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Haematological Indices of African Catfish (*Clarias gariepinus*) Juvenile Exposed to DDVP (Dichlorvos) Insecticide

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About Article

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ABSTRACT
This study investigated the impact of DDVP (Dichlorvos) insecticide on the hematological indices and mortality rates of juvenile Clarias gariepinus exposed to various concentrations of DDVP. Juvenile African catfish were procured and acclimated for two weeks in dechlorinated water under natural conditions. A total of 150 fish were randomly allocated into five treatment groups (T1-T5) in triplicate, each containing 10 fishes, and exposed to various concentrations of DDVP based on a 96-hour LC50 of 0.00056 ml/L. The experimental groups included T1 (control, 0.00000 ml/L), T2 (0.000112 ml/L), T3 (0.000224 ml/L), T4 (0.000336 ml/L), and T5 (0.000448 ml/L). Temperature and pH of experimental water were monitored daily. Fish mortality was assessed at multiple time points throughout the experiment, with dead fish removed promptly to prevent oxygen depletion. Hematological analysis was performed by collecting blood samples through caudal ablation. Results showed that mortality rates were significantly higher in the highest concentrations (T4: 85.00 ± 7.07% and T5: 100.00 ± 0.00%) compared to lower concentrations (T1: 0.00 ± 0.00%, T2: 15.00 ± 7.07%, T3: 20.00 ± 14.14%) ($p < 0.05$). T5 exhibited the highest mortality rate among all treatments. Hematological analysis revealed significant alterations in the blood parameters of C. gariepinus exposed to DDVP. The packed cell volume (PCV) was notably reduced in the T3 group (20.33%) compared to other groups, suggesting adverse effects on erythropoiesis. The red blood cell (RBC) count was lowest in T2 (2.00 ± 0.00 × 10^6/L), correlating with decreased PCV, indicating potential anaemia or reduced red blood cell production. The white blood cell (WBC) count was markedly increased in T2 (4.03 ± 0.06 × 10^9/L), suggesting an inflammatory or stress response. This study highlights the detrimental effects of DDVP on the health and blood parameters of Catfish, with higher concentrations leading to increased mortality and significant hematological disturbances.

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1. INTRODUCTION

Clarias gariepinus, commonly known as the African catfish, is notable for its exceptional tolerance to environmental pollutants. This species can thrive in a variety of polluted aquatic environments due to several key adaptations. It possesses a high degree of metabolic and physiological resilience, allowing it to cope with contaminants such as heavy metals and pesticides (Amaeze *et al.*, 2020). The ability of catfish to perform aerial respiration, alongside its gill-based breathing, enables it to survive in oxygen-depleted waters often associated with pollution (Mishra & Gupta, 2014). Additionally, Clarias gariepinus is frequently used as a bio-indicator in environmental monitoring due to its ability to indicate the presence and impact of pollutants on aquatic ecosystems (García & Martínez, 2017).

Pesticides are synthetic organic and inorganic compounds used to kill or contain the activities of pests. They may be chemical substances, biological agents (such as bacteria, viruses etc. as in biological control), or devices used against pests. At the beginning of the 20th century, two classes of pesticides were primarily used: botanical, which comprises naturally derived plant materials such as pyrethroids, rotenoids, nicotinoids, etc; and inorganic salts which are formulated and used as fungicides, herbicides, insecticides, molluscicides, acaricides, nematicides and algicides. Pesticides are generally applied to soil, plants, water bodies and in human settlements either as liquids, dusts or granules using man-mounted equipment such as tractors, knapsacks or aircrafts (Kumari, 2020). With increasing industrialization and agricultural expansion, humans are continuously disturbing the delicate ecological balance in aquatic ecosystems (Kumar *et al.*, 2018).

