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RESEARCH ARTICLE

EVALUATION OF THE IMPACT OF HEAVY METALS AND TOTAL PETROLEUM HYDROCARBONS CONTAMINATION ON ROADSIDE SOILS, IN EDO STATE.

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ABSTRACT

Heavy metals and Total Petroleum Hydrocarbon (TPH) contaminations were evaluated on roadside surface soils along Benin-Auchi road in Ekpoma, Edo State. The Control and contaminated samples were collected at sampling depth of 0 -15cm and 15 – 30 cm from along the roadside soils and a total of 12 samples were collected which were then taken to the laboratory and analysed for Heavy metals and Total Petroleum Hydrocarbons in the content. The mean values of samples were calculated and the control was compared with the samples from the various sites. The mean concentration of heavy metals on highway roadsides soils was 4309.21mg/kg Fe; 15.70mg/kg Cu: 0.15mg/kg Cd: 2.55mg/kg Cr: 123.01mg/kg Mn; 0.77mg/kg Ni: 0.38mg/kg Pb and 3734.21mg/kg Fe: 10.47mg/kg Cu; 0.08mg/kg Cd; 1.23mg/kg Cr; 183.71mg/kg Mn:0.30mg/kg Ni: 0.15 mg/kg Pb in the control soils. TPH for road side soils was 1599.26mg/kg and was far higher than that from the control (31.88mg/kg) which indicated that roadsides soils were more exposed to high levels of heavy metal and TPH contamination. Notwithstanding, the levels were below some established critical levels for TPH, copper, nickel, chromium, manganese and lead. It follows that these metals are not sufficiently high to cause serious damage on humans and plants, but if they gradually slip into neighbouring farms, they will enter the food chain resulting in serious health risk. Therefore, there is an urgent need for legislative measures to minimise the indiscriminate disposal of oil contaminated residues, vehicle emissions, road traffic and air pollution.

KEYWORDS

Heavy metals and Total Petroleum Hydrocarbon (TPH), copper, nickel, chromium, manganese, lead, health risk

1. INTRODUCTION

Heavy metal pollution of the soil is common in places near roadways (Ossai et al., 2019). The Earth's crust naturally contains heavy metals, which are enduring and non-degradable in all environmental conditions. The majority of these heavy metals are harmful to living things, and even those that are thought to be essential can become toxic if they are present in excess. Heavy metals can disrupt vital biochemical processes, endangering plant and animal growth as well as human health (Rai et al., 2019). Heavy metal buildup in the soil may regulate microbiological activity, resulting in toxicity and food chain pollution. Residents are exposed to contaminated water for drinking and other household uses due to the lateral migration of heavy metals into subterranean water (Alengebawy et al., 2021).

Heavy metals can enter the environment from both natural and man-made sources. The primary human-caused source of heavy metals is vehicle emissions, whereas the naturally occurring source of metals in soil is the chemical weathering of minerals (Ogundele et al., 2019). In their study in 2019, researchers highlighted that the main metal pollutants found in roadside settings are lead, cadmium, copper, and zinc (Ogundele et al., 2019). These pollutants are generated when gasoline is burned, tires wear out, oils leak, batteries corrode, and metallic elements like radiators corrode. In addition, the presence of TPH and heavy metals in soil and water has raised concerns about their effects on plant and animal life. While heavy metals refers to more than a dozen elements that are metals or metalloids, such as lead, manganese, copper, chromium, arsenic, cadmium, mercury, etc., total petroleum hydrocarbons (TPH) is a term used to describe a large family of several hundred chemical compounds that originally come from crude oil (Truskewycz et al., 2019).

The process of refining crude oil to produce petrochemicals for use in automobiles, such as lubricating oil and premium motor spirit (PMS), has contaminated air, water, and soil worldwide, endangering the health of people and ecosystems (WHO, 2022). In 2019 , researchers claim that because of motorized roadways are active sources of heavy metals and petroleum hydrocarbons, they have a significant effect on the environment (Ogundele et al., 2019). The petroleum fuels consist of saturated hydrocarbons, aromatic hydrocarbons and non-hydrocarbon compounds, as well as trace amounts of nitrogen, phosphorus and organic matter, which are easily absorbed into the soil surface (Adipah, 2019). All soil pollution caused by petroleum hydrocarbons leads to the deterioration of the physical, chemical and biological properties of the soil. it also restricts plant growth; there is a lack of oxygen and water; and lack nutrients based on nitrogen and phosphorus (Mohammadi et al., 2020). Both heavy metal levels in soil and its acidity are increased by hydrocarbon pollution or contamination (Priya et al., 2023). Through deviations from preliminary values, such pollution affects the soil and poses a threat to the ecosystem and public health. Hydrocarbon pollution leads to a decrease in soil pH and has a significant impact on crop production through reduced production in horticulture and agriculture (Li et al., 2019). The harmful components of these petroleum products have an adverse effect on the ecosystem of soil (Hussain et al., 2019). Over the past few decades, the pollution of soil by petroleum hydrocarbons has attracted public attention and become a major environmental concern on a global scale (Hussain et al., 2019). Total petroleum hydrocarbon

