

Investigation into the effect of abattoir effluent on open hand dug wells and boreholes at Zangon Shanu Zaria Kaduna

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Abstract:

Existence of abattoir in the midst of residents in Zangon Shanu Zaria post greater concern about the suitability of ground water for drinking and other domestic use in the area. In view of this, this research examined the effect of abattoir effluent on ground water quality at Zangon Shanu Zaria Kaduna State. Water samples were collected from six points including wells and boreholes in the study area. The water samples were tested for selected physical, chemical and biological parameters such as Total Dissolved Solid (88.6 – 173.1mg/L), Total Suspended Solid (60 – 240mg/L), Biological oxygen demanded (0.0 – 10mg/L), pH (6.95 – 7.89), turbidity (3.85 – 9.4NTU), Chemical oxygen demand (110 – 170mg/L), Temperature (26.2 – 26.9°C) and Chloride (15 – 38.5mg/L). The laboratory tests were carried out using standard analytical methods and procedures for water quality analysis. The results shows that ground water near slaughter house poses environmental and health risk to the users if not treated as the parameters examined shows the lowering of the water quality and making the groundwater unhealthy for drinking and other uses.

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1. Introduction

Wastewater is mostly discharged in to water bodies without proper treatment in developing countries [1]. Abattoir effluents, which are wastewater generated from slaughter houses or meat processing facilities, have significant environmental impacts, including potential contamination of groundwater [2]. The effects on groundwater quality depend on various factors such as the composition of the effluents, the disposal methods, geological conditions, and the proximity of the abattoir to groundwater sources [3]. Abattoir effluents may contain high levels of nutrients, including nitrogen and phosphorus, which can lead to nutrient contamination in groundwater. Elevated nutrient levels in groundwater can contribute to eutrophication, impacting the ecological balance of aquatic ecosystems [4].

Abattoir effluents can contain pathogens such as bacteria and viruses from animal wastes [5]. If not properly treated or managed, these pathogens can infiltrate into groundwater, posing a risk to public health if the contaminated groundwater is used for drinking water supply. In some cases, abattoir effluents may contain various chemicals such as blood, fats, oils, and detergents used in cleaning processes [6]. These chemicals can contaminate groundwater and affect its quality, potentially leading to the presence of organic and inorganic pollutants. The slaughtering process and various chemicals used in abattoirs can introduce heavy metals into the wastewater [7]. If not adequately treated, these heavy metals can leach into groundwater, posing risks to both the environment and human health. Abattoir effluents may have variable pH

levels, and if discharged without proper treatment, they can alter the pH of groundwater. Significant changes in pH can impact the solubility and mobility of certain elements, potentially leading to groundwater quality issues [8]. Disposal of untreated abattoir effluents can contribute to changes in the groundwater table. Excessive water extraction or discharge of large volumes of wastewater may influence the natural balance of groundwater levels, affecting local hydrology. If groundwater is used for irrigation in areas surrounding abattoirs, the contaminants present in the effluents may enter the soil and impact agricultural productivity [9]. This can lead to the accumulation of pollutants in crops and affect food safety. The vulnerability of groundwater to contamination depends on factors such as the type of aquifer, soil characteristics, and hydraulic conductivity. Some aquifers may be more susceptible to contamination from abattoir effluents than others. Improper disposal of abattoir effluents that leads to groundwater contamination may result in legal and regulatory consequences [10].

2. Methods

The data used in this study was generally obtained from laboratory water tests. Reconnaissance survey was carried out to familiarize the researcher with the various environmental characteristics of the study area. During this process, some vital information was obtained and this formed a foundational knowledge that helped to enhance the planning, costing as well as preparation of materials needed for the study. Reconnaissance survey was also

conducted to get information regarding the kind of animals kept and slaughtered in the abattoir, get a comprehensive knowledge on how the animals are being slaughtered, also know the existing waste management practices and source of water in the abattoir.

