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RESEARCH ARTICLE

Effects of Silver Nitrate ($AgNO_3$) Nanoparticles on the Growth Performance and Liver of *Cyprinus carpio*

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Abstract Water pollutants that contaminate water supplies and harm aquatic life all over the world and impact on their growth and physical parameters. Silver nanoparticles have wide use in industries because of their electrical, optical, and antibacterial qualities. The aquatic life has suffered as a result of its widespread use and application. The objective of the study was to investigate the effect of various concentrations of silver nitrate nanoparticles on growth performance and liver profile of *Cyprinus carpio*. In experimental design, total 60 fishes (15 fingerling/ aquarium) were subjected to different concentrations of $AgNO_3$ NPs 0 mg/L (T_o serve as control) group), 50 mg/L (T_1), 100 mg/L (T_2) and 150 mg/L T_3). The treatments were compared by applying one way Analysis of variance and variation among mean was evaluated by applying Duncan's Multiple Range Test (DMRT) in statistical software R (Version 4.3.3). Results showed that effect of silver nitrate nanoparticles on fish growth rate are toxic and showed non-significant ($P>0.05$) variation in average weight, specific growth rate and condition factor while, significant ($P<0.05$) in weight gain, average length and length gain and liver profile (bilirubin, albumin, total protein, alanine transaminase, alkaline phosphatase and aspartate aminotransferase) of *Cyprinus carpio*. It can be concluded that silver nitrate nanoparticles at higher concentration (150 mg/L) in T_3 have significant ($P<0.05$) toxic effect on fish growth rate and liver profile of *Cyprinus carpio*.

Keywords: antimicrobial, aquatic life, $AgNO_3$ NPs, adverse effects, water pollutant

Introduction

The rapid advancement of nanotechnology has revolutionized numerous scientific and industrial domains, leveraging the unique physicochemical properties of materials engineered at the nan scale (1–100 nm). Among these, silver nitrate nanoparticles ($AgNO_3$ NPs) have emerged as particularly significant due to their exceptional antimicrobial, catalytic, and optical characteristics [26,25]. These nanoparticles, composed of ultra-fine particles invisible to the naked eye, exhibit high reactivity and dispensability in aqueous environments, making them invaluable for applications ranging from water purification to

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biomedical diagnostics. In aquaculture, $AgNO_3$ NPs are increasingly employed to mitigate pollutants, pathogens, and bio fouling, thereby enhancing water quality and operational efficiency [10,25]. Their integration into fish feed formulations has also been explored to augment nutrient absorption, immune response, and growth performance in commerciallyvital species such as Gulfam and *Cyprinus carpio* [2,7].Concurrently, the exponential rise in $AgNO_3$ NP production projected to grow by 63% until 2024 raises critical ecological concerns [20]. Industrial and consumer products containing these nanoparticles often release them into aquatic ecosystems via wastewater discharge, agricultural runoff, and atmospheric deposition [14,19].
Once introduced, $AgNO_3$ NPs interact with biological systems in complex ways potentially disrupting metabolic functions and accumulating in vital organs. Fish, as primary inhabitants of aquatic environments, are especially vulnerable due to direct exposure through gills, skin, and dietary intake [15]. Their role as bio indicators of ecosystem health underscores the urgency of understanding nanoparticle-induced toxicity. Water pollution exacerbates these risks, with contaminants like heavy metals, pesticides, and nanoparticles compromising aquatic biodiversity and human health [1,6]. Nanoparticles, including $AgNO_3$ NPs, enter water bodies through treated sludge and industrial effluents, where their minute size and high surface-area-to-volume ratio facilitate uptake by organisms [11]. The liver, a primary detoxification organ in fish, is particularly susceptible, acting as a biological filter that concentrates 41–88% of circulating nanoparticles [4]. Despite this, the metabolic fate and hepatotoxic mechanisms of $AgNO_3$ NPs remain poorly elucidated, with existing studies highlighting dose-dependent histopathological alterations and enzymatic disruptions [13,31]. The common carp (Cyprinus carpio) serves as an ideal model for such investigations due to its ecological ubiquity, economic importance in global aquaculture, and sensitivity to environmental stressors [18]. Native to Eurasia but widely introduced, this species exhibits marked physiological responses to pollutants, making it a robust sentinel for nano toxicology studies. Prior research indicates that $AgNO_3$ NPs impair growth, alter behavior and induce oxidative stress in fish, yet comprehensive analyses of their hepatotoxic effects specifically on liver morphology, enzyme activity, and growth dynamics are scarce [7,29]. This knowledge gap is critical, as the liver governs essential processes like metabolism, nutrient storage, and toxin neutralization, directly influencing overall health and aquaculture yield. This study aims to evaluate the effects of $AgNO_3$ NPs on the growth performance and liver health of *Cyprinus carpio*. Specifically, we assess changes in growth parameters (weight gain, length gain, and specific growth rate) and liver enzyme activity (ALT, AST, ALP, bilirubin, albumin, and total protein) following exposure to varying concentrations of $AgNO_3$ NPs. The findings will contribute to understanding the ecological risks of nanoparticles in aquaculture and provide insights for sustainable fish farming practices.