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pollution of soil can have both immediate and long-term negative effects on the quality of the soil and its ability to function (Ossai, 2020). Petroleum hydrocarbons have an impact on the physicochemical qualities of soil, fungal and bacterial development, soil permeability and porosity, water holding capacity, hydrophobicity, and greater metal enrichment. Ultimately, they harm the soil ecosystem (Adipah, 2019).

Therefore, the objective of this study is to assess the impact of heavy metals and TPH contamination on road soils in Ekpoma, Edo State.

2. Materials and Methods

The study was carried out in Ekpoma, Edo state. The study area lies between latitude 06 08'35.1"E and longitude 06 46' 18.5"N. It has a mean annual rainfall of about 1500mm and rainy days of about 250. The mean annual temperature is about 31^{o}C and there are two distinct seasons, the dry season (November-March) and rainy season (April-October). The soils of the area are of sedimentary parent material origin, highly weathered and susceptible to erosion (Remison, 2005). It has a very high relative humidity of 40-90% and it is known for its excessive cold and harmattan during dry season.

Samples were taken from roadside soils exposed to high vehicular traffic and transportation along Benin – Auchi highways at four different sites designated with S1 - 1T4 junction, S2 - Idumebo, S3 - G2 - Ujoelen and S4 – Ujoelen extension and 2 sampling sites for the control. The control samples were taken from an open space about 20m from the road. Two samples were collected at each location at the depth of 0—15 cm and 15 – 30 cm using a soil auger. A total of 8 contaminated soil samples and 2 Controls were collected. The samples were properly labeled, air dried and stored in polythene bags and later taken to the laboratory for analysis.

For heavy metal analysis, 1gram of sample was digested in 250ml conical flask by adding 30ml of aqua regia and heated on a hot plate until volume remains about 7-12ml. This is to enable the sample to be efficient for further processes. The digest was filtered using what-man filter paper and the volume made up to the mark in a 50ml volumetric flask and was then stored in a plastic container for Atomic Absorption Spectrophotometer (AAS) analysis by thoroughly mixing the sample through shaking and 100ml of it transferred into a glass beaker of 250ml volume. The sample was aspirated into the oxidizing air-acetylene flame or nitrous oxide acetylene flame to facilitate absorption of radiation by atomic species during flame reactions. When the aqueous sample was aspirated, the sensitivity for 1% absorption was observed. Other parameters were determined using standard methods.

3. Results and Discussion

The results obtained from the analysis of the TPH and heavy metal content of the extract from the soil samples are reported in Table 1.

3.1 Chromium

Chromium was detected in all the samples shown in Table 1. Their concentration ranged from 0.00 – 13.84 mg/kg for soil. G2 (1) has the highest concentration of13.84 mg/kg chromium in soil samples and Control 1 and 2 has the lowest concentration of 0.00mg/kg chromium. All the chromium concentration in soil samples taken from all the locations are lower than the USEPA and NESREA limits of 50 mg/kg and 100mg/kg respectively. The industrial application of chromium salt can be the main source of chromium contamination of the soil and water. Waste combustion and the burning of fossil fuels are two other ways that chromium waste streams can enter the water and soil. Cancer and organ system toxicity can also result from long-term exposure to chromium through water or soil.