2.1 Water Sample Collection

Sampling of water is a critical step in assessing water quality and ensuring accurate analysis. Proper sampling techniques help obtain representative and reliable samples that reflect the characteristics of the water source. In this study, six water samples were collected in a cleaned container; the samples were collected from three (3) hand dug wells (WA, WB, WC), and one borehole (BHA) within the abattoir vicinity. The remaining two (2) samples were collected from one hand dug well (WD) and one borehole (BHB) outside the abattoir, 40m and 35.7m away respectively from effluent and waste disposal point as described below:

- WA is an open dug well, 9.76m away from the abattoir effluent and waste disposal point
- WB is an open dug well, 25.5Mm away from the abattoir effluent and waste disposal point
- WC is an open dug well, 15.4m away from the abattoir effluent and waste disposal point
- BHA is a Borehole, 21m from the abattoir effluent and waste disposal point
- WD is an open dug well, served as control which is 40m away from the abattoir effluent and waste disposal point
- BHB is a Borehole, served as control which is 35.7m away from the abattoir effluent and waste disposal point

The sampling time was 6:30am to 7:00am, this was to avoid any form of external contamination, and to avoid unnecessary change in colour due to excessive use of open wells that can cause the water to be temporarily turbid. For biological test, the sample water was collected from borehole after sterilization of the borehole nozzle. This is to neutralize any living external organism that can influence the test result. The water samples were then transported to the laboratory for testing. The laboratory tests conducted in this study were categorized in to Physical, Chemical and Biological tests.

2.2 Physical Characteristics

Physical tests involve the assessment of certain characteristics and properties that can be observed or measured without altering the chemical composition of the water [11]. These tests provide valuable information about the overall quality and suitability of water for various

purposes. Temperature, turbidity, total dissolved solids (TDS) and total suspended solids (TSS) are the physical tests conducted on water samples collected. Physical tests of water are often part of a comprehensive water quality assessment. Physical characteristics of water help in understanding the suitability of water for drinking, recreational activities, industrial use, and the preservation of aquatic ecosystems [12]. Regular monitoring of physical parameters is essential for ensuring the safety and quality of water resources.

2.3 Chemical characteristics

Chemical tests involve the analysis of various chemical parameters to assess water quality and detect the presence of specific substances. Chemical tests provide valuable information about the composition of water and its suitability for different purposes.

Chemical characteristics such as pH, Chemical Oxygen Demand (COD), Dissolved Solids (DO) and Chloride test were conducted on all water samples collected. Chemical tests are essential for evaluating water quality, ensuring compliance with regulatory standards, and identifying potential health and environmental risks [13]. They are often part of routine water quality monitoring programs conducted by environmental agencies, water utilities, and research institutions.

2.4 Biological characteristics

Biological tests involve the assessment of living organisms or indicators of biological activity to gauge the quality and health of the water [14]. Biological tests provide information about potential contamination, the presence of pathogens, and the overall ecological condition of water bodies [15]. In this study, Biological Oxygen Demand (BOD) were determined to assess the biological characteristics of the water.

Biological tests are crucial for assessing the ecological health and safety of water bodies. Biological tests provide valuable information about the potential risks associated with microbial contamination, the presence of pathogens, and the overall impact of human activities on aquatic ecosystems [16]. Regular monitoring using this test helps guide water management practices and ensures the protection of both environmental and public health.

3. Result and Discussion

3.1 Physical characteristics

Physical tests were conducted on water samples collected from the study area. The result is presented in Table 1.

