



Environmental Assessment of Abattoir Effluents on Physicochemical and Heavy Metal Profiles of Soil in Abraka, Delta State, Nigeria

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ABSTRACT

This study was carried out to assess the physicochemical and heavy metals profiles from abattoir effluents impacted soils in Abraka, Delta State, Nigeria. This study provides baseline data on soil contamination with abattoir effluents in Abraka, contributes to environmental monitoring and pollution control efforts, supports public health protection by identifying potential exposure risks and It informs policymakers and environmental agencies on the need for improved waste management. The bulk soil sample was collected from two different abattoir sites in Abraka, using soil auger. The samples were air dried for 5days, crushed, sieved using 2mm mesh and stored in a container before analysis. An Atomic Absorption Spectrophotometer (ASS) was used to determine the concentration of the heavy metals, while the physicochemical profile was determined following standard methods. The results established that soil physicochemical parameters were influenced by abattoir effluents. From the results Fe (0.45 mg/kg), Co (0.30 mg/kg), Pb (0.05 mg/kg), Zn (0.04 mg/kg), Cr (0.03 mg/kg), Ni (0.02 mg/kg), Cd (0.02 mg/kg) and As (0.01mg/kg), all the values were below the WHO permissible limits except Iron (Fe) which shows highest concentration. Indicating that they are in safe range. The study also maintained that the continuous discharge of untreated abattoir wastes into the environment may result in the alteration of soil physical and chemical parameters as well as increase of these metals which may cause several health risks, ecological risks and reduce crop yield and productions. The current study has great implications in environmental degradation and primary treatment unit.

CITATION

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INTRODUCTION

Environmental pollution is an effect caused by undesirable changes in the natural environment that have a harmful impact on animals, plants and humans. Pollutants can exist in three forms; liquids, solids or gases. A substance becomes a pollutant when its concentration exceeds its natural abundance, which are caused either by human

activities or by natural phenomena (Khasanova *et al.*, 2023; Agbogidi *et al.*, 2025). Abattoir effluents are known to alter soil physicochemical properties and are sources of heavy metals.

Heavy metals are referred to as metals that occur naturally and have an atomic number higher than 20. Heavy metals have an atomic weight greater than 63.5 and a specific

gravity higher than 5.0g/cm^3 and can be hazardous to human health and the environment at high concentrations (Chukwu and Gulser, 2025). They are a significant class of contaminants that affect the environment. Heavy metals may occur from natural processes (weathering of minerals, erosion, biogenic source, volcanic activities) and anthropogenic processes (Pesticides, steel industries, coal combustion, effluent, ore mining, insecticide and herbicides) and end up in various environmental compartments (soil, water, air and their interface) (Ali *et al.*, 2021).

An abattoir is a facility mainly designed to carry out the inspection of animals, the sanitary slaughtering, processing, and proper preservation, and storage of meat products for human consumption. Abattoirs aim to improve the efficiency with which consumable parts of the meat processing cycle are recovered for human consumption (Ogun *et al.*, 2023). Abattoir operations generate different types of highly organic waste at different levels involved in the process right from animal arrival to meat packaging. The Abattoir facility has various waste and waste generation points and handling options which act as contaminants. The environment hence, is a high risk of environmental pollution like underground water pollution, air pollution, nuisance, odour, soil pollution, and public health risks through the transmission of zoonotic diseases to humans (Joachim *et al.*, 2022). The logging of abattoir effluent in the soil result to the depletion of the available oxygen in the soil (Ja'afaru *et al.*, 2021). Various organs of cattle such as muscle, blood, liver, kidney, viscera and hair have been found to contain heavy metals such as Lead (Pb), Copper (Cu), Iron (Fe), Arsenium (As) and Chromium (Cr). When untreated abattoir effluent or waste water are discharged into the environment and soil in particular, they alter the pH and other physicochemical properties of the soil (Ja'afaru *et al.*, 2021).