3.2 Cadmium

Cadmium concentration was negligible in all the samples shown in Table 1. Their concentration shows 0.00 (ND) mg/kg for soil. All the Cd concentration in soil were lower than 1.00mg/kg and 3.00 mg/kg allowed by USEPA and NESREA. Cd generally is soluble in water. As a result, they tend to bioaccumulate, are generally more bioavailable and mobile in the soil. Prolonged exposure to cadmium through soil or water can poison organ systems such as the skeletal, urinary, reproductive and respiratory systems and cause cancer. The use of cadmium as a corrosive reagent in industry is one of the ongoing causes of cadmium contamination that may affect locals. Exposure, even in small amounts, can cause adverse effects on the kidneys, liver, skeletal and cardiovascular systems, and lead to visual and hearing impairments.

Compared to all other metals, road dust often had relatively low Cd concentrations, this is consistent with the findings of researchers in 2009 (Faiz et al., 2009). An average of 2.84 mg/kg cadmium was found in the study in 2013 for the road section of the Arniko Highway between Kathmandu and Bhaktapur in Nepal (Raj and Ram, 2013). Abrasion, lubricants, galvanized car parts and the gradual wear of car tires can cause high levels of lead contamination. In diesel oils, cadmium concentrations range from 0.07 to 0.10 ppm, while in lubricating oils they range from 0.20 to 0.026 ppm. The use of soil additives such as phosphate fertilizers and sewage sludge leads to the accumulation of cadmium in agricultural soils (Ramachandran and D'Souza, 1998).

3.3 Copper

Copper was detected in all the samples as shown in Table 1. Their concentration ranged from 8.32 – 18.93 mg/kg in the sampled soils. G2(1) roadsides soil samples has the highest concentration of 18.93 mg/kg in soil and Uj (2) has the lowest concentration. The Cu concentration of all samples collected are all below the USEPA and NESRA limits of 100 and 50 mg/kg, respectively. Brake dust, which contains Cu in particular, is used in brakes to control heat transport (Christiana and Samuel, 2013). Cu translocated into crops becomes hazardous for human consumption when accumulated in excess (Bentum et al., 2011).

3.4 Lead

Lead concentration ranged from ND – 0.80 mg/kg for soil. Uj (1) road sides soils has the highest concentration and the CT (2) samples have the lowest concentrations. The lead (Pb) concentration in all soil samples is below the USEPA and NESREA allowable limits of 50 and 164 mg/kg. The high Pb content observed in the soil of the study area could be due to the indiscriminate disposal of waste from lead-acid batteries and lead-containing solder; Metal alloys, lead-based paints, waste oil, waste incineration, scrap and scrap automobile parts (Nkansah et al., 2011). Approximately 75% of the Pb contained in leaded gasoline enters the atmosphere directly. Only 25% of the Pb released from vehicles is deposited in coarse fraction near roads, and the remaining fine fraction remains in the air and contaminates areas further from the site of its emission (Fergusson and Kim, 1991). The main sources of Pb in the atmosphere are the combustion of Pb-added gasoline, smelting, and vehicle exhaust emissions associated with urban transportation (Khan et al., 2011).

Pb has no known biological benefit to humans as it can damage various systems of the body, including the nervous system, reproductive system and kidney, in addition to causing hypertension and anemia (WHO, 2011).

3.5 Zinc

The average Zn concentration was 45.64 mg kg^{-1} in roadside soils and varied from 30.54 to 65.02 mg kg^{-1} in the workshop area. These values were high compared to those in control soils (5.59–8.53 mg kg^{-1}). Zn, which is used in brake pads due to its heat-conducting properties, could be released during mechanical abrasion during the combustion of engine oil and tires of automobiles (Christiana and Samuel, 2013). Zn could disrupt biochemical activities in soils by retarding the growth of microorganisms, and earthworms (Wuana and Okieimen, 2011) are considered phytotoxic at elevated concentrations, which directly affects crop yields and soil fertility (Bentum et al., 2011). Zn concentration in Chaoyangas soil varied between 22.787 and 669.597 mg/kg, indicating slight contamination, which is supported by the geoaccumulation index (Liu et al., 2013). Zinc concentration in the studied soils were below the recommended values of 200 mg kg^{-1} given (CCME, 2001).

3.6 Manganese

Manganese had an average mean of 61.3 mgkg^{-1}, ranging from 20.5 to 91.34 mgkg^{-1}. The manganese concentration varies greatly in both sampling areas. The Mn concentration in the control soils was between 6.13 and 10.47 mg kg-1, the average mean was 8.56 mg kg-1. Roadside soils showed high levels of pollution attributed to motor vehicles. Several researchers have found that the concentrations of metals Pb, Cu, Zn, Cd and Ni decrease rapidly within 15–30 m from the roadside (Mmolawa et al., 2011; Mahbub et al., 2009). When roadside samples were compared to control soil samples, concentrations of all metals measured were higher. It is possible to compare the metal concentrations found in our research with heavy metal levels in surface soil in other cities. Sources of heavy metals in agricultural soils are influenced by raw materials, mining, fertilizer use and pesticides (Wei and Yang, 2010). In contrast, heavy metals were mainly introduced into urban soils and street dust by traffic and industry.