Table 1: Result of physical characteristics of water samples

S/N	Parameter	UNIT	WA	WB	WC	WD	BHA	BHB	WHO Standard	Nigerian Standard
1	Temperature	°C	26.9	26.4	26.3	26.4	26.2	26.7	-	-
2	TDS	Mg/L	173.1	144.1	153.5	93.8	88.6	98.3	-	500
3	Turbidity	NTU	9.4	7.6	8.20	3.7	6.72	3.85	5	5
4	TSS	Mg/L	240	150	170	120	100	60	-	-

3.1.1 Turbidity

Turbidity test was conducted on all water sample collected for this study. Turbidity is a measure of the cloudiness or haziness of water caused by the presence of suspended particles. Turbidity indicates how much the water has lost its transparency due to the scattering and absorption of light by these particles [17]. The suspended particles can include silt, clay, algae, organic matter, and other fine particles. The turbidity test result is presented in Table 1. From Table 1, it could be observed that, turbidity is greatly affected by the activities in the abattoir. Turbidity of the well water and borehole within the abattoir have been increased with the proximity to the effluent and waste disposal point. As the source of water distance increased such as BHB, the turbidity is very minimum (3.85 NTU). Also, as the distance becomes closer to effluent disposal point such as WA, the turbidity becomes higher (9.4 NTU). This is attributed to the presence of impurities originated from abattoir effluents and waste. Such turbid water can be harmful to human health [18].

3.1.2 Total dissolved solids (TDS)

Total dissolved solids (TDS) is another parameter that was investigated in this study. Total Dissolved Solids (TDS) is a measure of the combined concentration of inorganic and organic substances present in water in a dissolved form [1]. TDS includes minerals, salts, metals, cations, anions, and other dissolved substances [19]. The result of TDS is also presented in Table 1. As revealed in Table 1, TDS increases with the proximity to the effluents and waste disposal point. WD and BHB which are far from disposal point have water with lower total dissolved solids. WA and WC are the closest water source to effluent and waste disposal point, their TDS are relatively higher compared to other water sources. The highest TDS of 173.1 mg/L was recorded in WA, this value is within the acceptable limit by Nigerian Standard for Drinking Water. Higher TDS levels can have various effects on water quality and human health.

3.1.3 Total Suspended Solid (TSS)

Total Suspended Solid (TSS) test was conducted on all water samples collected from study area. The result of TSS test is presented in Table 1. TSS is a water quality parameter that measures the concentration of suspended particles in water [20]. These particles can include both organic and inorganic matter, such as silt, clay, plankton, industrial waste, and other particles that are too small or light to settle rapidly [21]. The result of TSS shown in Table 1 indicated an increase in TSS with the increase in the proximity of water source to the effluent and waste disposal point. The closest water sources i.e., WA and WC have higher TSS compared to other water sources especially WD and BHB. TSS of 10mg/L to 50 mg/L is considered moderate, 50 mg/L to 100 mg/L is considered to be high and above 100 mg/L is considered very high. Monitoring TSS is crucial for assessing water quality, as higher levels can have various environmental and health implications [22]. Therefore, it is evident that, TSS of water within the study zone is from high to very high due to abattoir activities.

3.2 Chemical Characteristics

The chemical characteristics of water is composition of various chemical substances present in water. These substances can include both natural components and those introduced through human activities [23]. Understanding the chemical characteristics of water is crucial for the assessment of water quality and ensuring its suitability for various uses

3.2.1 Chemical Oxygen Demand

Chemical Oxygen Demand (COD) is a water quality parameter that measures the amount of oxygen required to chemically oxidize both organic and inorganic substances in water. It is a crucial indicator of the overall pollution level in water bodies, particularly the presence of substances that can be oxidized by strong chemical oxidizing agents. This test was conducted on all water samples collected from various sources in the study area. The result of COD test is presented in Table 2.

