



**BITUMEN POLLUTION AND HEAVY METAL CONCENTRATION IN SURFACE SOIL:
IMPLICATION FOR SOIL CONSERVATION**

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Abstract

Bitumen-derived heavy metals pose a serious threat to the environment by contaminating soil and harming plants, animals, and ecosystems. The study was carried out at Ode-Irele in Ondo State of Nigeria where there were seepages of bitumen as well as exploratory activities. Composite samples of soils in bitumen seepages and exploratory sites were collected to a depth of 15cm and that of the control was obtained at Ebute-Irele. Heavy metals in soils – Mn, Fe, Cu, Zn, Pb, Cr, Cd, Ni, V, and As were determined using atomic absorption spectrometry. Data were analyzed using descriptive statistics and t-tests of unpaired samples. Results showed that Mn (805.00 ± 136.30 mg/kg, 870 ± 198.00 mg/kg), Fe (992.50 ± 115.30 mg/kg, 1110.00 ± 141.40 mg/kg), Pb (8.0 ± 3.00 mg/kg, 290 ± 56.60 mg/kg), and As (4.80 ± 1.30 mg/kg, 5.00 ± 0.00 mg/kg) were respectively common to soils where there were bitumen seepages and where exploratory activities had taken place with higher concentrations than corresponding values in bitumen. The values of Mn, Cu, Zn, Pb, Ni, As, Cr and Cd respectively in both seepage and exploratory soils exceeded FEPA (1991) guidelines. Higher concentrations of heavy metals in bitumen-polluted soil should be continuously monitored during bitumen mining as they may represent significant environmental risks to soil conservation.

Keywords: Bitumen, Conservation, Heavy metal, Pollution, Soil

Introduction

Bitumen, as defined by Zhao *et al.*, (2021), is a very viscous and dense kind of unconventional petroleum that can also be found as oil sands or bituminous sands. High boiling point hydrocarbons make up bitumen, and these molecules have a comparatively low hydrogen-to-carbon ratio. Carbon is 80.2-84.3%, hydrogen is 9.8-10.8%, nitrogen is 0.2-1.2%, sulphur is 0.9-6.6%, oxygen is 0.4-1.0%, nickel is 10-139 ppm, vanadium is 7-1590 ppm, iron is

5-147 ppm, manganese is 0.1-3.7 ppm, calcium is 1-335 ppm, magnesium is 1-134 ppm, and sodium is 6-159 ppm, according to the elemental analysis of bitumen from different sources (Asphalt Institute and Eurobitumen, 2015). "Sources of heavy metals according to Alengebawy *et al.* (2021) include geogenic, industrial, agricultural, pharmaceutical, domestic effluents, and atmospheric sources. It is also known that bitumen contains highly condensed polycyclic aromatic hydrocarbons, some of which, along with their derivatives, pose a

serious risk to human health due to their high toxicity, mutagenicity, and carcinogenicity (Chokor and Ediagbonya, 2024). High-condensed polycyclic aromatic hydrocarbons are also known to be present in bitumen. These compounds, along with several of their derivatives, are recognized to be extremely hazardous to human health due to their high toxicity, mutagenicity, and carcinogenicity (Ediagbonya *et al.*, 2024). In addition to these negative impacts on human health, bitumen development during mining and exploration may result in environmental degradation Akinsulore and Akinsulore (2021). As Alengebawy *et al.* (2021) attests, one of the main causes of environmental pollution is bitumen prospecting and subsequent mining. As shown by Alengebawy *et al.* (2021), bitumen prospecting and subsequent mining is a major contributor to environmental degradation. These heavy metals are rather dense in comparison to water, according to Briffa *et al.* (2020), and if toxicity and heaviness are thought to be associated, then heavy metals also contain metalloids like arsenic, which can be dangerous even at low exposure levels (Briffa *et al.*, 2020). There are toxicological and environmental effects associated with these elevated heavy metal concentrations.

Elevated levels of heavy metals in soils contaminated by bitumen can cause poisoning in animals and humans interacting with the environment, as these metals are transferred from plants to animals and people through the food chain (Abdullahi *et al.*, 2021). When plants are exposed to heavy metals, one of the effects of the metals is oxidative stress, which typically leads to cellular damage (Mansoor *et al.*, 2023). In addition, the yield, richness and variety of plant communities are impacted by toxic heavy metals, which have a detrimental effect on the environment

(Angon *et al.*, 2024). Specifically, when high concentrations of heavy metals impact plant abundance and diversity indices of biotic integrity the biotic integrity in various ecosystem types used to be severely impacted (Ehis-Eriakha and Akemu, 2022). The capacity of plants to mitigate heavy metal toxicity in such contaminated soils was shown by (Ogunsusi and Adeleke, 2018; Ogunsusi and Adeleke, 2019) to be the cause of the higher heavy metal concentrations in soils and bitumen samples compared to equivalent values in plants. The results of (Ogunsusi and Adeleke, 2019) have demonstrated that relationships and interactions between metals in bitumen-polluted water can impact metal availability, even at dangerous concentrations, for the ecosystem and biota that depend on such water.