Soils contaminated by heavy metals can lead to uptake by crops, introducing metals into the food chain. Heavy metals can alter microbial communities in soil, suppressing beneficial bacteria and fungi essential for nutrient cycling. Cd and Pb, in particular, reduce microbial biomass and enzyme activity (Agbogidi *et al.*, 2025; Udo *et al.*, 2025). When untreated abattoir effluent or waste water are discharged into the environment and soil in particular, they alter the pH and other physicochemical properties of the soil (Ja'afaru *et al.*, 2021). Soils contaminated by heavy metals can lead to uptake by crops, introducing metals into the food chain. Heavy metals can alter microbial communities in soil, suppressing beneficial bacteria and fungi essential for nutrient cycling. Cd and Pb, in particular, reduce microbial biomass and enzyme activity (Agbogidi *et al.*, 2025; Udo *et al.*, 2025; Agbogidi *et al.*, 2026).

Ogun *et al.* (2024) noted that abattoirs are hidden sources of plant heavy metals and other pollutants in Lagos,

Nigeria. Ogun *et al.* (2024) further maintained that abattoir wastes contain heavy metals which are acquired by plant through bioaccumulation, biomagnification, bioconcentration and remain persistent via food chain in the ecosystem. Abattoirs are major contributors of soil pollution with Lead, Nickel, Zinc, Manganese, Copper, Chromium, Cobalt and Cadmium especially in urban areas. Abattoirs pollutants which negatively impact ecosystems and biota Abattoir effluent contains Ca, Mg, Na, Cl, oxidisable substance, sulphate, Total Dissolved Solid (TDS) and acidic pH. It increased nutrient availability and influences plant growth and development. Water quality changes due to abattoir effluent. It also influences soil properties. It is against this back that a study on the environmental assessment of abattoir effluent on soil physicochemical and heavy metal has been embarked upon with a view to provide baseline information to the preurban area of Abraka, Delta State, a hub for academic institutions.

MATERIALS AND METHODS

Study area: The study site is Abraka, Delta State, Nigeria. Abraka is located within latitudes $5^{\circ}45'$ and $5^{\circ}50'N$ of the equator and longitude 6° and $6^{\circ}15'E$ of the Greenwich meridian.

Sample collection: Abattoir soil samples were collected from two (2) different abattoir locations, from Urhuoka and NUT respectively in Abraka, Delta State, Nigeria using soil auger. The two soil samples were mixed together to form bulk or composite samples. The abattoir soils were collected at the spot where the waste water are discharged.

Sample preparation: The samples were air-dried at room temperature for 5 days to remove moisture content. Stones, plant roots, and other debris were manually removed from the samples. The dried soil samples were gently crushed using a mortar and pestle to obtain uniform particle size. The samples were then sieved through a 2 mm mesh sieve to remove coarse particles. The prepared samples were stored in clean labeled containers pending for physicochemical and heavy metal analyses using a Varian AA240 Atomic Absorption Spectrophotometer following the procedure outlined by the American Public Health Association (APHA, 2022).

Heavy metal determination: Heavy metals like Pb, Cd, Fe, Zn, Co, Cr, Ni, and As was determined. 1g of each sample was digested in aqua regia for 5 days. The resulting extract was then centrifuged at 30,000 rpm for 15 minutes, and the heavy metal content was determined using calibration curves generated from standard metal solutions in an identical acid matrix, optimized for atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Table 1 presents the physicochemical parameters of abattoir effluents in Abraka, Delta State, Nigeria. While Table 2 shows the heavy metals in the sample. The

observed values were compared of both the physicochemical and heavy metal were compared with the recommended limit as established by the WHO (2025).

Table 1: Physicochemical parameters of abattoir effluents contaminated soils in Abaraka, Delta State, Nigeria