Table 2: Result of chemical characteristics of water samples

S/N	Parameter	UNIT	WA	WB	WC	WD	BHA	BHB	WHO Standard	Nigerian Standard
1	COD	Mg/L	140	130	170	120	125	110	-	-
2	pH		7.73	7.87	7.89	7.19	7.13	6.95	6.6 – 8.5	6.5 – 8.5
3	DO	Mg/L	38	30	34	30	30	30	-	-
4	Chloride	Mg/L	35.5	32	31.5	15	38.5	38	250	250

From Table 2, the amount of COD in the different waters from various sources indicated a trail in which the closer source to effluent and waste disposal point the higher the COD. The highest COD of 170mg/L is recorded for WC which is 15.4m away from abattoir's effluents and waste disposal point. Although there is no WHO's COD limit, but high COD levels indicate a greater amount of organic and oxidizable inorganic substances in the water, suggesting higher pollution. COD of 10mg/L to 50 mg/L is considered moderate, 50 mg/L to 100 mg/L is considered to be high and above 100 mg/L is considered very high. Therefore, ground

water in this area has very high COD which indicate very high organic pollutants in the water. The test does not differentiate between biodegradable and non-biodegradable organic matter, making it a useful indicator of the total oxygen demand but not specific to the type of pollutants.

3.2.2 pH Characteristics

pH test was conducted on all water samples collected from the study area. pH is a measure of the acidity or alkalinity of water. It is an important parameter in water quality assessment as it can influence various chemical and

biological processes [24]. The result for pH test is presented in Table 2, the result shows that waters from all sources satisfied WHO standard for drinking water in terms of pH. But a careful observation indicated an increase in basicity with the increase in proximity of water source to the effluents and waste disposal point. The increase of basicity is attributed to the chemical compounds induced by the abattoir activities [25]. Compounds such as bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), and hydroxide (OH^-) ions are responsible for degree of basicity of water [26], the compounds may be originated from the composition of abattoir effluents which can be influenced by the breakdown of organic matter, including animal tissues and blood. As organic matter decomposes, it can contribute to changes in the chemical composition of the effluent, including the production of bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), and hydroxide (OH^-) ions [27].

3.2.3 Dissolve oxygen

Dissolve oxygen is another parameter investigated in this study. The result is also presented in Table 2. Dissolved Oxygen (DO) is a crucial parameter in water quality assessment, and it refers to the amount of oxygen dissolved in water. The concentration of dissolved oxygen is essential for the survival of aquatic organisms and is indicative of the overall health of water bodies [28]. Dissolved oxygen (DO). From Table 2, the dissolved oxygen concentration appears to be constant among the other water sources apart from the closest sources i.e., WA and WC. The higher DO in WA and WC may be attributed to the limited bacterial decomposition on the abattoir effluent, therefore less oxygen is consumed [29], contributing to higher DO levels which is reflected on the groundwater source closer the effluent disposal point.

3.2.4 Chloride test

Chloride test was conducted on all water samples collected for this study. Chloride (Cl^-) is an essential component in water, and its presence is natural. However, elevated chloride levels can have various effects on water quality and its suitability for specific uses. Table 2 contains the result of chloride test conducted in this study. From table 2, all the water samples have a very low chloride content therefore it is very safe for drinking in terms of chloride content. Low chloride levels reduce the corrosivity of water, helping to prevent corrosion of metal pipes, plumbing fixtures, and infrastructure [30].

3.3 Biological Characteristic

3.3.1 Biological Oxygen Demand

Biological Oxygen Demand (BOD) test was conducted on all water samples collected in this study. Biochemical Oxygen Demand is a key parameter used to measure the amount of dissolved oxygen that is consumed by microorganisms in the biological decomposition of organic matter in water. BOD is an important indicator of water quality, particularly in assessing the level of organic pollution. The result of BOD test is presented in Table 3, from the result WA has higher BOD. High BOD levels suggest a significant presence of biodegradable organic pollutants, potentially leading to oxygen depletion and

negatively impacting aquatic ecosystems affects human lives [31]. Other sources have low to moderate BOD level. WB, WD and BHB has moderate BOD level which signifies moderate pollution. WB and BHB have low BOD level, this suggests that the water contains a relatively small amount of biodegradable organic matter, indicating good water quality [32].