Soil contamination by heavy metals is a significant environmental and toxicological issue that affects soil, plant, and ecosystem conservation, with repercussions for both humans and animals. Because it is necessary to determine the levels of concentrations and toxicology of heavy metals in areas where bitumen deposits exist, the purpose of this study is to evaluate the levels of heavy metals in bitumen-deposited soils in Ode-Irele to determine the implications for soil conservation.

Materials and Methods

Study Area

The study was carried out at Ode-Irele in Ondo State of Nigeria where there were seepages of bitumen as well as exploratory activities during geological mapping and investigation for bitumen along the bitumen belt (Ogunsusi and Adeleke, 2017). Ode-Irele is located in the southern fringe of the state longitude 04°47'E to 05°10'E and latitude 06°16'N to 06°40'N (21).

Method of Data Collection

At a depth of 15 cm, three composite samples

of soils were taken: four replicates of the soils where bitumen seepages occurred, two duplicates of the soils where exploratory activities were conducted, and four repetitions of the control at Ebute-Irele. These samples were brought to the University of Ibadan's Agronomy Department laboratory so that their metal content could be examined. Data on soil were gathered using the Completely Randomised Block Design (CRBD) technique. Heavy metals in soils were determined using Bulk Atomic Absorption Spectrometry model 210/211/VGP.

The process entails using concentrated H_2SO_4 to break down soil samples. The samples were diluted and fed into atomic absorption spectrophotometer after being digested. Subsequently, a spray chamber inside the digested soil sample was used to introduce it into the flame created by the air and acetylene gases, breaking it up into tiny droplets. The specimen went via an internal monochromator that emitted light at a wavelength particular to the metal under study; the absorption is proportionate to the element's concentration. The piece became dissolved, vaporized, and atomized in the fire. After that, the mixture was run through a detector, which changed the light signal into an electric signal that was proportionate to the amount of light. A

calibration curve was used to find the concentration of each metal in the solution.

Data Analysis

The data collected were subjected to descriptive statistics and t-tests of unpaired samples.

Results and Discussion

Relationship between Heavy Metals in Bitumen and Seepage Surface Soils of Ondo State Bitumen Belt

Table 1 presents a comparison of the heavy metal content of bitumen and related surface soils in the seepage site. The outcome demonstrated that there was no statistically significant difference between the mean values of all metals in bitumen and the corresponding seepage surface soils. The results show the presence of Mn (805.00 ± 136.30 mg/kg), Fe (992.50 ± 115.30 mg/kg), Pb (8.50 ± 3.00 mg/kg), V (8.00 ± 0.80 mg/kg), and As (4.80 ± 1.30 mg/kg) were higher in seepage soil than 612 ± 140.00 mg/kg, 760.50 ± 150.60 mg/kg, 7.80 ± 1.30 mg/kg, 6.00 ± 1.30 mg/kg, and 4.00 ± 0.00 mg/kg respectively in bitumen. On the other hand, Cu (192.50 ± 73.50 mg/kg), Zn (244.30 ± 47.70 mg/kg), Cr (10.90 ± 2.70 mg/kg), Cd (3.40 ± 0.60 mg/kg), and Ni (27.20 ± 23.10 mg/kg) in bitumen were higher than 140.00 ± 73.50 mg/kg, 215.00 ± 105.40 mg/kg, 9.75 ± 0.50 mg/kg, 2.50 ± 1.00 mg/kg, and 13.00 ± 8.70 mg/kg respectively in seepage soil.