S/N	Soil properties	Physicochemical parameters	Resulted value	WHO/ FAO Permissible limit
1	Textual class		Sandy loam	
2	Sand (gkg ⁻¹)		77.20	
3	Clay (gkg ⁻¹)		10.0	
4	Silt (gkg ⁻¹)		11.0	
5		Electrical conductivity (µs/cm)	0.20	<1000
6		pH	6.90	6-9
7		Available phosphate (ppm)	8.60	0-5
8		Nitrogen (N) %	0.70	
9		Nitrate (NO ₃) (mg/kg)	80.00	40-50
10		Organic carbon (%)	1.65	1.724
11		Phosphorus (P) (mg/kg)	59.30	<50
12		Calcium (Ca) (mg/kg)	5.81	<150
13		Magnesium (Mg) (mg/kg)	4.20	<4.50
14		Moisture content (%)	14.60	N/A
15		Water holding capacity (%)	51.60	N/A
16		Sodium (Na) (mg/kg)	0.18	<4.5
17		Chloride (Cl) (mg/kg)	12.30	200
18		Temperature (°C)	29-61	30

Source: Laboratory analysis

Table 2: Concentration of heavy metals (mg/kg) in abattoir effluent-impacted soil samples in Abraka, Delta State, Nigeria

S/N	Heavy metals	Abattoir soil sample (mg/kg)	WHO Permissible limit
1	Pb	0.05	0.117
2	Cd	0.02	0.48
3	Fe	0.45	0.01
4	Zn	0.04	0.60
5	Co	0.30	1.00
6	Cr	0.03	1.30
7	Ni	0.02	0.05
8	As	0.01	1.00

Source: Laboratory analysis

The result shows that the soil is predominantly Sandy (69.0%), Clay (20.0%) and Silt (11.0%). The analysed soil is a textual class of sandy loamy with amost a more or less neutral pH of 6.90 and slightly acidic, which provides a suitable pH condition for plant growth and development and also favourable to microbia activities (Agbogidi *et al.*, 2026). Nitrate NO₃⁻ recorded a concentration of 80mg/kg, which is higher than than the WHO permissible limit of 40-50mg/kg. This increase may be due to large discharge of animal blood, urines, feaces into the soil (Sani *et al.*, 2020) had similar findings. This could pose serious health risks and cause groundwater contamination. Increasing the concentration of nitrate in groudwater have led to serious

health risks such as birth defects, cancer methenoglobinemia (Singh *et al.*, 2025). Phosphorus which is an essential nutrient supporting respiration, stroage and transfer of energy, also recorded a concentration of 59.30mg/kg which is higher than WHO permissible limit of <50mg/kg, which is in line with Sani *et al.* (2020). According to Ebong *et al.* (2020), the increase of nutrients like phosphorus in soil originate from discharge of organic contents like blood, fat, faece and undigested foods into the soil. The main components of soil organic matter is soil organic carbon, which is an essential ingredient of healthy soil. The result also shows that the concentration of organic carbon is 1.65% which is slightly close to the WHO permissible limit of 1.724%, is still fit for

agricultural practices. Continuous discharge of abattoir effluents will elevate the concentration of organic carbon and pose environmental risks (Agbogidi, 2026).

Electrical conductivity recorded a concentration of 0.20us/cm which is below the WHO permissible limit of <1000us/cm. According to Abasi *et al.* (2024), the presence of soluble salts in abattoir effluents and the dissociation of ions in these salt can elevate the concentration of electrical conductivity of soil. Table 1 shows that there is very low salinity in the soil.

Sodium (Na) and Chloride (Cl) record a low concentration of 0.18mg/kg and 12.30mg/kg which falls below WHO permissible limit of <4.5mg/kg and 200mg/kg. The low concentration of sodium and chloride shows that there is low salt and chloride pollution, because the soil has a textual class of sandy loam, which rainwater can carry soluble sodium deeper into the soil profile due to the porosity of the soil.

The findings from the analysis shows with the physicochemical and heavy metal levels in soils were moderately within the WHO minimum permissible limit for soil standards except iron (Fe), which shows high concentration (0.45 mg/kg) above WHO limit. This record is similar to Ja'afaru *et al.* (2021) and Taiwo *et al.* (2025) studies. These findings unequivocally demonstrate that contamination driven by abattoir activities compromises agricultural integrity and, by extension, poses a severe threat to public health and food safety (Ezeomodo and Okafor, 2025).