Materials and Methods

Data Collection

The experiment was conducted in the Fisheries Laboratory, Department of Zoology, University of Agriculture, Faisalabad, from March to April 2024. Healthy fingerlings of *Cyprinus carpio* (average weight: 15 ± 2 g; length: 10 ± 1 cm) were obtained from the Government Fish Hatchery, Faisalabad. The fish were acclimatized for 10 days in dechlorinated tap water under controlled conditions (temperature: 25 ± 2°C; dissolved oxygen: 6.5 ± 0.5 mg/L; pH: 7.2 ± 0.3).

Nanoparticle preparation and Exposure

Silver nitrate nanoparticles ($AgNO_3$ NPs; 20 nm and 40 nm) were synthesized and characterized by the Physics Department, University of Agriculture, Faisalabad. The fish were divided into four treatment groups (n=15 per group): Control (T_0): 0 mg/L $AgNO_3$ NPs

- T_1: 50 mg/L $AgNO_3$ NPs
- T_2: 100 mg/L $AgNO_3$ NPs
- T_3: 150 mg/L $AgNO_3$ NPs

The experiment lasted 28 days, with fish fed a commercial diet (0.05 g pellets) twice daily. Water quality parameters were monitored weekly.

Growth Performance Analysis

Growth parameters were assessed using the following formulas:
Weight gain (%) = [(Final weight – Initial weight) / Initial weight] × 100
Length gain (%) = [(Final length – Initial length) / Initial length] × 100
Specific growth rate (SGR, %/day) = [(ln Final weight – ln Initial weight) / Days] × 100
Condition factor (CF) = (Body weight (g) / (Total length (cm))³.

Liver Function Assessment

At the end of the trial, five fish per group were anesthetized (200 ppm clove powder), and blood samples were collected from the caudal vein. Serum was separated via centrifugation (5000 rpm, 4°C, 20 min) and analyzed for:
Alanine transaminase (ALT)
Aspartate aminotransferase (AST)
Alkaline phosphatase (ALP)
Total protein, albumin, and bilirubin Biochemical assays were performed using QCA diagnostic kits (Micro Lab 300® spectrophotometer).

Statistical Analysis

Data were analyzed using one-way ANOVA followed by Duncan's Multiple Range Test (DMRT) in R software (Version 4.3.3). Significance was set at $p < 0.05$.

Results and Discussion

Growth Performance

Cyprinus carpio exposed to silver nitrate nanoparticles ($AgNO_3$ NPs) at concentrations of 0 (T_o), 50 (T1), 100 (T2), and 150 mg/L (T3) for 4 weeks showed concentration-dependent impacts on growth parameters (Tables 1–2). While survival remained 100% across all treatments, significant effects were observed in key metrics: Weight gain decreased markedly at 150 mg/L (T3: 0.19 ± 0.19 g) compared to control (T_o: 0.60 ± 0.10 g; $p = 0.00459$, ANOVA).