Table 1. Heavy Metals in Bitumen and Seepage Surface Soils of Ondo State Bitumen Belt

Taxa	Mean g/kg		t-value	Degree of Freedom	P	Standard Deviation	
	Seepage Soil	Bitumen				Seepage Soil	Bitumen
Mn	805.00	612.00	1.62	4	0.18	136.30	140.00
Fe	992.50	760.50	2.14	4	0.10	115.30	150.60
Cu	140.00	192.50	0.94	4	0.40	73.50	23.30
Zn	215.000	244.30	1.51	4	0.74	105.40	47.70
Pb	8.50	7.80	0.30	4	0.78	3.00	1.30
Cr	9.75	10.90	0.94	4	0.40	0.50	2.70
Cd	2.50	3.40	1.14	4	0.32	1.00	0.60
Ni	13.00	27.20	1.19	4	0.30	8.70	23.10
V	8.00	6.00	2.43	4	0.07	0.80	1.30
As	4.80	4.00	0.80	4	0.47	1.30	0.00

N.B: Marked regressions are significant at $p \leq 0.05$

Comparison of Heavy Metals in Bitumen and Associated Exploratory Surface Soils

Comparisons of heavy metals in bitumen and associated exploratory surface soils are presented in Table 2. The findings indicated that bitumen (6.00 ± 1.30 mg/kg) had a substantially lower mean value of V than exploratory surface soil (10.00 ± 0.00 mg/kg) ($P < 0.05$). However, it was discovered that there was no statistically significant difference between the mean values of Mn, Fe, Cu, Zn, Pb, Ni, As, Cr, and Cd in surface exploration soil and bitumen ($P > 0.05$). However, compared to the corresponding values of 612.00 ± 140.00 mg/kg, 760.50 ± 150.60 mg/kg, $192.50 \pm$

23.30 mg/kg, 244.25 ± 47.70 mg/kg, 7.80 ± 1.30 mg/kg, and 4.60 ± 0.40 mg/kg in bitumen, respectively, Mn (870.00 ± 198.00 mg/kg), Fe (1110.00 ± 141.40 mg/kg), Cu (215.00 ± 21.20 mg/kg), Zn (290.00 ± 56.60 mg/kg), Pb (10.00 ± 0.00 mg/kg), and As (5.00 ± 0.00 mg/kg) were higher in exploratory soil. Conversely, bitumen had higher levels of Ni (27.20 ± 23.10 mg/kg), Cr (11.00 ± 2.50 mg/kg), and Cd (3.90 ± 0.14 mg/kg) than similar values in exploratory soil (15.00 ± 7.10 mg/kg, 10.00 ± 0.00 mg/kg, and 3.50 ± 0.14 mg/kg, respectively). Therefore, compared to bitumen, the values of seven out of 10 heavy metals were higher in exploratory soil.

Table 2. Heavy Metals in Bitumen and Exploratory Surface Soils of Ondo State Bitumen Belt

Variable	Mean(mg/kg)		t-value	Degree of Freedom	P	Standard Deviation	
	Exploratory soil	Bitumen				Exploratory soil	Bitumen
Mn	870.00	612.00	1.51	2	0.27	198.00	140.00
Fe	1110.00	760.50	2.39	2	0.14	141.40	150.60
Cu	215.00	192.50	1.01	2	0.42	21.20	23.30
Zn	290.00	244.25	0.87	2	0.47	56.60	47.70
Pb	10.00	7.80	2.44	2	0.13	0.00	1.30
Ni	15.00	27.20	0.72	2	0.55	7.10	23.10
As	5.00	4.60	1.33	2	0.31	0.00	0.40
Cr	10.00	11.00	0.56	2	0.63	0.00	2.50
V	10.00*	6.00*	4.44*	2*	0.05*	0.00*	1.30*
Cd	3.50	3.90	0.79	2	0.52	0.71	0.14

N.B: Marked regressions are significant at $p \leq 0.05$

Trace Heavy Metals in Bitumen Seepage, Exploratory, and Control Surface soils

As indicated by Table 3, the concentrations of heavy metals in seepage and control surface soils were found to be significantly lower in seepage soil than in control soils, which had Mn (805 ± 136.30 mg/kg), Cu (140.00 ± 73.50 mg/kg), Zn (215.00 ± 105.48 mg/kg), and Cd (2.50 ± 1.00 mg/kg) at 1130 ± 206.60 mg/kg, 300.00 ± 25.80 mg/kg, 370 ± 24.50 mg/kg, and 4.03 ± 0.26 mg/kg, respectively. Seepage soil had lower

levels of Pb, V, and As than the control soil, however, these differences were not statistically significant. Conversely, seepage soil had a much higher level of Fe (992.50 ± 115.30 mg/kg) than control soil (297.50 ± 84.20 mg/kg). It was discovered that Fe, Cu, Pb, Ni, As, and Cr exceeded the FEPA critical levels. The results in Table 3 also show that the levels of Cu (215.00 ± 21.21 mg/kg) and Zn (290 ± 56.57 mg/kg) in the exploratory soil were significantly lower than those in the control soil (300.00 ± 25.82 mg/kg and $370 \pm$

24.49 mg/kg, respectively). On the other hand, compared to 297.50 ± 84.21 mg/kg and 8.9 ± 0.14 mg/kg, respectively, in the

control, Fe (1110.00 ± 141.42 mg/kg) and V (10.00 ± 0.00 mg/kg) in the exploratory soil were substantially greater.