3.7 Total Petroleum Hydrocarbons

TPH concentrations at petrol stations having minimum of 399.83 ± 106.19

and maximum of 450.83 ± 90.58 lg/g, respectively, mechanic workshops, 362.60 ± 185.84 and 428.55 ± 119.00 lg/g, respectively, while the National Electric Power Authority (NEPA) station reported 356.20 ± 210.30 lg/g as compared to the control mean of 26.63 ± 4.58 lg/g (Moreso et al., 2002). In soil samples collected from a garage, near Crawford University, Igbesa, Ogun state, the sites contained mean TPH values of 19.43 ± 1.27,16.11 ± 1.85 and 11.43 ± 4.33 mg/g (Adeleke et al., 2010). Much higher levels of TPHs in the order of 1,179.3 to6,354.9 mg kg^{-1}, with the average of 2,676.6 mg kg^{-1}, were reported from agricultural soils adjacent to petrochemical complex in Guangzhou, the capital city of Guangdong Province in southern China (Li et al. 2012a, b).

The total concentration of petroleum hydrocarbons (TPH) in the roadside soil ranged from 351.30 to 4424.05 mg kg^{-1}, a TPH concentration of 21.93 - 88.11 mg kg^{-1} was in the control at a depth of 0 –15 cm and 15–30 cm from the surface. All sites had a higher concentration of total petroleum hydrocarbons than the control site, which is 10 km away and has less exposure to atmospheric and roadside dust. The highest mean TPH value was observed at site 2 (4424.05 mg kg^{-1}) (Table 1). These results confirm the TPH concentration measured at 0-15 cm depth for the top soils ranging from 55 ± 13 to 302 ± 14 mg kg^{-1} from the Niger Delta region of Nigeria, 3 months after an extensive oil spill (Okop and Ekpo, 2012). In automobile landfills, the total petroleum hydrocarbon content at all sites ranged from 486 to 4,438.7 mg kg^{-1} at a depth of 0–15 cm (Chukwujindu et al., 2008). The (TPH) concentration in automobile workshop contaminated soils ranged from 90.72 to 121.79 mg kg^{-1}, while in agricultural sites it was 44.94-83.4 mg kg^{-1}, while in the control, a TPH concentration of 4.55 mg kg^{-1} was present at a depth of 0–15 cm above the surface (Khan and Kathi, 2021). Furthermore, TPH concentrations at gas stations with a minimum of 399.83 ± 106.19 and a maximum of 450.83 ± 90.58 lg/g, mechanical workshops, 362.60 ± 185, respectively .84 and 428.55 ± 119.00 lg/g, respectively (Adeniyi and Afolabi, 2002). The National Electric Power Authority (NEPA) station reported 356.20 ± 210.30 lg/g compared to the control mean of 26.63 ± 4.58 lg/g . In soil samples collected from a garage near Crawford University, Igbesa, Ogun State, the sites contained mean TPH values of 19.43 ± 1.27, 16.11 ± 1.85 and 11.43 ± 4.33 mg/g (Adeleke et al. 2010). Agricultural soils adjacent to the petrochemical complex in Guangzhou, capital of Guangdong Province in southern China, reported much higher TPH values ranging from 1,179.3 to 6,354.9 mg kg^{-1}, with an average value of 2,676.6 mg kg^{-1} reported (Li et al. 2012a, b).

