

EVALUATION OF ELEMENTAL CONTAMINATION LEVELS IN GROUNDWATER AND SOIL NEAR ANTHROPOGENIC SITES IN IBADAN, NIGERIA

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ABSTRACT

Waste disposal is a major challenge confronting and threatening the environment globally. Heavy metals can be found in almost all planetary surroundings, such as dumping sites and biological activities. Contaminated soil and groundwater with these metals have turned into a serious issue for the residents and agricultural experts in Ibadan, because of the damage and havoc caused to human life and agricultural products. The five different samples were obtained from different groundwater and soil sites and then analyzed for elements: Cadmium (Cd), Manganese (Mn), Nickel (Ni), Chromium (Cr), Zinc (Zn), Cobalt (Co), and Lead (Pb); after acid digestion using Atomic Absorption Spectrophotometer, while physicochemical parameters (pH and conductivity) were also determined in soil and water samples. The samples of soil were taken in triplex at 15 cm intervals in depth, while the samples of water were collected from different hand-dug wells below 15 m deep. The following ranges results (in mg/kg) were obtained for soil samples: Pb (0.04-0.08); Cr (0.05-0.08); Cd (0.02-0.05); Zn (0.54-4.49); Co (0.04-0.07); Mn (0.03-0.06) and Ni (0.06-0.13); while the pH ranged from (7.6-8.5); conductivity (406-683) uS/cm. The following values of results (in mg/L) were obtained for water samples: Pb (0.01-0.03); Cr (0.02-0.04); Zn (0.6-1.1); Co (0.01-0.04); Mn (0.01-0.06) and Ni (0.02-0.03), but Cd was not found, while pH ranged from (6.3-6.9) and conductivity (264-607) uS/cm. The concentrations of Mn, Ni, and Pb in groundwater collected from Sango and Moniya were above the WHO/SON permissible limits. The results revealed that the concentrations of Ni, Co, Pb, Cr, and Cd in soil were above the WHO/SON acceptable bounds. Also, Mn and Zn were lower than the bound.

Keywords: Dumpsite, Heavy metals, Soil samples, Groundwater samples.

INTRODUCTION

Waste disposal is a major challenge threatening and confronting the environment globally in elemental contamination of water, crops, and soils. Heavy metals simply mean metals with a specific gravity greater than 5 gcm⁻³. The major existing or popular heavy metals are arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), copper (Cu), iron (Fe), and nickel (Ni) (Bakshi *et al.*, 2018). Nickel and iron are required and important to all categories of living things at minimum concentrations (Bakshi *et al.*, 2018). Also, some elements like mercury, cadmium, and lead are very unpleasant to every living thing at any concentration, either in high or low concentrations. They contribute to metabolic abnormalities in life, specifically, consumers feed on crops and some different plants

grown from polluted soil (Bakshi *et al.*, 2018). In most cases, heavy metals exist naturally on the outer layer of the Earth with wide contrasts in concentrations. Also, the contamination from human impacts or anthropogenic activities has added to the great existence of elements in the ecosystem. The most common issue arises from environmental contamination of elements, mainly arriving from various sources like agricultural chemicals, mining activities, solid and liquid wastes, urban-industrial aerosols, and industries (Agbemafle *et al.*, 2019). Concentration of elements in the soil in the vicinity of anthropogenic sites is contributed by some factors such as: level of scavenging, runoff, types of waste, and topography (Liu *et al.*, 2020).

Waste disposal has been viewed as a major effect of modernization (Zu *et al.*, 2019). Because of rapid urbanization, demographic growth, and lifestyle change, waste is at a high level in the municipalities of developing nations (Umutesi *et al.*, 2018). This has turned into environmental contamination, categorically in growing nations where paramount achievements towards developed disposal practices and waste management haven't been established in higher states (Chen *et al.*, 2019). Generally, with the high impact of the developed technology in advanced nations, most community solid waste and wastewater are being collected and treated properly before being disposed of.

Human good health is associated with a healthy environment. The heavy metals present in some disposed materials in open anthropogenic sites are of great disturbance and dangerous to human beings in touch with the groundwater and soil polluted by improper disposal of waste management (Dashtey, 2024; Hu *et al.*, 2024). Waste disposal and its generation have been observed as major concerns of elemental pollution in the soil. There are so many steps suggested for disposing of waste that lead to the mixing of the waste and creating filtrate that relocates it to the soil and groundwater (Ekere *et al.*, 2017). The results of the breakdown of organic substances in community solid waste by micro-organisms result in toxic liquids called filtrate that comprises macro inorganic components, organic material, and elemental contaminants, both in the aquatic environment and soil (Wuana and Okieimen 2020). Similarly, dumpsites with leachate are not properly maintained in developing nations, and improperly managed filtration disperses, penetrates, and flows into the groundwater, thereby polluting the environs and the people in the surroundings of the dumpsite (Umutesi *et al.*, 2018; Kasan *et al.*, 2018). Apart from that, several dumpsites are moved close to the communities, and most waste is dropped carelessly without being mindful of or considering the major effects on the environment. More so, in some anthropogenic sites, refuse is set on fire at the sites, resulting in a harmful

environment (Zhang *et al.*, 2021).