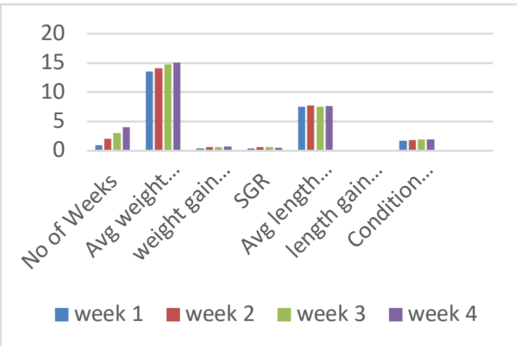

Figure 3.1: A Graphical Demonstration of the Growth Performance of Cyprinus carpio In Terms Of Specific Growth Rate, Length Condition Factor And Weight T Group.

Table 3.1: *Growth Performance of Cyprinus carpio In Terms Of Average Weight, Weight Gain, SGR, Average Length, Length Gain, Condition Factor and Survival Rate in T_1 for 4 weeks.*

Group T_1 50mg/L							
Weeks	Avg W. (g)	Weight Gain (g)	SGR	Avg. L (cm)	Length gain (cm)	Condition factor	Survival Rtae %
1	13.33	0.45	0.45	7.52	0.02	1.76	100
2	13.97	0.63	0.63	7.54	0.03	1.86	100
3	14.52	0.57	0.57	7.57	0.03	1.91	100
4	15.22	0.64	0.64	7.59	0.02	2.0	100
Mean ± SD	14.26 ±0.69	0.57±0.07	0.57±0.07	7.55±0.02	0.02±0.05	1.88±0.08	100±0

Length gain was significantly reduced in T3 (0.01 ± 0.007 cm) versus T_o (0.03 ± 0.007 cm; $p = 0.0178$).

Specific Growth Rate (SGR) declined at 150 mg/L (T3: 0.41 ± 0.05%) but showed no statistical significance ($p = 0.134$).

Table 3.3: *Growth Performance of Cyprinus carpio In Terms Of Average Weight, Weight Gain, SGR, Average Length, Length Gain, Condition Factor and Survival Rate in T_3 for 4 weeks.*

			Group T_3				
No. of Weeks	Avg. weight (g)	Weight Gain (g)	SGR	Avg. length (cm)	Length gain (cm)	Condition factor	Survival Rtae %
1	13.33	0.39	0.42	7.51	0.01	1.75	100
2	13.71	0.38	0.45	7.51	0.01	1.81	100
3	13.74	0	0.46	7.53	0.02	1.81	100
4	13.74	0	0.33	7.52	0	1.82	100
Mean ± SD	13.63±0.17	0.19±0.19	0.41±0.05	7.51±0.008	0.01±0.007	1.79±0.02	100±0

Condition factor and average weight exhibited no significant differences across treatments ($p > 0.05$).

Liver enzymes and Biochemical Markers

$AgNO_3$ NPs induced significant hepatic toxicity ($p < 0.001$ for all enzymes): ALT decreased in T1 (4.27 ± 0.149 U/L) and T2 (5.70 ± 0.123 U/L) but increased in T3 (15.7 ± 1.51 U/L) versus control (24.23 ± 0.1 U/L).

Table 3.4: *Effect Of Concentrations of Silver Nitrate Nanoparticles on the Weight of Cyprinus carpio*

No. of weeks		T_o		T_1		T_2		T_3
	Avg weight	weight gain	Avg weight	Weight gain	Avg weight	Weight gain	Avg weight	Weight gain
1	13.51	0.45	13.33	0.45	13.34	0.45	13.33	0.39
2	14.07	0.64	13.97	0.63	13.85	0.63	13.71	0.38
3	14.71	0.59	14.52	0.57	14.51	0.45	13.74	0.00
4	15.12	0.75	15.22	0.64	15.93	0.53	13.74	0.00
Mean ± SD	14.35 ±0.61	0.60±0.10	14.26 ±0.69	0.57±0.07	14.40±0.97	0.50±0.06	13.63±0.17	0.19±0.19

Albumin and bilirubin also showed significant elevations at 100–150 mg/LAST and ALP exhibited dose-dependent increases, peaking at T3 (AST: 37.4 ± 2.1 U/L; ALP: 54.83 ± 3.07 U/L).