Table 3. Trace Heavy Metals in Bitumen Seepage, Exploratory, and Control Surface soils

Taxa	Mean (mg/kg)		t-value	Degree of Freedom	P	Standard Deviation	
	Seepage Site	Control Site				Seepage	Control
Mn	805.00*	1130.00*	2.63*	6*	0.04*	136.30*	206.60*
Fe	992.50*	297.50*	9.74*	6*	0.00*	115.30*	84.20*
Cu	140.00*	300.00*	4.11*	6*	0.01*	73.50*	25.80*
Zn	215.00*	370.00*	2.87*	6*	0.03*	105.48	24.50*
Pb	8.50	10.00	1.00	6	0.36	3.00	0.00
Cr	9.75	9.75	0.00	6	1.00	0.50	0.50
Cd	2.50*	4.03*	2.95*	6*	0.03*	1.00*	0.26*
Ni	13.00	10.00	0.69	6	0.52	8.72	0.00
V	8.00	8.90	2.17	6	0.07	0.82	0.14
As	4.75	5.00	0.3333	6	0.75	1.26	0.82
	Mean mg/kg)		t-value	Degree of Freedom	P	Standard Deviation	
	Exploratory site	Control site				Exploratory	Control
Mn	870.00	1130.00	1.47	4	0.22	197.99	206.56
Fe	1110.00*	297.50*	9.24*	4*	0.00*	141.42*	84.21*
Cu	215.00*	300.00*	3.97*	4*	0.02*	21.21*	25.82*
Zn	290.00*	370.00*	2.61*	4*	0.05*	56.57*	24.49*
Pb	10.00	10.00	0.00	4	1.00	0.01	0.01
Cr	10.00	9.75	0.67	4	0.54	0.00	0.50
Cd	3.50	4.03	1.44	4	0.22	0.71	0.26
Ni	15.00	10.00	1.63	4	0.18	7.07	0.00
V	10.00*	8.90*	10.37*	4*	0.00*	0.00*	0.14*
As	5.00	5.00	0.00	4	1.00	0.00	0.82

N.B: Marked regressions are significant at $p \leq 0.05$

Discussion

Relationship between Heavy Metals in Bitumen and Seepage Surface Soils of Ondo State Bitumen Belt

The non-significant difference recorded for all heavy metals between seepage soil and bitumen is a pointer to the equitable balance of the heavy metals in both. This balance could be attributed to the gradual release of the metal from the bitumen deposit, continued leaching of the metals from the

bitumen into the soil, and continued absorption of the metals by plants from the soil. However, the results showed that the seepage soil had larger levels of five of the ten metals Mn, Fe, Pb, V, and As than the bitumen had. This indicates that the bitumen around the surface soil was more likely to leak these heavy metals. This could have been made possible possibly because these heavy metals are more mobile than the others. Three of these five Mn, Fe, and V are essential elements found in bitumen. This suggests

Table 4. Trace Heavy Metals in the Bitumen Seepage, Exploratory, Control Surface Soils, and Bitumen Sample

Location	Metals (mg/kg)									
	Mn	Fe	Cu	Zn	Pb	Ni	As	Cr	V	Cd
Seepage										
Loda (S1)	730	970	200	290	10	10	5	10	8	3
Ludasa (S2)	820	1000	200	270	10	20	5	9	8	3
Petu (S3)	680	860	50	60	4	2	3	10	9	1
Lofo (S4)	990	1140	110	240	10	20	6	10	7	3
Mean	805.00	992.50	140.0	215.0	8.50	13.00	4.75	9.75	8.00	2.00
			0	0						
Exploratory										
Ludasa	1010	1210	230	330	10	20	5	10	10	4
Loda	730	1010	200	250	10	10	5	10	10	3
Mean	870.00	1110.00	215.0	290.0	10.00	15.00	5.00	10.00	10.00	3.50
			0	0						
Control 1	1210	320	330	370	10	10	5	9	8.9	3.8
Control 2	890	200	310	340	10	10	6	10	9.0	4.4
Control 3	1370	400	290	400	10	10	4	10	8.7	4.0
Control 4	1050	270	270	370	10	10	5	10	9.0	3.9
Mean	1130.00	298.00	300.0	370.0	10.00	10.00	5.00	10.00	9.00	4.00
			0	0						
Bitumen/ Exploratory	711	867	209	278	6.9	10.9	4.9	12.8	6.9	3.8
Bitumen/ Seepage	513	654	176	210.5	8.7	43.5	4.3	9.2	5.1	3.4
Mean	612.00	760.00	192.5	244.3	7.80	27.20	4.00	10.90	6.00	3.40
			0	0						
FEPA 1991	0.1 -0.5	400	1.00	300- 400	0.05	0.1	0.20	0.03	10	0.01/ 0.003
WHO/FAO 2001 soil	2000	50000	100	300	100	31-75	10	50	-	3