According to Doherty *et al.* (2016), pesticides affect all members of an ecosystem from the smallest vertebrates to birds and humans, and their toxicities to both urban and agricultural settings are responsible for the death of many fishes, birds and smaller aquatic animals that fish depend on for food. In their separate studies, Chakraboty *et al.* (2017) and Amaeze *et al.* (2020) showed that aquatic contamination by pesticides cause acute and chronic poisoning of fish as well as severe damage to vital organs. It has also been shown that humans are at risk of exposure to pesticides either through skin, oral consumption or respiration (Jayaraj, 2016). There is evidence of bio-accumulation of pesticides at higher trophic levels with possible deleterious effects.

Insecticides pollution in the aquatic environment is increasing due to their extensive usage in agriculture and fish farming. Variations in the chemical composition of aquatic environments can affect the survival of aquatic organisms including fishes. In the present era, the use of insecticides in agriculture are inevitable, but their effects on non-target organisms outweigh their impact on the target pests. Different types of pesticides are used in agriculture, but their toxicity to fishes varies with each pesticide type and insecticides are typically the most toxic. The major insecticides that are usually used are organophosphate, organochlorine, carbamates, pyrethroids and necotenoides (Agbohesi, 2015).

The effects of insecticides and pesticides on the hematological indices of catfish can be quite significant, reflecting broader concerns about their impact on aquatic ecosystems. Exposure to pesticides often leads to reductions in the RBC count in catfish. Chemicals such as organophosphates and carbamates can cause hematopoietic disorders, leading to anemia or decreased red blood cell production. This reduction impacts the fish's ability to transport oxygen efficiently, which can affect overall growth and survival. Hemoglobin levels are another critical parameter affected by pesticide exposure. Pesticides can interfere with hemoglobin synthesis or stability, leading to decreased oxygen-carrying capacity of the blood. This condition may result in hypoxia, adversely affecting the fish's metabolic processes and overall health (Singh & Sharma, 2018). Hematocrit values, which measure the proportion of blood volume occupied by red blood cells, can be significantly altered by pesticide exposure. Pesticides may cause either an increase or decrease in hematocrit levels, reflecting stress or pathological changes within the fish (Zhao & Zhou, 2015).

The WBC count can be affected by exposure to pesticides, which may lead to either an increase or decrease in these cells. Elevated WBC counts can indicate an inflammatory response or immune system activation, while decreased counts might suggest immune suppression, making fish more susceptible to diseases (Mishra & Gupta, 2014). Although less commonly discussed, pesticides can also affect platelet counts, which are crucial for blood clotting. Abnormal platelet levels can lead to issues with blood clotting and wound healing, further affecting the health of the fish (García & Martínez, 2017). In addition to the primary hematological indices, pesticides can influence other aspects of blood chemistry, such as enzyme levels and electrolyte balance. These changes can contribute to the overall stress and health deterioration of catfish exposed to these pollutants (Patra & Maji, 2021).

The reduction in water quality cannot be ruled out as a major contributing factor to declining aquatic productivity and fish catches. The increase in the use and application of pesticides in agriculture in Nigeria today, which contributes greatly to aquatic pollution and hence reduction in water quality is mainly due to the increase in agricultural activities. Fish are one of the most widely distributed organisms in an aquatic environment and being susceptible to environmental contamination may reflect the extent of the biological effects of environmental pollution in waters (Soni *et al.*, 2020).

DDVP (Dichlorvos) insecticide is one of the most currently and widely used insecticides in this part of the world and several studies have detected its presence in water bodies at levels above the limits determined by local and international authorities (for example the Maximum Contaminant Level of 3μg/L by United State Environmental Protection Agency, 2019). Knowledge on the nature of these alterations would be pivotal to accurate diagnosis of pesticide toxicity. The nature of the haematological, biochemical, morphological and histopathological alterations associated with DDVP (Dichlorvos) insecticide poisoning remains to be clearly defined in aquatic animals, hence the need for this study.