Table 3.5: *ANOVA Of Various Concentration of Silver Nitrate Nanoparticles on the Average Weight of Cyprinus carpio*

SOV	DF	SS	MS	F-Value	P-Value
Treatment	3	1.254	0.4181	0.994	0.429ns
Error	12	5.049	0.4208		
Total	15	6.303			

Table 3.6: *Mean Comparison Of Test Values Of Effects Of Different Conc. Of Silver Nitrate NPs on the Avg. Weight of Cyprinus carpio*

Treatment		mean comparison test
T_o	Control	14.35 ±0.61
T_I	50 mg/L	14.26 ±0.69
T_2	100 mg/L	14.40±0.97
T_3	150 mg/L	13.63±0.17

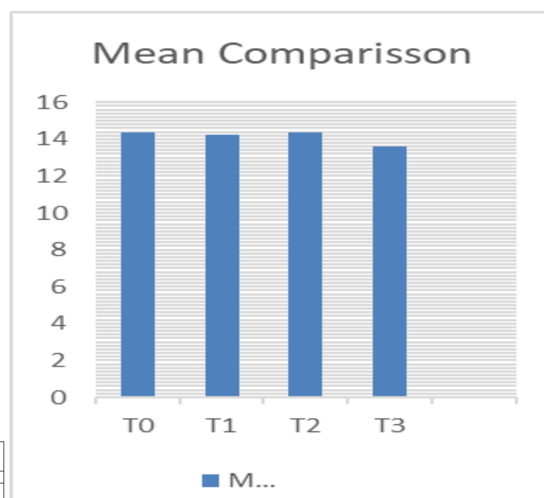

Figure 3.2: *Graph mean comparison of Avg. weight of Cyprinus carpio in various 4 treatments*

Figure showed that (DMRT) Mean Comparison Test Values of effects of different concentrations (0,50,100,150mg/L) of silver nitrate NPs at various 4 treatments on the average weight of *Cyprinus carpio.* Total protein surged at higher concentrations (T2: 14 ± 2.16 g/dL; T3: 20.67 ± 1.63 g/dL).

Water Quality Parameters

Physicochemical properties (pH, dissolved oxygen, temperature) remained stable weekly across all treatments, confirming that growth and liver alterations were nanoparticle-induced.

Discussion

The pervasive introduction of silver nitrate nanoparticles ($AgNO_3$NPs) into aquatic ecosystems via anthropogenic activities represents a critical environmental challenge, with profound implications for ecological stability and aquatic organism health. As highlighted by [1], water contamination from industrial, medical, and technological applications facilitates the accumulation of nanoparticles in aquatic environments, where their high reactivity, extensive surface area, and photolytic properties though beneficial for wastewater treatment [16] also render them persistent pollutants. Silver nanoparticles (AgNPs), a dominant subset of aquatic contaminants, induce severe health disruptions in aquatic life, particularly fish, as evidenced by their detrimental effects on growth metrics and organ function[9,28]. This study corroborates prior findings, demonstrating that $AgNO_3$NPs significantly impair growth performance in Cyprinus carpio (common carp), a species vital to global aquaculture and food security in developing nations [21].

Specifically, dose-dependent exposure resulted in statistically significant reductions ($P<0.05$) in weight gain, average length, and length gain, aligning with observations by Noor and Rasheed [22, 27]. These growth impediments likely stem from altered feeding behaviours and compromised nutrient absorption, as nanoparticles disrupt digestive processes and induce physiological stress. Paradoxically, while intentional incorporation of $AgNO_3$NPs into fish feed may enhance growth and immunity in controlled aquaculture settings [25], their unintended environmental release elicits toxicological consequences that undermine these benefits. Hepatotoxicity emerged as a critical concern in this investigation, with $AgNO_3$NPs inducing marked biochemical alterations in liver enzymes and proteins. Liver parameters such as alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), bilirubin, and total proteins serve as sensitive biomarkers for pollutant-induced damage, reflecting cellular integrity and metabolic function [3].