Table 3: Biological Oxygen Demand

Parameters	BOD mg/L
WA	10.0
WB	2.0
WC	4.0
WD	0.0
BHA	4.0
BHB	2.0

4. Conclusion

The aim of this study is to determine the effect of abattoir effluents on the quality of ground water. The aim was achieved through the experimental tests conducted on water samples in the laboratory. The following conclusions are drawn.

The result of physical characteristics indicated TSS range of 60 – 240mg/L, TDS of 88.6 to 173.1mg/L and turbidity of 3.85 to 9.4NTU. These values were found to be high in almost all the water samples, therefore it poses serious concern about the health of people that uses the ground water for drinking and other domestic uses. Chemical characteristics investigated also shows a similar pattern in terms of COD which was found to be between 110 to 170mg/L, the higher concentration of COD pose serious health hazard to people living surround the abattoir.

Biological Oxygen Demand also shows higher concentration of 10mg/L for water sources closer to the effluent disposal point. This indicates presence of biodegradable pollutants in the water which also pose health risk to the dwellers of Tudun Shanu area in Zaria due to the abattoir activities. Therefore, it is pertinent for the relevant authorities to impose strict measures to ensure abattoir effluent water is treated prior discharge in to water bodies.

Reference

- [1]. Bijekar, S., Padariya, H. D., Yadav, V. K., Gacem, A., Hasan, M. A., Awwad, N. S. and Jeon, B. H. (2022). The state of the art and emerging trends in the wastewater treatment in developing nations. *Water*, 14(16), 2537.
- [2]. Elemile, O. O., Raphael, D. O., Omole, D. O., Oloruntoba, E. O., Ajayi, E. O. and Ohwavorua, N. A. (2019). Assessment of the impact of abattoir effluent on the quality of groundwater in a residential area of Omu-Aran, *Nigeria. Environmental Sciences Europe*, 31(1), 1-10.
- [3]. Akankali, J. A., Davies, I. C. and Tambari-Tebere, A. (2022). Pollution Impacts of Abattoir and Associated Activities Wastes on The Water Quality of Eagle Island Creek, Niger Delta, Nigeria. *International Journal of Contemporary Applied Researches*, 9(2), 63-85.