Clarias gariepinus are widely used to evaluate the health of aquatic ecosystems, and biochemical changes observed in fish serve as biomarkers of environmental pollution (Salbeg *et al.*, 2020). Mortality or bioassay experiments in general present the most preferred way to evaluate the ecological influence of toxic compounds as their effects on fish and ecological risks cannot be determined by chemical analysis (Sumon *et al.*, 2018; Raghavendra *et al.*, 2020). Toxicity tests provide basis for understanding the limiting effects of various chemicals on organisms. Similarly, knowledge of the sub-lethal effects of toxic compounds at the hematological, biochemical, genetic and histopathological levels is very important for delineating fish health status and for understanding future ecological impact. The findings from this study provided information that are of relevance in setting out environmental limits as regards use of DDVP (Dichlorvos) insecticide.

2. LITERATURE REVIEW

Merged into the introduction with minimal synthesis. Create a dedicated section for literature review comparing previous toxicological findings (acute and sublethal) related to DDVP and catfish. Analyze research gaps.

Acute exposure to DDVP can lead to a cholinergic crisis, characterized by symptoms such as salivation, lacrimation, urination, defecation, gastrointestinal distress, and emesis (SLUDGE syndrome). Severe cases may result in muscle convulsions, respiratory distress, and even death (Li *et al.*, 2024). Chronic exposure to sub-lethal doses of DDVP can lead to long-term neurological damage, including cognitive deficits, motor dysfunction, and peripheral neuropathy. Studies have shown that prolonged inhibition of AChE can cause irreversible damage to the nervous system, affecting both central and peripheral nervous systems (Vasquez *et al.*, 2023).

Research on the effects of DDVP (dichlorvos) has explored its impact on oxidative stress, enzyme activity changes, and various biological pathways. DDVP exposure induces oxidative stress by generating reactive oxygen species (ROS), which can damage cellular components such as lipids, proteins, and DNA. This oxidative damage disrupts cellular function and contributes to toxic effects. Kumar *et al.* (2023) found that exposure to DDVP increased markers of oxidative stress, including elevated levels of malondialdehyde (MDA) and reduced glutathione (GSH) in fish. DDVP affects antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx). Wang *et al.* (2022) reported significant changes in the activity of these enzymes in aquatic organisms exposed to DDVP, reflecting a response to oxidative damage.

As an organophosphate, DDVP irreversibly inhibits AChE, leading to the accumulation of acetylcholine and overstimulation of neural pathways. This inhibition is a primary mechanism of DDVP toxicity. Fukuto (2023) details how DDVP affects AChE activity and the subsequent neurological effects. Beyond AChE, DDVP also affects butyrylcholinesterase (BChE), which plays a role in the breakdown of acetylcholine and other esterases. Zhou *et al.* (2023) demonstrated that DDVP exposure reduces BChE activity, contributing to its neurotoxic effects. DDVP-induced inhibition of AChE disrupts normal neurotransmission, leading to symptoms such as tremors, convulsions, and impaired motor functions. Li *et al.* (2024) explored how this disruption affects neurotransmitter balance and neural activity. Emerging evidence suggests that DDVP may interfere with endocrine systems, affecting hormone levels and signaling pathways. Miller *et al.* (2023) reviewed how organophosphates like DDVP can act as endocrine disruptors, impacting growth, development, and reproductive health in aquatic organisms. DDVP has also been shown to affect immune system function, leading to altered immune responses and increased susceptibility to infections. Chen *et al.* (2022) investigated the impact of DDVP on immune parameters in fish, highlighting changes in immune cell activity and cytokine levels.

3. METHODOLOGY

3.1. Fish Preparation

A 12 weeks completely randomized design (CRD) feeding trial was conducted at the site of Fisheries Technology Department, Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria. Juveniles of African catfish (C. gariepinus), were procured from the Teaching and Research farm of the Federal Polytechnic Ado Ekiti, Ekiti State Nigeria. Juvenile fish were used in the experiment because they are more susceptible to environmental changes than older/more mature fishes. 10 healthy juveniles of Clarias gariepinus, regardless of sex were randomly selected, weighed, distributed and replicated thrice into five (5) plastic aquarium tanks (42.5 × 30.5 × 22.5cm) contained 50 liters of dechlorinated water (one hundred and fifty (150) fish). For the range finding test, four healthy fish were selected into an aquarium tank containing 15L of water after which DDVP (Dichlorvos) insecticide were added to determine the LC50. The experiment was designed into five treatments with concentration of DDVP (Dichlorvos) insecticide below the determined LC50 (0.00056ml/L) as T1 (0.00000; control), T2 (0.000112ml/L), T3 (0.000224ml/L), T4 (0.000336ml/L) and T5 (0.000448ml//L) as presented in Table 1.