Our data revealed significant elevations in AST and ALT activities indicators of hepatocyte injury alongside increased total protein and bilirubin levels in exposed common carp, consistent with findings by Matranga and Corsi [17] and Khorshidi [8]. Conversely, ALP activity decreased significantly, suggesting nanoparticle interference with enzymatic pathways, a phenomenon also reported by Wang [30]. These perturbations underscore a dose-dependent accumulation pattern, wherein $AgNO_3$NPs preferentially bio accumulate in the liver, followed by gills and muscles, with the highest concentration (150 mg/L) inflicting severe damage compared to lower doses (50 mg/L). This bioaccumulation initiates upon nanoparticle entry into the bloodstream, followed by hepatic sequestration [5], ultimately manifesting as chronic toxicity that compromises vital organs, including the heart and gills [24]. The oxidation state of silver further influences its eco toxicological impact. In aquatic systems, AgNPs exist as Ag^0, Ag^+, Ag^{2+}, and Ag^{3+}, with nanoparticulate silver (Ag^0) exhibiting heightened bioavailability and toxicity relative to bulk silver due to its propensity for cellular uptake and ion release [28,12]. This characteristic exacerbates chronic exposure risks, as evidenced by persistent alterations in liver enzymes and growth parameters in our study. Notably, the highest treatment concentration (T3) induced the most pronounced declines in swim performance, growth, and biochemical homeostasis, highlighting the concentration-dependent nature of $AgNO_3$NP toxicity. These findings align with global concerns regarding nanoparticle bioaccumulation and their potential to disrupt aquatic food webs [23].

In conclusion, this study substantiates that $AgNO_3$NPs pose significant threats to aquatic biota, particularly fish, through growth inhibition and hepatotoxic mechanisms. However, the environmental reality involves concurrent exposure to multiple pollutants organic and inorganic which may interact synergistically or antagonistically. Future research must therefore prioritize long-term, multifactorial studies to elucidate the cumulative impacts of mixed contaminants. Advanced simulations and mechanistic models are essential to predict nanoparticle behaviour, transport, and chronic hepatotoxicity in complex aquatic systems. Such efforts will inform regulatory frameworks and mitigation strategies, safeguarding ecological integrity and human health against emerging nano scale pollutants.

Author Contributions

Tehreem Shakoor and Muhammad Saail Abbas designed the study, collected and analyzed data, and drafted the manuscript. Muhammad Naeem (supervisor) and Maryam Riasat (co-supervisor) oversaw the study and reviewed the manuscript. All authors approved the final version.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Acknowledgment

This work is part of a research.

Data Availability

Data will be made available on request.