- [4]. Mishra, R. K. (2023). The effect of Eutrophication on Drinking Water. *British Journal of Multidisciplinary and Advanced Studies*, 4(1), 7-20.
- [5]. Ahmad, F., Pathak, V., & Singh, A. (2023). Effect of slaughterhouse waste on sewage channel. *World Journal of Advanced Research and Reviews*, 19(3), 1227-1236.
- [6]. Usman, M., Sameen, A., Khan, M. I., ur Rahman, U., Khan, U. M., Anwar, S. and Sahar, A. (2022). Treatment of Fatty Effluents. In *Food Processing Waste and Utilization* (pp. 89-115). CRC Press, Boca Raton Florida.
- [7]. Nandomah, S., and Tetteh, I. K. (2023). Potential ecological risk assessment of heavy metals associated with abattoir liquid waste: A narrative and systematic review. *Heliyon*, 9(8), 1-10.
- [8]. Abanyie, S. K., Apea, O. B., Abagale, S. A., Amuah, E. E. Y. and Sunkari, E. D. (2023). Sources and factors influencing groundwater quality and associated health implications: A review. *Emerging Contaminants*, 100207.
- [9]. Yahaya, S. M., Mahmud, A. A. and Abdu, N. (2023). The use of wastewater for irrigation: pros and cons for human health in developing countries. *Total Environment Research Themes*, 100044.
- [10]. Ogun, M. L., Anagun, O. S., Awote, O. K., Oluwole, S. O., Kappo, S. C. and Alonge, F. O., (2023). Abattoirs: The Hidden Sources of Plants' Heavy Metals and Other Pollutants in Lagos, Nigeria.
- [11]. Kontogeorgis, G. M., Holster, A., Kottaki, N., Tsochantaris, E., Topsøe, F., Poulsen, J. and Kronholm, J., (2022). Water structure, properties and some applications—A review. *Chemical Thermodynamics and Thermal Analysis*, 6, 100053.
- [12]. Chitrakshi, and Haritash, A. K. (2022). Appraisal of hydrochemistry and suitability assessment for water in an agriculture-dominated aquatic ecosystem of Rajasthan, India. *Rendiconti Lincei. Scienze Fisiche e Naturali*, 33(4), 851-866.
- [13]. Luvhimbi, N., Tshitangano, T. G., Mabunda, J. T., Olaniyi, F. C. and Edokpayi, J. N., (2022). Water quality assessment and evaluation of human health risk of drinking water from source to point of use at Thulamela municipality, Limpopo Province. *Scientific Reports*, 12(1), 6059.
- [14]. García-Avila, F., Loja-Suco, P., Siguenza-Jeton, C., Jiménez-Ordóñez, M., Valdiviezo-Gonzales, L., Cabello-Torres, R. and Aviles-Anazco, A. (2023). Evaluation of the water quality of a high Andean Lake using different quantitative approaches. *Ecological Indicators*, 154, 110924.
- [15]. Mukhopadhyay, A., Duttgupta, S. and Mukherjee, A., (2022). Emerging organic contaminants in global community drinking water sources and supply: A review of occurrence, processes and remediation. *Journal of Environmental Chemical Engineering*, 10(3), 107560.
- [16]. [Wang, Y., Zhou, B., Chen, H., Yuan, R. and Wang, F., (2022). Distribution, biological effects and biofilms of microplastics in freshwater systems-a review. *Chemosphere*, 299, 134370.
- [17]. Sanchez, R., Groc, M., Vuillemin, R., Pujo-Pay, M. and Raimbault, V., (2023). Development of a Frugal, In Situ Sensor Implementing a Ratiometric Method for Continuous Monitoring of Turbidity in Natural Waters. *Sensors*, 23(4), 1897.
- [18]. Alum, E. U., Uti, D. E., Agah, V. M., Orji, O. U., Ezeani, N. N., Ugwu, O. P. and Itodo, M. O., (2023). Physico-chemical and bacteriological analysis of water used for drinking and other domestic purposes in Amaozara Ozizza, Afikpo North, Ebonyi State, Nigeria. *Nigerian Journal of Biochemistry and Molecular Biology*, 38(1), 1-8.
- [19]. Segaran, R., Jusoh, M. and Rosli, A., (2022). Major Ion Concentration Analysis and Evaluation of Malaysian-Sourced Groundwater for Drinking Water. *Chemical Engineering Transactions*, 97, 469-474.
- [20]. Putri, A. I. and Arisalwadi, M., (2023). Analysis of The Influence Between Turbidity Value on Total Suspended Solid (TSS) Value At The River Water Surface In Kutai Kartanegara. *Frontier Advances in Applied Science and Engineering*, 1(1), 14-20.
- [21]. Adjovu, G. E., Stephen, H., James, D. and Ahmad, S., (2023). Measurement of total dissolved solids and total suspended solids in water systems: a review of the issues, conventional, and remote sensing techniques. *Remote Sensing*, 15(14), 3534.
- [22]. Lemessa, F., Simane, B., Seyoum, A. and Gebresenbet, G., (2023). Assessment of the Impact of Industrial Wastewater on the Water Quality of Rivers around the Bole Lemi Industrial Park (BLIP), Ethiopia. *Sustainability*, 15(5), 4290.
- [23]. Darko, G., Obiri-Yeboah, S., Takyi, S. A., Amponsah, O., Borquaye, L. S., Amponsah, L. O. and Fosu-Mensah, B. Y., (2022). Urbanizing with or without nature: Pollution effects of human activities on water quality of major rivers that drain the Kumasi Metropolis of Ghana. *Environmental Monitoring and Assessment*, 194(1), 38.
- [24]. Zhu, X., Wang, L., Zhang, X., He, M., Wang, D., Ren, Y. and Pan, H., (2022). Effects of different types of anthropogenic disturbances and natural wetlands on water quality and microbial communities in a typical black-odor river. *Ecological Indicators*, 136, 108613.
- [25]. Bazrafshan, E., Zakeri, H. R., Vieira, M. G. A., Derakhshan, Z., Mohammadi, L., Mohammadpour, A. and Mousavi Khaneghah, A., (2022). Slaughterhouse Wastewater Treatment by Integrated Chemical Coagulation and Electro-Fenton Processes. *Sustainability*, 14(18), 11407.
- [26]. Abbas, Q., Shakoar, A., Naushad, M. and Yousaf, B., (2022). In-situ oxidative degradation of sulfamethoxazole by calcium peroxide/persulfate dual oxidant system in water and soil. *Process Safety and Environmental Protection*, 164, 696-705.
- [27]. Haritash, D., (2018). Assessment of water quality of Siliserh Lake in Alwar, Rajasthan Doctoral dissertation, Delhi Technological University.
- [28]. Mandape, S. M. and Kamdi, R. R., (2022). Diversity of Aquatic Insect as a Bioindicator with Water