Table 1: Concentration of DDVP in each Treatment

T1 (control)	T2	T3	T4	T5
0.0000ml/L	0.000112ml/L	0.000224ml/L	0.000336ml/L	0.000448ml/L

3.2. Exposure setup

The fish were acclimatized for two weeks in two plastic tanks of 50L capacity each and fed daily with commercial feeds contained 42-45% crude protein. In order to sustain a good hygienic condition and to avoid pollution, fecal wastes and other devastate materials were siphoned off every day. Deceased fishes were removed with the help of plastic forceps to prevent further or possible deterioration of the water quality and eminence. For the duration of acclimatization, water in the tanks were renewed every day with well aerated tap water. The feeding was discontinued 24 hours before the experimental run to prevent interference of feces. For the present study, DDVP (Dichlorvos) insecticide was obtained as a commercially available insecticide from an agrochemical outlet in Ado Ekiti

3.3. Sub-lethal toxicity bioassay

Based on the results of the range finding test, the 96-hours LC50 were calculated as 0.00056ml/L and used to determine the concentrations of DDVP (Dichlorvos) insecticide used during the sub-lethal toxicity bioassay (Ali *et al.*, 2018; Amaeze *et al.*, 2020). Fresh specimens were exposed to concentrations below the LC50 (0.00056ml/L) in triplicates, at a stocking density of 10 fish per aquarium tank. A total of one hundred and fifty fishes were used i.e. five treatments (T1 (0.00000; control), T2 (0.000112ml/L), T3 (0.000224ml/L), T4 (0.000336ml/L) and T5 (0.000448ml//L) in triplicates (Table 1). 15 plastic aquaria were used for the sub-lethal experiment. Fish were fed with pelleted commercial feed at 5% body weight daily which were split into 2 rations.

3.4. Mortality

Examination of the experimental set-up for fish mortality were made at the end of 1, 2, 4, 6 and 12 hours post exposure and then twice daily before termination of the experiment (Olusegun, 2011). Juveniles of *Clarias gariepinus* were certified dead when there is cessation in opercular movement and a gentle prodding elicited no response. The number of dead fish were recorded against the time of death in a tabular form in each treatment (Oluah *et al.*, 2020). Dead fish were immediately removed to avoid dissolved oxygen depletion (Kumari, 2020).

3.5. Blood Collection

Blood samples were collected by the caudal ablation method from both the control and exposed fishes at the end of the experiment. The blood samples were dispensed into tubes containing ethylenediaminetetraacetate (EDTA) anticoagulant and transported in ice-packed bags to the Microbiological Laboratory unit of Ekiti State University Teaching Hospital, Ado Ekiti for haematological analysis. Red blood cells and white blood cells were counted by Neubauers improved heamocytometer using Hayems and Turks solution as diluting fluids, respectively. Packed Cell Volume (PCV), Mean Corpuscular Haemoglobin Concentration 30 (MCHC), Mean Corpuscular haemoglobin (MCH) and Mean Corpuscular Volume (MCV) were calculated respectively using standard formula described by Hussain *et al.* (2019).

3.6. Quality Assurance/Quality Control

In the context of quality assurance and control for DDVP (Dichlorvos) insecticide exposure assessment, a standard operating procedures were carried out for sample collection, preparation and analysis. The use of laboratories and personnel that are accredited and certified for fish toxicology assessment were made mandatory to ensure that this research work met recognized quality standards. Proper sampling techniques were used to track samples accuracy. All equipment and instruments used in this research work were used to ensure accuracy and precision (Ayebidun & Ajibare, 2023).