References

[1] Alrumman, S.A., El-kott, A.F. and Kehsk, M.A. (2016). Water pollution: Source and treatment. American Journal of Environmental Engineering, 6(3), 88-110.
[2] Amal, M. N. A., & Zamri-Saad, M. (2011). Streptococcosis in tilapia (Oreochromis niloticus): a review, 195-206.
[3] Bakshi, S., He, Z. L., & Harris, W. G. (2015). Natural nanoparticles: implications for the environment and human health. Critical Reviews in Environmental Science and Technology, 45(8), 861-904.
[4] Bourquin, S., Mercuzot, M., Pellenard, P., Beccaletto, L., Schnyder, J., Baudin, F., & Gand, G. (2022). Reconsidering Carboniferous–Permian continental paleoenvironments in eastern equatorial Pangea: facies and sequence stratigraphy investigations in the Autun Basin (France). *International Journal of Earth Sciences*, *111*(5), 1663-1696.
[5] Das, S., Chakraborty, J., Chatterjee, S., & Kumar, H. (2018). Prospects of biosynthesized nanomaterials for the remediation of organic and inorganic environmental contaminants. Environmental Science: Nano, 5(12), 2784-2808.
[6] Dube, E., & Okuthe, G. E. (2023). Engineered nanoparticles in aquatic systems: Toxicity and mechanism of toxicity in fish. Emerging Contaminants, 9(2), 100–152.
[7] Fajordo, C., Martinez-Rodriguez, G., Blasco, J., Mancera, J. M., Thomas, B., & De Donato, M. (2022). Nanotechnology in aquaculture: Applications, perspectives and regulatory challenges. Aquaculture and Fisheries, 7(2), 185-200.
[8] Khorshidi, Z., Moghanlou, K. S., Imani, A., Behrouzi, S., Policar, T., & Rahimnejad, S. (2021). Interactive Effects of Curcumin and Silver Nanoparticles on Growth, Hemato-Biochemical Parameters, Digestive Enzymes Activity and Histology of Common Carp (*Cyprinus carpio*). Microscopy Research and Technique, 87(10), 353-364.
[9] Khoshnamvand, M., Hanachi, P., Ashtiani, S., & Walker, T. R. (2021). Toxic effects of polystyrene nanoplastics on microalgae Chlorella vulgaris: Changes in biomass, photosynthetic pigments and morphology. Chemosphere, 280(2), 130-145.
[10] Kumar, R., Sankhla, M. S., Kumar, R., & Sonone, S. S. (2021). Impact of pesticide toxicity in the aquatic environment. Biointerface Research in Applied Chemistry, 11(3), 10131-10140.
[11] Klaine, S. J., Alvarez, P. J., Batley, G. E., Fernandes, T. F., Handy, R. D., Lyon, D. Y., & Lead, J. R. (2008). Nanomaterials in the environment: behavior, fate, bioavailability, and effects. Environmental Toxicology and Chemistry: An International Journal, 27(9), 1825–1851.
[12] Liu, P. T., Stenger, S., Li, H., Wenzel, L., Tan, B. H., Krutzik, S. R., & Modlin, R. L. (2006). Toll-like receptor triggering of a vitamin D-mediated human antimicrobial response. Science, 311(5768), 1770-1773.
[13] Lin, K. F., Cheng, H. M., Hsu, H. C., Lin, L. J., & Hsieh, W. F. (2015). Band gap variation of size-controlled ZnO quantum dots synthesized by sol–gel method. Chemical Physics Letters, 409(4–6), 208–211.
[14] Malhotra, S., Welling, M. N., Mantri, S. B., & Desai, K. (2016). In vitro and in vivo antioxidant, cytotoxic, and anti-chronic inflammatory arthritic effect of selenium nanoparticles. Journal of Biomedical Materials Research Part B: Applied Biomaterials, 104(5), 993–1003.
[15] Malhotra, N., Ger, T. R., Uapipatanakul, B., Huang, J. C., Chen, K. H. C., & Hsiao, C. D. (2020). Review of copper and copper nanoparticle toxicity in fish. Nanomaterials, 10(6), 11-26.
[16] Mangla, D., Abbasi, A., Aggarwal, S., Manzoor, K., Ahmad, S., & Ikram, S. (2019). Effective removal of “non-biodegradable” pollutants from contaminated water. Metal oxide-based photocatalyst for the degradation of organic pollutants in water, 159(4), 483-503.
[17] Matranga, V., & Corsi, I. (2012). Toxic effects of engineered nanoparticles in the marine environment: model organisms and molecular approaches. Marine environmental research, 76(31), 32-40.
[18] Mercuzot, M., Bourquin, S., Pellenard, P., Beccaletto, L., Schnyder, J., Baudin, F.,& Gand, G. (2022). Reconsidering Carboniferous–Permian continental paleoenvironments in eastern equatorial Pangea: facies and sequence stratigraphy investigations in the Autun Basin (France). International Journal of Earth Sciences, 111(5), 1663-1696.
[19] Mishra, A., Kumari, M., Pandey, S., Chaudhry, V., Gupta, K. C., & Nautiyal, C. S. (2014). Biocatalytic and antimicrobial activities of gold nanoparticles synthesized by Trichoderma sp. Bioresource Technology, 166(22), 235–242.
[20] Nadeem, M., Khan, R., Afridi, K., Nadhman, A., Ullah, S., Faisal, S., & Abbasi, B. H. (2020). Application of nanotechnology in agriculture and refinement of environmental pollutants. J. Nanotech, 11(1), 18-26.
[21] Naguib, M., Mahmoud, U. M., Mekkawy, I. A., & Sayed, A. E. D. H. (2020). Hepatotoxic effects of silver nanoparticles on Clarias gariepinus; Biochemical, histopathological, and histochemical studies. Toxicology Reports, 7(88), 133-141.
[22] Noor, R., Maqsood, A., Baig, A., Pande, C. B.,

