, particularly ammonia and nitrate, is particularly worrying. High ammonia is very toxic to fish, even at low concentrations, and can result from poor nitrogen excretion and protein breakdown under stress conditions. These findings agree with observations by Osman *et al*. (2007), who reported disrupted enzyme activity in African catfish exposed to environmental pollutants, leading to buildup of nitrogen waste products.

Behavioural and physiological disturbances

The behavioural responses of *C. gariepinus* juveniles to Fieldklear exposure showed a progressive worsening in normal function as herbicide concentration increased. The change from normal activity in the control to unusual swimming patterns, circular movements, and frequent jumping at the highest concentration indicates nerve-damaging effects, likely resulting from disruption of chemical messengers in the nervous system. These observations are consistent with the nerve-damaging mechanisms documented for various herbicides, which can interfere with nerve signal transmission (Rauf, 2015). The dose-dependent increase in gill movement speed and the development of difficult breathing strongly suggest gill irritation and breathing stress. This response is likely due to several factors, including direct chemical irritation of gill tissue, reduced oxygen availability due to declining dissolved oxygen levels, and possible tissue damage in gill structure. Similar behavioural problems, including over-activity, loss of balance, and breathing difficulty, have been reported in Indian carp exposed to malathion (Sawhney and Johal, 2000) and in common carp exposed to organophosphate pesticides (Rauf and Arain, 2013). The progressive loss of balance and severely reduced response to external signals at higher concentrations point to significant nerve damage. Loss of balance and coordination suggests damage to the balance system and central nervous system, which are critical for orientation and movement control in fish. The almost complete stop in feeding activity at the highest concentration shows severe body function problems and indicates general toxicity, as feeding suppression typically occurs only under extreme stress or discomfort. This finding has important implications for fish farming, as reduced feed intake would severely affect growth and production (Pankhurst, 2011).

Conclusion

The research was designed to provide comprehensive information on the differential impacts of these commonly used herbicides on fish health, water quality and behavioural responses, particularly in contexts where agricultural and aquacultural activities overlap. This study demonstrates that organisms, especially *C. gariepinus* juvenile are very sensitive to toxicological effects, and it affects fish behavioural patterns and alters water quality negatively. Further research should examine the effects of herbicide exposure during different life stages, including embryonic development, larval stages, and adult fish, as sensitivity to toxicants often varies across life stages.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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