3.7. Water Quality Monitor

Temperature and pH of the test solution and the control were monitored every 24 hours using mercury in glass thermometer and pH meter (American Public Health Association, 2005).

3.8. Statistical analysis

The statistical analysis were carried out using Statistical package for social sciences version 20 (SPSS, 2014) . The data were expressed as mean ± standard deviation and multivariate analysis of variance were used to show significant variations at $p<0.05$.

4. RESULTS AND DISCUSSION

Mortality rates of fish exposed to DDVP insecticide

The mortality rates of fish exposed to different concentrations of DDVP insecticide are presented in Table 2. The table revealed that the mortality rates in T4 (85.00 ± 7.07%) and T5 (100.00 ± 0.00%) are significantly high compared to T1 (0.00 ± 0.00%), T2 (15.00 ± 7.07%), and T3 (20.00 ± 14.14%). Specifically, T4 and T5 showed significantly elevated mortality rates ($p < 0.05$) when compared to the other treatment groups, with T5 exhibiting the highest mortality rate.

Table 2: Mortality rates of *Clarias gariepinus* exposed to DDVP insecticide

	T1	T2	T3	T4	T5
Mortality	$0.00±0.00^a$	$1.50±0.71^a$	$2.00±1.41^a$	$8.50±0.71^b$	$10.00±0.00^b$
%Mortality	$0.00±0.00^a$	$15.00±7.07^a$	$20.00±14.14^a$	$85.00±7.07^b$	$100.00±0.00^b$

Means±SD on the same row with homogenous superscripts indicate no significant difference (p>0.05).

4.1. Haematology of *Clarias gariepinus* exposed to DDVP insecticide

The heamatological parameters of Clarias gariepinus juveniles exposed to different concentrations of DDVP (Dichlorvos) insecticide are presented in Table 3. The table reveals significant variations in the hematological parameters of Clarias gariepinus juveniles exposed to different concentrations of DDVP. The PCV was significantly reduced in T3 (20.33%) compared to other groups, suggesting a potential adverse effect of higher DDVP concentrations on erythropoiesis. The RBC count in T2 (2.00 ± 0.00 $\times 10^6$/L) was the lowest, correlating with the observed decrease in PCV, which indicates possible anemia or reduced red blood cell production in response to the pesticide.

The MCV and MCH were elevated in T2, reflecting possible macrocytic anemia, while the MCHC remained relatively stable across groups, indicating that the overall concentration of hemoglobin in the red cells was not significantly affected. The hemoglobin level was significantly lower in T3 (7.44 ± 0.69 g/dl), aligning with the observed decrease in PCV and RBC counts. This suggests that exposure to higher DDVP concentrations may impair hemoglobin synthesis or red cell turnover. There was a marked increase in WBC count in T2 (4.03

± 0.06 ×10^9/L), which could be indicative of an inflammatory or stress response due to DDVP exposure. Granulocytes were significantly higher in T2 (32.77 ± 0.83%), suggesting a shift towards a more inflammatory response, while lymphocytes and monocytes varied, with lymphocytes decreasing in T3 (Table 3).

Table 3: Haematological parameters of Clarias gariepinus exposed to DDVP insecticide

Parameter	T1	T2	T3	T4
PCV %	29.00±1.00b	28.00±1.00b	20.33±0.58a	31.00±1.00c
RBC (x10^6/L)	4.00±0.00b	2.00±0.00a	3.67±1.15b	3.00±0.00ab
MCHC (g/dl)	33.27±0.38a	33.40±0.53a	34.33±1.53a	32.97±0.88a
MCV(fL)	80.82±0.24b	117.19±0.64d	69.56±2.69a	110.57±1.50c
MCH(pg/cell)	27.21±0.50b	39.13±0.33d	24.12±1.80a	36.23±1.06c
Haemoglobin (Hbg/dl)	10.19±0.50b	10.48±1.07b	7.44±0.69a	10.42±1.07b
WBC (x 10^9/L)	1.10±0.10a	4.03±0.06d	2.20±0.20c	1.63±0.32b
Granulocytes (x10^9/L)	0.30±0.01a	1.25±0.14d	0.72±0.05c	0.51±0.01b
GRA %	24.30±0.52a	32.77±0.83b	32.95±0.99b	32.43±1.12b
Lymphocytes (x10^9/L)	0.86±0.04a	2.58±0.02d	1.41±0.01c	1.06±0.01b
LYMPH %	73.33±1.53c	69.00±1.00b	64.67±0.58a	66.00±1.00a
Monocytes(x10^9/L)	0.06±0.01c	0.00±0.01a	0.04±0.00b	0.04±0.01b
MON %	4.00±0.00c	0.00±0.00a	2.00±0.00b	2.33±0.58b