Zahra, S. M., Saad, A., & Singh, S. K. (2023). A comprehensive review on water pollution, South Asia Region: Pakistan. Urban Climate, 48(66), 101-413.

[23] Nti, E. K., Cobbina, S. J., Attafuah, E. E., Senanu, L. D., Amenyeku, G., Gyan, M. A., & Safo, A. R. (2023). Water pollution control and revitalization using advanced technologies: Uncovering artificial intelligence options towards environmental health protection, sustainability and water security. Heliyon, 9(7), 445-555.

[24] Oliveira, M., Ribeiro, A., Hylland, K., & Guilhermino, L. (2013). Single and combined effects of microplastics and pyrene on juveniles (0+ group) of the common goby Pomatoschistus microps (Teleostei, Gobiidae). Ecological indicators, 34(1), 641-647.

[25] Onuegbu, U. C., Agarwal, A., & Singh, N. B. (2018). Growth Performance of Cultured African Catfish (C. gariepinus) Fingerlings in the Presence of Nano and Macro CuO Feed Supplements. Journal of Scientific & Industrial Research, 77(1), 499-503.

[26] Rahman, A. U., Nazir, S., Irshad, R., Tahir, K., ur Rehman, K., Islam, R. U., & Wahab, Z. (2023). Toxicity of heavy metals in plants and animals and their uptake by magnetic iron oxide nanoparticles. Journal of Molecular Liquids, 32(1), 114-455.

[27] Rasheed, A., Iqbal, K. J., Safdar, A., Nasir, A., Jabeen, R., Tara, N., & Almarzoug, M. H. (2023). Toxicological effects of zinc oxide nanoparticles on hemato-biochemical profile of common carp (*Cyprinus carpio*). Journal of King Saud University-Science, 35(7), 102-835.

[28] Siddiqi, K. S., Husen, A., & Rao, R. A. (2018). A review on biosynthesis of silver nanoparticles and their biocidal properties. Journal of Nanobiotechnology, 16(6), 1-28.

[29] Vali, S., Mohammadi, G., Tavabe, K. R., Moghadas, F., & Naserabad, S. S. (2023). The effects of silver nanoparticles (Ag-NPs) sublethal concentrations on common carp (*Cyprinus carpio*): Bioaccumulation, hematology, serum biochemistry and immunology, antioxidant enzymes, and skin mucosal responses. *Ecotoxicology and environmental safety*, *194*(1), 110-353.

[30] Wang, H., Thorling, C. A., Liang, X., Bridle, K. R., Grice, J. E., Zhu, Y., & Roberts, M. S. (2015). Diagnostic imaging and therapeutic application of nanoparticles targeting the liver. Journal of Materials Chemistry B, 3(6), 939-958.

[31] Yilmaz, A., Ekiz, H., Gültekin, I., Torun, B., Barut, H., Karanlik, S., & Cakmak, I. (2020). Effect of seed zinc content on grain yield and zinc concentration of wheat grown in zinc-deficient calcareous soils. Journal of Plant Nutrition, 21(10), 2257–2264.

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