Iron (Fe) recorded the highest concentration of 0.45 mg/kg among all the analyzed metals from abattoir soil and exceeded the WHO permissible limit of 0.01 mg/kg. The increase concentration of iron may result from large discharge of animal blood, organic wastes, and wastewater generated from abattoir operations. According to Bhat *et al.* (2024), Iron (Fe), is a key essential micronutrient required by organism for their cellular processes such as respiration, photosynthesis, etc., and also functions as a cofactor for the enzymes of vital metabolic pathways. Excessive iron uptake can triggers toxicity, which damages plant cell membranes, stunts growth, and severely reduces crop yield and overall vitality (Harish *et al.*, 2023).

High increase was also observed in Cobalt (Co) with a concentration of 0.30 mg/kg, which was below the WHO permissible limit of 1.00 mg/L. This shows that cobalt contamination in the soil is within WHO acceptable levels and may not pose immediate environmental impact. Cobalt at high concentrations in plants are noxious and causes several damages to plant physiological and biochemical functions (Khalid *et al.*, 2023). As reported by Khan *et al.* (2023) that cobalt (Co) are present in animal blood, the continuous discharge of animal blood into the environment elevates the concentration of cobalt in soil. High Cobalt (Co) toxicity in soil limits the net

photosynthesis process in plant, decrease the iron containing enzyme activity, disrupt the structural integrity of chloroplasts and also affect the availability of essential nutrients in soil (Khalid *et al.*, 2023).

Further findings also shows that Lead (Pb) concentration 0.05 mg/kg falls below the permissible limit of 0.117 mg/L which is in line with Agbogidi *et al.* (2025) report. This suggests that lead contamination in the abattoir site is relatively low due to low discharge of bone to the environment and may not presently pose serious environmental risks or health problem. According to Nandomah and Tetteh (2023), Pb is builds up in the bone marrow where red blood cells are made. However, continuous discharge of abattoir effluents into the soil and environment could lead to gradual accumulation over time which will increase the concentration of lead. Pb exposure can induces neurological, respiratory, urinary, and cardiovascular disorders due to immune modulation, oxidative, and inflammatory mechanisms (Balali *et al.*, 2021).

Zinc (Zn) concentration was 0.04 mg/kg, which was below the WHO permissible limit of 0.60 mg/kg. These shows that the concentration of zinc in the soil has less effect to the soil as reported by Babagana *et al.* (2025), that low zinc concentration suggests waste generated from abattoir operation has caused minimal contamination in soil. Zinc is a vital trace element for flora and fauna growth, however, excessive accumulation of zinc in soil trigger significant environmental degradation, which will result in reduction of soil fertility and potential toxicity to both plants and microorganisms (Van and Nga, 2024). It is reported that zinc is a trace element which is important for man's well being and excess accumulation in soil can have detrimental effects on plant growth and human nutrition (Van and Nga, 2024).

Chromium (Cr) concentration was 0.03 mg/kg, which was far below the WHO permissible limit of 1.30 mg/kg which is similar Ebong *et al.* (2020). The low concentration of Chromium (Cr) observed in this study may be as result of less discharge of animal hides and skins, as reported by Sharma *et al.* (2021) that of tannery effluent such as animal hides and skin are major source of toxic heavy metals like Chromium (Cr) in the environment. According to Xu *et al.* (2022), HCrO_4 and CrO_4^{2-} are the most common Cr compounds found in soil which plant can easily absorb and also contaminate the soil. Xu *et al.* (2022) further noted that the presence of Cr in plant at high concentration can affect plant growth, root cell and development of plant tissues. Plants absorb Cr using their root system, Cr are moved to the various parts of the plant alongside with essential nutrients, which affect the growth of stems, leaves and other reproductive part of plant. High concentration of Cr leads to wilting of root cell, plasmid wall separation and induce a high frequency of chromosomal aberration in root tip cells. It also reduce the

volume and the number of root cells and it also inhibit root cell division and differentiation (Xu *et al.*, 2022). Exposure to chromium has been identified as a cause of allergic dermatitis in humans (Elemile *et al.*, 2019).