Elemental waste consistently persists in the waste dumping, at a threat to the surrounding environment. This arises in environmental issues and harmful states due to the infecting implication of elements in plants and possible and conceivable health effects to animals and human beings' intake of those vegetables (Agbemafle, 2019). Immediately, elementals penetrate the soil; they cannot be degraded either chemically or biologically and can exist in the surroundings for a long time, so they result in major harmful effects and environmental contamination to the ecosystem, including bioaccumulation (Kasam *et al.*, 2018). There is a probability and a good chance of an additional issue with soil pollution affecting the penetration of hazardous heavy metals into the food chains across intake and consumption by plants and implicating food safety (Ozcan *et al.*, 2016). The stockpiling of heavy metals in groundwater and soil has a negative impact to the biological functions of plants like nutrient absorption, photosynthesis and gaseous exchange that arise in dry matter accumulation and plant growth reduction (Ozcan *et al.*, 2016).

The environmental contamination of heavy metals and health-associated impacts are together with the leading outcomes of health issues throughout the globe. For instance, the accumulation of heavy metals like lead (Pb) in the human system interferes with the working of mitochondria, therefore reducing inhalation and exhalation, and also leads to paralysis, constipation, eventual death, and swelling of the brain (Gupta *et al.*, 2019). As reported (Ali *et al.*, 2019), heavy metals like lead (Pb) are a major toxic element without any natural or organic role and have a negative influence on adolescents in serious ways. The condition is very sensitive in developing nations where environmental observation was not prioritized by the representatives or shareholders. The concentration of heavy metals in the surroundings is not only assigned to geographical factors, but also the activity of human adjustment and amendment considerably affects the nutrient composition of water, crops, and soils (Phothisansakul and Runguphan, 2017). There is an increase in production of industrial, municipal, and domestic waste due to industrial growth, water bodies without treatment, and those that are carelessly dumped in landfills (Umutesi *et al.*, 2018).

All the elementals present in the surroundings are of high ecological importance due to their harmfulness at some concentrations, moving material through non-degradable and food chains, which is accountable for their collection in the biosphere (Nieder and Benbi, 2023). The major raw material for feeding and nurturing people's wants for a good food supply and better surroundings is soil (Kumar *et al.*, 2024). Immediately, crops (plants) are germinated in the land contaminated with domestic and industrial waste, or the community can consume elements in the form of moveable particles from the solution of soil through foliar absorption or their roots. The bioaccumulation of those elements gets consumed in the roots, stems, fruits, grains, and leaves of crops (Guerrieri *et al.*, 2024). Most elements, such as Pb, Hg, As, and Cd, are highly toxic and poisonous to humans, animals, and plants (Akter *et al.*, 2023). In anthropogenic sites, the community wastes are comprised of elements like: Mn, Cd, Zn, Ni, Pb, Cu, Hg, Co, and Fe that finally settle in the soil as they submerge when they are filtered out from the anthropogenic sites (Akter *et al.*, 2023; Maphuhla and Oyedeji, 2024).

STUDY AREA

Some dumpsites (5) situated within three Local Government Areas in Ibadan with longitude and latitudes: Ibadan north (Sango dumpsite on 7°39'N and 3°57'E), Ido (Apete on 7°26'N and 3°49'E), Ido (Ologuneru on 7°32'N and 3°54'E), Ibadan north (Eleyele dumpsite on 7°28'N and 3°50'E) and Akinyele (Moniya on 7°55'N 3°91'E) were selected for this study.

MATERIALS AND METHODS

Soil and water sampling

The soil and groundwater were taken from different locations as an area of study. Fifteen soil samples were obtained in triplicate at different sites at depths of 15.0, 30.0, and 45.0cm using a calibrated soil auger, while five water samples were collected from a hand-hug well. Sterilized plastic jars were used to take the water samples directly for physicochemical parameters and Elemental analysis. The pH, conductivity, and temperature of the samples were recorded in situ with a pocket digital pH meter, conduct meter, and thermometer, respectively.

Soil analysis

The samples of soil obtained were immediately placed in fresh, labelled plastic bags and sealed tightly. All soil samples were transported to the laboratory before analysis.