Means±SD on the same row with homogenous superscripts indicate no significant difference (p>0.05).

4.2. Discussion

4.2.1. Mortality rates of fish exposed to DDVP insecticide

The results demonstrated a clear dose-response relationship between DDVP exposure and fish mortality. At lower concentrations (T1, T2, and T3), the mortality rates remained relatively low, indicating a lower acute toxicity of DDVP at these levels. In contrast, higher concentrations (T4 and T5) resulted in substantially higher mortality rates, reflecting increased toxicity. The significantly higher mortality rates observed in T4 and T5 suggest that the concentration of DDVP at these levels is lethal to a large proportion of the fish population. This is consistent with the known effects of organophosphate insecticides, which are known to disrupt acetylcholine esterase activity, leading to neurotoxic effects and potentially high mortality rates in aquatic organisms.

The lower mortality rates in the control (T1), T2, and T3 may be attributed to the sub-lethal concentrations of DDVP, where the fish are exposed to levels that are not immediately fatal but could still induce stress or sublethal effects. This finding which showed a significant increase in fish mortality with higher concentrations of DDVP insecticide, align with the research of Khan *et al.* (2010), which demonstrated that exposure to various pesticides, including organophosphates, results in higher mortality rates among fish at elevated concentrations and that even sub-lethal doses can impact fish health and behavior.

The high mortality rates (85% and 100% in T4 and T5, respectively) recorded in this study, correspond with the findings of Singh and Sharma (2018) who reported that mortality rates in fish exposed to high doses of organophosphates often exceeded 70%, which is consistent with the mortality rates observed in our T4 and T5 treatments. The observation of lower mortality rates in T1, T2, and T3 at lower concentrations aligns with Mishra and Gupta (2014), who found that lower concentrations of pesticides could result in sub-lethal effects, such as stress and behavioral changes, without immediate high mortality. Mishra and Gupta (2014) emphasized that even sub-lethal doses could impact fish health, affecting growth and reproduction, which underscores the importance of not only considering lethal effects but also sub-lethal impacts in environmental assessments.

The results suggest that high concentrations of DDVP pose a severe risk to fish populations, which aligns with García and Martínez (2017) who reported that pesticide exposure can lead to substantial mortality and disrupt aquatic ecosystems. They highlighted the need for integrated pest management to minimize pesticide impacts on aquatic life, reinforcing the importance of our recommendations for alternative solutions and regulatory measures. The dramatic increase in mortality at higher DDVP concentrations observed in this study highlights acute toxicity. Zhao and Zhou (2015) discussed how organophosphates can lead to high mortality due to their acute effects. However, they also pointed out the need for assessing chronic exposure effects, which can have long-term consequences on fish populations. This study provides a snapshot of acute effects, suggesting a need for further investigation into chronic exposure scenarios to understand long-term impacts.

Haematology of Clarias gariepinus exposed to DDVP insecticide

The hematological effects of DDVP (dichlorvos) on Clarias gariepinus juveniles were evident in the significant alterations observed in various blood parameters. These findings are consistent with and expand upon previous research on the impact of organophosphates and other pesticides on aquatic organisms. The observed reduction in PCV and RBC counts in Clarias gariepinus juveniles, particularly in T3, aligns with findings from earlier studies on organophosphates. For instance, research by Nwani *et al.* (2012) demonstrated that exposure to organophosphates led to significant decreases in PCV and RBC counts in freshwater fish, suggesting that insecticides adversely affect erythropoiesis and can induce anemia. Similarly, the findings of Omwoyo *et al.* (2021) noted that high concentrations of organophosphates such as DDVP can disrupt normal blood cell production, causing anemia-like symptoms in fish.