Nickel (Ni) recorded a concentration of 0.02 mg/kg, which was below the WHO permissible limit of 0.05 mg/kg which also tallies with the reports of Ameh *et al.* (2026). This low concentration may due less anthropogenic source of nickel in the abattoir vicinity, as reported by Baba *et al.* (2020) that the anthropogenic source of nickel is scrap metal waste, example stainless steel. Nandomah and Tetteh (2023) also noted that animal obtain nickel by feeding on Ni-containing feeds and water, and the metal finds its way into abattoir effluent through excretion and egestion. Although the concentration is low, prolonged accumulation of nickel in soil may become harmful to plants and humans. Elemile *et al.*, 2019 reported that when the concentration of nickel exceed the permissible limit, it become a major source of cancer. It has been reported that the polluting agricultural soils with Ni, increases it's presence in terrestrial ecosystems and food production systems posing a threat to both food security and safety (Rizwan *et al.*, 2024). Hayyat *et al.* (2020) also reported that high concentration of Ni becomes phytotoxic and causes change in some plants antioxidant enzymes activity such as SOD (superoxide dismutase), APX (Ascorbate peroxides) and CAT (Catalase). Hayyt *et al.* (2020) also noted that the symptoms of nickel toxicity in plant include growth inhibition, chlorosis, necrosis and wilting. Ni toxicity can inhibit seed germination and damage the cell membrane's functioning. Plants are the primary producers in food chain, accumulation of heavy metals such nickel from soil may pose a severe health risk to humans (Rizwan *et al.*, 2024).

Cadmium (Cd) had a concentration of 0.02 mg/kg, which was also below the WHO permissible limit of 0.48 mg/kg. The low concentration observed may be as a result of feeding animals with diet containing low amount of cadmium, Nandomah and Tetteh (2023) reported that mammals organs such as livers and kidneys houses most significant levels of cadmium when fed with Cd containing diets. Nandomah and Tetteh (2023) further maintain that plants assimilate and accumulate cadmium in soil in the food chain. Nevertheless, cadmium is highly toxic even at low concentrations and when accumulated by plants it enter into the food chain (Malik *et al.*, 2025). Udu *et al.* (2025) reported that if the observed concentration of cadmium is within acceptable limits, its presence is ecologically significant, but continuous deposition could increase bioavailable Cd and facilitate uptake by edible plants. Babagana *et al.* (2025) reported that abattoir effluents contain Cd and if the concentration levels exceed permissible limits, it can pose ecological and health risks. Arsenic was detected at a minimal concentration of 0.01mg/kg which is below the WHO permissible limit of

1.00mg/kg. This shows that arsenic concentration is within safety range in the soil. Arsenic (As) is one of the most toxic and cancer causing metals which is generally entered the food chain via intake of As contaminated water or food and harmed the life of living things especially human beings (Khan *et al.*, 2021). Generally, the study revealed that most of the heavy metals analyzed were within the permissible limits recommended by the World Health Organization, except iron (Fe), which exceeded the recommended limit. This suggests that abattoir activities contribute to heavy metal accumulation in the soil and may lead to environmental pollution if not properly managed. Continuous discharge of untreated abattoir effluents may increase the concentration of these metals over time, thereby posing risks to soil quality, plants, groundwater, and human health.

CONCLUSION

The findings from this work established that soil physicochemical parameters are significantly altered by abattoir effluents. Evidence of this research also shows that abattoir operations are major source of heavy metals. Although, all the observed values fall within WHO/FAO permissible limits, except few parameters. This research shows that disposal of untreated abattoir effluent into the environment will elevate the concentration of heavy metals in soil. If such contamination continues, it could result in pollution of environment, posing health risks to humans and animals, causing food chain contamination, degrading soil quality and result in toxicity to plants.

RECOMMENDATIONS

It is recommended that Abattoir effluents should be treated before being discharged into the environment to reduce the release of heavy metals and other pollutants into the soil in the same very modern waste management facilities, including wastewater treatment units and designated waste disposal sites, should be provided in abattoirs. Environmental monitoring by government agencies should be strengthened. The current study has great implications on environmental degradation, sustainability and public health conditions.