The soil was spread out evenly on a labeled, clean nylon sheet positioned on a level plain, then air-dried in the laboratory at room temperature for seven days. After that, the soil was ground and later sieved on a 2mm mesh size; five (5) grams of the soil sample was put in a flat-bottom flask, 10 ml of nitric/perchloric acid, the ratio of 2:1, and put on a water bath at 105°C. Hydrochloric acid and distilled water, in a ratio of 1:1, were added to the mixture again for 30 minutes. The digested was then separated from the digester and filtered solution, then allowed to settle to room temperature. The cooled digest was washed into a standard volumetric flask, then filled up to the mark with added distilled water.

Assessment of the heavy metals (Ni, Zn, Co, Pb, Mn, Cd, and Cr) was done in an atomic absorption spectrophotometer AAS (Model 210), Buck Scientific, after calibration of the equipment with different standard concentrations.

Water Sample Analysis

Different water samples for heavy metals analysis were collected in 120 ml plastic bottles, which were thoroughly washed initially with detergent and rinsed with distilled water. The plastic containers were finally rinsed with 20% nitric acid (HNO₃) before sampling. The samples were preserved by adding 1.5 ml of concentrated HNO₃ to each liter of the sample. Digestion with HNO₃ was employed following AOAC (2003). The digested sample was analyzed using a Buck Scientific Model 210 Atomic Absorption Spectrophotometer AAS for the elements.

RESULTS AND DISCUSSION

Table 1: Physico-chemical properties and heavy metal concentrations in water samples

Location	pH	Conductivity (uS/cm)	Pb (mg/L)	Cr (mg/L)	D (mg/L)	Zn (mg/L)	Co (mg/L)	Mn (mg/L)	Ni (mg/L)
S1	6.8	342	0.03	0.03	N/D	1.1	0.04	0.06	0.03
S2	6.7	461	0.01	0.03	N/D	0.7	0.03	0.01	0.02
S3	6.9	432	0.01	0.02	N/D	0.8	0.01	0.04	0.02
S4	6.3	264	N/D	0.04	N/D	0.6	0.01	0.04	0.02
S5	6.8	607	0.02	0.03	N/D	0.9	0.04	0.06	0.03

Table 2: Results of physico-chemical properties and heavy metals concentrations in soil samples

Location	Dp (cm)	pH	Co (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Zn (mg/kg)	Co (mg/kg)	Mn (mg/kg)	Ni (mg/kg)
S1	1.5	7.9	49.6	0.07	0.07	0.04	65.06	0.03	0.09	0.09
S1	3.0	8.1	44.4	0.07	0.08	0.04	57.05	0.06	0.06	0.06
S1	4.5	8.2	41.1	0.08	0.07	0.04	79.04	0.06	0.07	0.07
S2	1.5	8.5	35.5	0.05	0.07	0.04	49.06	0.04	0.11	0.11
S2	3.0	8.5	40.6	0.06	0.08	0.05	80.05	0.05	0.12	0.12
S2	4.5	8.3	59.8	0.07	0.08	0.05	65.04	0.05	0.13	0.13
S3	1.5	8.1	48.7	0.06	0.08	0.04	70.04	0.03	0.09	0.09
S3	3.0	8.3	32.1	0.05	0.08	0.04	59.05	0.06	0.08	0.08
S3	4.5	8.3	41.8	0.06	0.08	0.04	65.05	0.06	0.08	0.08

S3	5.0	2.0	06.06	03.67	06.05	12.0	0.0	0.0	0.0	0.0
S4	5.9	7.7	53.07	05.04	79.07	05.15	0.0	0.0	0.0	0.0
S4	3.0	8.0	68.3	05.06	03.62	06.05	14.0	0.0	0.0	0.0
S4	4.5	7.8	42.06	05.04	54.05	04.08	0.0	0.0	0.0	0.0
S5	5.8	7.4	67.05	06.05	81.06	05.10	0.0	0.0	0.0	0.0
S5	3.0	8.1	51.06	06.04	80.05	06.09	0.0	0.0	0.0	0.0
S5	4.5	7.8	44.04	07.02	67.04	05.07	0.0	0.0	0.0	0.0

S-1 SANGO; S-2 APETE; S-3 OLOGUNERU; S4-ELEYELE; S5- MONIYA

Table 3: WHO and SON standards for physico-chemical properties and heavy metals concentrations

Standard	pH	Conduct	Pb	Cr	Cd	Zn	Co	Mn	Ni
WHO	6.5	1400	0.01	0.05	0.03	3.0	0.05	0.05	0.02
SON	6.5	1000	0.01	0.05	0.03	3.0	0.05	0.05	0.02

The water samples of the pH proved that it is a little or moderately acidic, then it falls in the range of WHO/SON acceptable limits, apart from L4 groundwater, which is lower than the acceptable limit (Table 1). The values obtained here are similar to those reported (Longe and Balogun, 2010) in that the samples of water were mostly acidic, with a pH mean of 6.70 and in the range of acceptable WHO standards. The lower value of pH assists the mobile ions of heavy metals. It was discovered that the pH values of the samples' soil were measured at triplicate depths and fell in the range of WHO acceptable limits and slightly basic.