The increase in MCV and MCH in T2, and the relatively stable MCHC, suggested that higher pesticide concentrations might lead to macrocytic anemia. This is consistent with the study by Shabana *et al.* (2018), which observed macrocytic changes in fish exposed to high levels of chlorpyrifos, another organophosphate. Shabana *et al.* (2018) found similar alterations in MCV and MCH, indicating that pesticides can impact the size and hemoglobin content of red blood cells. The significant decrease in hemoglobin levels in T3 supports the findings of similar studies where decreased hemoglobin was associated with pesticide exposure. Ikenweiwe *et al.* (2019) reported decreased hemoglobin levels in fish exposed to organophosphates, which they attributed to the toxic effects of these chemicals on erythropoiesis and hemoglobin synthesis. The reduction in hemoglobin in T3 suggests that high doses of DDVP significantly impair the fish's ability to maintain adequate oxygen-carrying capacity.

The marked increase in WBC counts and granulocytes in T2 indicated an inflammatory response. This finding corroborates with research by Sinha *et al.* (2014), who found elevated WBC counts and granulocyte percentages in fish exposed to pesticides, indicating a stress or inflammatory response. The increase in WBC and granulocytes in T2 aligns with the study of Asare *et al.* (2020), which reported that organophosphate exposure led to elevated WBC counts, reflecting an immune response to the chemical stressor. Moreover, the decrease in lymphocytes and monocytes in T3 compared to T1 and T2 also supports previous findings. According to a study by Olayemi *et al.* (2017), reduced lymphocyte counts in fish exposed to high pesticide concentrations suggest a compromised immune system, possibly due to the toxic effects of the pesticide on immune cells or their production.

5. CONCLUSION

This study investigated the impact of DDVP (dichlorvos) insecticide on the mortality rates and hematological properties of Clarias gariepinus juveniles. The study established that exposure of Clarias gariepinus to DDVP insecticide shows a clear dose-dependent increase in mortality rates i.e. higher concentrations of DDVP (T4 and T5) result in significantly higher mortality compared to lower concentrations (T1, T2, and T3). This suggests that DDVP is highly toxic to fish at elevated concentrations, with severe impacts on their survival. The study also established that exposure to DDVP (dichlorvos) insecticide adversely affects the hematological profile of Clarias gariepinus juveniles. Increased pesticide concentrations were associated with significant reductions in PCV, RBC count, and hemoglobin levels, indicative of anemia.

Additionally, alterations in white blood cell counts and differential leukocyte counts suggest an inflammatory or stress response. The findings revealed significant alterations in various blood parameters, highlighting the detrimental effects of pesticide exposure. Overall, the study underscores the adverse effects of DDVP on the hematological health of Clarias gariepinus juveniles, with implications for their overall well-being and survival in environments contaminated with this pesticide.

RECOMMENDATION

This study recommends that it is crucial to monitor and regulate the use of DDVP in aquatic environments to prevent harmful effects on fish populations. Also, further studies should be conducted to elucidate the mechanisms underlying the hematological changes observed and to assess the long-term impacts of DDVP exposure. It is further recommended that the development and use of less toxic, more environmentally friendly pest control methods (such as Integrated Pest Management (IPM) strategies that combine biological, cultural, and physical control methods) in aquatic environments should be explored to minimize reliance on chemical pesticides and mitigate their impact on aquatic ecosystems. Finally, education and training should be provided for farmers, pesticide applicators, and environmental managers on the safe handling and application of pesticides. Awareness programs should focus on minimizing pesticide runoff and reducing potential harm to aquatic environments. By following these recommendations, the negative impacts of DDVP on aquatic life can be minimized, promoting healthier ecosystems and safeguarding the well-being of aquatic organisms.

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