REFERENCES

- Abasi, C. Y., Aliene, O. G., Salvation, E. P., and Nimighaye, O. (2024). The impacts of abattoir waste on soil and water quality: a review. *International Journal of Research and Innovation in Applied Science*, 9(11): 72-83.
- Agbogidi, O.M., Chijindu, P.C., Egboduku, W.O., Kamalu, O.J., Okpewho, O.P. and Umukoro, B.O. (2025). Rudiments of soil science. Jef Ventures, Warri, Delta State, Nigeria. 385p.

- Agbogidi, O. M., Ogbe, O., and Usen, E. (2025). Physicochemical and metal profiles of soils as influenced by crude oil contamination in Abraka, Delta State, Nigeria. *World Journal of Applied Science and Technology*, 17(1): 65–70.
- Agbogidi, O. M. (2026). Conservation and management of natural resources (2nd ed.). Delta State University Printing Press. 118p.
- Ali, M. M., Hossain, D., Khan, M. S., Begum, M., and Osman, M. H. (2021). Environmental pollution with heavy metals: a public health concern. In *Heavy metals-their environmental impacts and mitigation*, pp. 1-96.
- Ameh, Y. A., Eneji, I. S., Wuana, R. A., and Itodo, A. U. (2026). Physicochemical characteristics and heavy metal distribution in agricultural soils of Nasarawa State, Nigeria. *Asian Soil Research Journal*, 10(2):60–77.
- American Public Health Association (APHA) (2022). Standard methods for the examination of water and wastewater (24th ed.). American Public Health Association publishers. Washington D.C. 1516p.
- Baba, A., Garba, S. T., and Bello, H. S. (2020). Bioremediation potential of immobilized *Corynebacterium kutscheri* in the treatment of tannery industrial effluent from Challawa Industrial Estate, Kano State, Nigeria. *Journal of the Turkish Chemical Society Section A: Chemistry*, 7(2):335-350.
- Babagana, M., Bako, A. U., Abdul-Azeez, U. M., and Bakari, A. (2025). Assessment of heavy metals, pollution indices, and physicochemical characteristics of borehole water from abattoir sites in Kaduna Metropolis, Kaduna State, Nigeria. *Dutse Journal of Pure and Applied Sciences*, 11(4):224-237.
- Bhat, M. A., Mishra, A. K., Shah, S. N., Bhat, M. A., Jan, S., Rahman, S., Baek, K.-H., and Jan, A. T. (2024). Soil and Mineral Nutrients in Plant Health: A Prospective Study of Iron and Phosphorus in the Growth and Development of Plants. *Current Issues in Molecular Biology*, 46(6):5194-5222.
- Chukwu, E. C., and Gulser, C. (2025). Morphological, physiological, and anatomical effects of heavy metals on soil and plant health and possible remediation technologies. *Soil Security*, 18:1-11.
- Ebong, G. A., Ettesam, E. S., and Dan, E. U. (2020). Impact of abattoir wastes on trace metal accumulation, speciation, and human health-related problems in soils within Southern Nigeria. *Air, Soil and Water Research*, 13:1-14.
- Egboduku, W.O., Udo, M.W., Obogbayiro, I.O., Michael, O., Okonigbo, B.D., and Agbogidi, O.M. (2025). Impacts of bakery effluents on the performance of maize (*Zea mays* L.) and soil physiochemical parameters in Abraka, Delta State, Nigeria. *Science World Journal*, 20(3):1231-1235.
- Elemile, O. O., Raphael, O. D., Omole, D. O., Oluwatuyi, O. E., Ajayi, E. O., Umukoro, O., and Elemile, M. G. (2019). Assessment of the impact of abattoir activities on the physicochemical properties of soils within a residential area of Omu-Aran, Nigeria. In *IOP Conference Series: Materials Science and Engineering*, 640(1):1-10.
- Ezeomodo, I.C. and Mmesoma, O.S. (2025). Effects of abattoir waste discharges on the soil quality of Kwata, Awka South L.G.A, Anambra State, Nigeria. *Journal of Sustainability and Environmental Management*, 4(3):155-164.
- Harish, V., Aslam, S., Chouhan, S., Pratap, Y., and Lalotra, S. (2023). Iron toxicity in plants: a review. *International Journal of Environment and Climate Change*, 13(8):1894-1900.
- Hayyat, M. S., Adnan, M., Awais, M., Bilal, H. M., Khan, B., and Rahman, H. A. (2020). Effect of heavy metal (Ni) on plants and soil: a review. *International Journal of Applied Research*, 6(7):313-318.
- Ja'afaru, M. I., Adeyemo, O. M., Okafor, C. H., and Bristone, P. (2021). Effects of abattoir effluents on heavy metal tolerance, bacteriological quality and physicochemical parameters of contaminated soil in Yola, Adamawa State, Nigeria. *Nigerian Annals of Pure and Applied Sciences*, 4(1):8-21.
- Joachim, T. A., Akande, I., and Oke, T. (2022). Abattoir waste management strategies in Nigeria: a case of Ota, Ogun state Nigeria. *International Journal of Scientific and Research Publications*, 12(8):84-92.
- Khalid, S., Shahid, M., Naz, R., Niazi, N. K., Al-Kahtani, A. A., ALOthman, Z. A., Fatima, R., and Murtaza, B. (2023). Cobalt in soil-plant-human system: a data-analysis review. *Preprints*, 23p.
- Khan, Z. I., Liu, W., Mubeen, I., Alrefaei, A. F., Alharbi, S. N., Muhammad, F. G., and Ugulu, I. (2023). Cobalt availability in the soil plant and animal food chain: a study under a peri-urban environment. *Brazilian Journal of Biology*, 83:1-11.