- Quality Parameters of Selected Wainganga River Basin Areas of Pauni, District Bhandara, (Ms). *International Journal of Research in Bioscience and Agricultural Technology*, 10(2), 80-86.
- [29]. Rathi, B. S., Kumar, P. S., Rangasamy, G., & Rajendran, S. (2024). A critical review on Biohydrogen generation from biomass. *International Journal of Hydrogen Energy*, 52, 115-138.
- [30]. Beliveau, B., (2022). Investigating Lead Corrosion in Drinking Water Systems, Doctoral dissertation, Worcester Polytechnic Institute.
- [31]. Rasheed, F. A., (2022). Influence of organic pollution strength from Sulaymaniyah municipal wastewater on the water quality of Tanjero River. *Arabian Journal of Geosciences*, 15(10), 989.
- [32]. Liu, B., Jun, Y., Zhao, C., Zhou, C., Zhu, T. and Shao, S., (2023). Using Fe (II)/Fe (VI) activated peracetic acid as pretreatment of ultrafiltration for secondary effluent treatment: Water quality improvement and membrane fouling mitigation. *Water Research*, 244, 120533.
- [33]. Segaran, R., Jusoh, M. and Rosli, A., (2022). Major Ion Concentration Analysis and Evaluation of Malaysian-Sourced Groundwater for Drinking Water. *Chemical Engineering Transactions*, 97, 469-474.
- [34]. Ogun, M. L., Anagun, O. S., Awote, O. K., Oluwole, S. O., Kappo, S. C. and Alonge, F. O., (2023). Abattoirs: The Hidden Sources of Plants' Heavy Metals and Other Pollutants in Lagos, Nigeria.
- [35]. Usman, M., Sameen, A., Khan, M. I., Rahman, U., Khan, U. M., Anwar, S. and Sahar, A., (2022). Treatment of Fatty Effluents. In Food Processing Waste and Utilization (pp. 89-115). CRC Press, Boca Raton, Florida.
- [36]. Wang, Y., Zhou, B., Chen, H., Yuan, R. and Wang, F., (2022). Distribution, biological effects and biofilms of microplastics in freshwater systems-a review. *Chemosphere*, 299, 134370.
- [37]. World Health Organization, (2022). Guidelines for drinking-water quality: incorporating the first and second addenda. World Health Organization, Geneva.
- [38]. Yahaya, S. M., Mahmud, A. A. and Abdu, N., (2023). The use of wastewater for irrigation: pros and cons for human health in developing countries. *Total Environment Research Themes*, 100044.
- [39]. Zhu, X., Wang, L., Zhang, X., He, M., Wang, D., Ren, Y. and Pan, H., (2022). Effects of different types of anthropogenic disturbances and natural wetlands on water quality and microbial communities in a typical black-odor river. *Ecological Indicators*, 136, 108613.