The conductivities of the water samples ranged from 264 to 607uS/cm (Table I), and they fall within the WHO permissible limits (WHO, 2011). Likewise, the values of the soil samples' conductivities ranged from 406 to 683uS/cm, and they fall below the WHO/SON permissible limit (SON, 2015) as observed in Table II. Electrical conductivities are always affected by the appearance of elemental ions in soils and water samples. The Ni and Pb concentrations in S1 and S5 were detected to be above the WHO/SON permissible limits. Cadmium was not revealed at all in any of the samples of water. Similarly, lead was not discovered in the S4 samples of water. Human health is threatened by the presence of heavy metals like Pb and Nickel found in groundwater bodies. (Asemota *et al.*, 2025; Ge *et al.*, 2025). The higher values of Pb concentration present in other samples of water can be

attributed to the improper disposal and different activities around water sources. However, the concentration of Cr, Co, Mn, and Zn in all the samples falls in the range of WHO/ SON acceptable limits for drinking water, with Zn possessing the minimum concentration. (Table II). Zn concentration falls below the WHO/ SON permissible limit except for the depth 15cm of the S2 sample with the highest concentration. This can be figured to die casting, pennies, and spent batteries deposition for cars present the location as it is nearer to a car park. The obtained values for Mn in samples of the soils in S1 and S5 were above in comparison to the WHO/SON permissible limits, but the remaining fell within the limits. The values of Pb concentrations at the depths and all the locations above the WHO/SON limit of 0.01mg/L. The higher values of Pb concentrations correspond to the results reported by Adelekan and Abegunde (2011). The traces and observation of higher values of Pb concentrations may be traced to the Pb-based paints, metal products, pipes at the refuse dumpsite, dumping of waste batteries, cosmetics, and burning of fossil fuel, which have filtered into the soil (Khan *et al.*, 2024). Cd and Ni concentrations were higher than the WHO/SON acceptable limits at all depths and locations. The increase in the status of Cd could be essential and normal due to the fact that the geographical features of the area and the filtrate from agricultural land in areas where the use of phosphate fertilizer may be frequent. The higher the values of Nickel concentration in all the samples could be as a result of improper disposal of industrial effluent due to the nearest of different industries to these sites. Nickel is dangerous to human health and can cut across the food chain through plant intake from polluted soil (Khan *et al.*, 2024; Rizwan *et al.*, 2024). The concentration of Co samples in all areas falls in the range of the WHO/SON permissible limits. The concentrations of Cr in all soil samples are higher than the acceptable limit of WHO/SON, apart from S4 (depth at 15.0 and 45.0cm), which is in the range of permissible limits. The substances saved from industrial and community wastes, liquid fuels, and water erosion of rocks with higher Chromium contents can be associated with the higher concentration values of Cr (Dotaniya *et al.*, 2023; Astuti and Rauf, 2023).

CONCLUSION AND RECOMMENDATIONS

Waste disposals have the potential to ultimately pollute the soil and groundwater they come in contact with. Several studies have shown that locations close to industrial activities, such as effluent waste discharged, anthropogenic sites, and scrap metal parts, are marked by contamination of soils, water, and agricultural products. Most heavy metals are hazardous; hence, their concentration must be reduced to acceptable levels before discharging them into the environment. Otherwise, they ultimately pollute the soil and groundwater they come in contact with and thus cause threats to public health. The concentrations of Zn, Ni, Pb, Mn, Cr, and Co in the wells at the five sites were generally found to decrease steadily with increasing distance away from the anthropogenic sites. Zn enters underground water sources from the deterioration of metal scraps. Possible origin and root of Pb in water are scraps of motor, lead materials, and batteries disposed of on the dumping sites. The concentration values of Pb at the dumping sites S1 and S5 are well over the allowable limits set by SON/WHO. Besides this, all the metals investigated have their concentration within the acceptable limits of the WHO.

However, further research should determine the health effects and implications of heavy metals on the human population living in

Ibadan, also putting into consideration the probability that such heavy metals can penetrate and accumulate in plants, forcing their wish to the human body, via the food chain.

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