Khasanova, S., Alieva, E., and Shemilkhanova, A. (2023). Environmental pollution: types, causes and consequences. In *BIO Web of Conferences*, 63:1-7

Malik, I. S., Khan, Z. I., Ahmad, K., Nadeem, M., Akhtar, S., Ashfaq, A., and Ullah, S. (2025). Food chain risk assessment of cadmium accumulation and the relationships among diversely irrigated pasture-reared ruminants. *Scientific Reports*, 15(1):1-32.

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):1-19.

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. In *Heavy Metals-Recent Advances*, pp. 31-43.

Rashid, A., Schutte, B. J., Ulery, A., Deyholos, M. K., Sanogo, S., Lehnhoff, E. A., and Beck, L. (2023). Heavy metal contamination in agricultural soil: environmental pollutants affecting crop health. *Agronomy*, 13(6):15-21.

Rizwan, M., Usman, K., and Alsafran, M. (2024). Ecological impacts and potential hazards of nickel on soil microbes, plants, and human health. *Chemosphere*, 357:1-12.

Sani, A., Ahmad, M. I., and Abdullahi, I. L. (2020). Toxicity effects of Kano central abattoir effluent on *Clarias gariepinus* (Juveniles). *Heliyon*, 6(7):1-7.

Singh, A., Rudnick, D., Snow, D., Misar, C., Birru, G., Proctor, C., and Iqbal, J. (2025). Intra-and inter-annual variability of nitrogen and irrigation management effects on nitrate leaching and maize yield in the Bazile Groundwater Management Area, Nebraska. *Agriculture, Ecosystems and Environment*, 381:1-11.

Taiwo, B. A., Jelil, O., and Oluwafemi, S. Y. (2025). Environmental assessment of heavy metal contamination and physicochemical properties in abattoir wastewater. *GSC Advanced Research and Reviews*, 22(3):92-102.

Udo, M. W., Egbofuku, W. O., Okonigbo, B. D., Micheal, O., Obogbayiro, I. O., Domma, O. P., and Agbogidi, O. M. (2025). Heavy metal status of soils impacted with palm oil wastes in Abraka, Delta State, Nigeria. *FUDMA Journal of Sciences*, 9(12):59-62.

Van, H. T., and Nga, L. T. Q. (2024). Effects of Zn pollution on soil: pollution sources, impacts and solutions. *Results in Surfaces and Interfaces*, 17:1-9.

World Health Organization. (2025). *Fasciola: background document for the WHO guidelines for drinking-water quality and the WHO guidelines on sanitation and health* (No. WHO/HEP/ECH/WSH/2025.48). World Health Organization publishers, Geneva, 14p.