TABLE 1: Concentration of TPH and Heavy Metals in the sampled Soils.

				lmg/kg							
Location	**pH**	**TPH**	**Zn**	**Cu**	**Fe**	**Pb**	**Cd**	**Cr**	**Mn**	**Ni**	**Hg**
G2 (1)	6.9	3301.74	47.3	18.93	20972.11	0.27	0.02	13.34	84.51	37.7	0
G2 (2)	5.64	2265.15	50.74	15.37	11928.76	0.2	0.01	11.84	70.4	30.12	0
1T4 (1)	6.12	4424.05	38.11	17.05	19704.83	0.38	0.3	6.54	91.34	31.32	0
1T4 (2)	6.15	3400.64	39.3	16.11	16336.78	0.35	0.1	6.19	86.51	33.15	0
UJ (1)	6.3	3942.51	65.02	10.47	51088.8	0.8	0	4.84	20.5	45	0
UJ (2)	6.8	2051	54.1	8.32	41011.5	0.58	0	2.26	15.35	32.01	0
OX(1)	5.75	794.15	40.01	15.7	4894.73	0.4	0	2.11	65.65	34.11	0
OX(2)	5.65	351.3	30.54	13.95	3289.47	0.38	0	1.39	56.17	18.39	0
Mean	**6.16**	**2566.32**	**45.64**	**14.49**	**21153.37**	**0.42**	**0.05**	**5.02**	**61.3**	**32.73**	0
CT 1	7.3	88.11	6.64	13.95	1868.42	0.1	0	0	10.47	16.2	0
CT 2	6.6	21.93	5.59	10.47	1407.89	0	0	0	6.13	13.06	0
CT 3	6.95	78.3	8.53	9.68	1291.43	0.3	0.15	0.04	8.53	18.01	0
CT 4	6.5	68.93	7.85	10.17	1734.21	0.15	0	0.03	9.09	10.78	0
Mean	**6.84**	**64.32**	**7.15**	**11.07**	**1575.49**	**0.14**	**0.04**	**0.018**	**8.56**	**14.51**	0

Legend

CT1 – Control Soils (50 metres from the road sides at the depth of 0-15cm); CT2– Control Soils (20 metres from the road sides at the depth of 15-30cm); CT3 – Control Soils (20 metres from the road sides at the depth of 0-15cm); CT4– Control Soils (50 metres from the road sides at the depth of 15-30cm); G2 (1) –G2 junction - Ujoelen highways, at the depth of 0-15 cm; G2 (2) – G2 Junction - Ujoelen highway at the depth of 15-30 cm; 1T4 - 1T4 Junction at the depth of 0-15 cm, OX1 - Oxford Street junction at the depth of 0-15 cm;OX2 - Oxford Street junction at the depth of 15-30 cm; in Benin – Auchi highway.

4. Conclusion

Heavy metals and petroleum hydrocarbons have been proved to be toxic to both human and environmental health. This study has shown that there is considerable amount of these metals in roadside soils (1T4 Junction, Oxford Street junction, G2 - Ujoelen highways, Ujoelen highways) in Benin – Auchi highway, Ekpoma Edo State. The mean concentration of heavy metals on highway roadsides soils ranged from 4309.21mg/kg Fe; to, 15.70mg/kg Cu; 0.15mg/kg Cd; 2.55mg/kg Cr; 123.01mg/kg Mn; 0.77mg/kg Ni; 0.38mg/kg Pb and 3734.21mg/kg Fe; 10.47mg/kg Cu; 0.08mg/kg Cd; 1.23mg/kg, Cr; 183.71mg/kg Mn; 0.30mg/kg Ni: 0.15 mg/kg Pb in the control soils. TPH for road side soils was 1599.26mg/kg and was far higher than that from the control (31.88mg/kg).

The results showed that highways soils were more exposed to elevated levels of heavy metal and TPH contamination. Though the levels were below some established critical levels for TPH. Copper, nickel, chromium, manganese and lead. Statistical analysis of the soil samples showed that there was a significant difference at 5% level in the pH, Total petroleum hydrocarbon, Iron, Copper, Cadmium, Chromium, Manganese, Nickel, Lead and Aluminum, of the roadside soils and control and no significant difference in the mercury content of the soil. This implies that these metals are not high enough to pose damage to humans and plant but if leaked into adjacent agricultural fields, they slowly find entry into food chain leading to serious health hazards.

Recommendation

Therefore, there is an urgent need for policy regulations to minimize indiscriminate disposal of oil contaminated residues, vehicular emissions, road transport and traffic emissions and the wear and tear of mechanical parts in vehicles beside urban highways.

Owing to the toxicity and possible bio accumulation heavy metals, the compounds of heavy metals should be subjected to mandatory routine monitoring. As industrial activities which will lead to continuous pollution of the soils is on the increase, it is advisable to bring to the awareness of the people, risks and/effects of these metals to human in order to prevent further pollution.

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