N.B: Marked regressions are significant at $p \leq 0.05$

that the primary source of these heavy metals was bitumen (Ediagbonya and Ajayi, 2021), from which they eventually collected in the related seepage surface soil. This is in agreement with the conclusion of (Huang *et al.*, 2020) that weathering of the parent carbonate rocks was discovered to be the main potential origin of heavy metals. The two other metals, Pb and As, which likewise accumulated significantly in the seepage site's surface soil but are not bitumen's constituent elements, suggest that the metals' leaching from the bitumen deposit is their source. Therefore, the five heavy metals since they collect more in seepage

soil than the other metals may represent potential environmental hazards and make soil conservation a little bit difficult. The threats may develop if there is a prolonged buildup of the heavy metals without remediation. Bitumen sample (Ogunsusi and Adeleke, 2019) exhibits a preponderance of Mn, Fe, and V among other elements, as indicated by the elemental analysis. The higher levels of Cu, Zn, Cr, Cd, and Ni in bitumen compared to associated seepage surface soil may be attributed to the degree of immobility of the heavy metals. This finding is consistent with that of (Yuan *et al.*, 2018) regarding the immobility of heavy metals.

Comparison of Heavy Metals in Bitumen and Associated Exploratory Surface Soils

This study's findings on vanadium were statistically higher in exploratory surface soil than in bitumen; this could be explained by the metal being mobilized as a result of exploratory activities that may have softened the bitumen. These findings are consistent with those of (Khan *et al.*, 2023) which found that certain heavy metals were more concentrated in sludge and plant than equivalent values in effluents. The results of (Ogunsusi and Adeleke, 2018) further demonstrated that plants had a higher vanadium value than soil. This demonstrates that the metal was mobile enough to leak from bitumen into the soil as a result of exploratory activities and that plant also absorbed the metal throughout the phytoremediation process. The statistically significant increase in V in exploratory surface soil may indicate Vanadium's possible toxicity. This may have been caused by the fact that bitumen's elemental composition, V, has the highest metallic component (Asphalt Institute and Eurobitumen, 2015), which may have contributed to its concentration in exploratory soil. Since it is found in natural deposits found in crude oil deposits and fossil materials all over the world as reservoirs, vanadium is also recognized to be widely distributed in the Earth's crust (Yuan *et al.*, 2021). Large amounts of vanadium in the form of organometallic complexes pose a risk to human health and the environment when they are released, either naturally or as a result of man-made processes. For the benefit of the soil and all living things that depend on it, severe soil conservation measures are required due to the risk posed by the high concentration of V in bitumen exploratory soil.

The results of this investigation have once again demonstrated that exploratory soil

had higher concentrations of seven of the 10 heavy metals under investigation Mn, Fe, Cu, Zn, Pb, As, and V than bitumen. This is consistent with the finding of Alabi *et al.* (2019) that the concentration of heavy metals in soil samples were found to decrease as the spatial distances of the sampled locations increased from the point source. "This suggests once more that heavy metals are now more transportable due to exploratory activities. Mn, Fe, and V are the three heavy elements that are essential to bitumen (Asphalt Institute and Eurobitumen, 2015; Onojake *et al.*, 2017). The greater levels of the aforementioned heavy metals in exploratory soil compared to bitumen may have been caused by elemental components of bitumen that are now more mobile due to exploratory activity. Cu, Zn, Pb, and As levels in exploratory soil are higher than those in bitumen, which suggests that these elements are more mobile than Mn, Fe, and V. The results of this investigation is in tandem with that of Ogunsusi and Adeleke (2018) who found that the metals were significantly higher in exploratory surface soil than in plants. Because of this, the higher concentrations of the aforementioned heavy metals represent a serious threat to soil conservation and the biota that depends on it. On the other hand, the degree of immobility of the heavy metals may account for the higher levels of Ni, Cr, and Cd in bitumen compared to related exploration surface soil. An additional indication of nickel's predominance in bitumen above that of the related exploratory soil is the element's elemental composition. The results of (Yuan *et al.*, 2018) corroborate this conclusion. However, additional research is needed to determine how Ni interacts with each of Cr and Cd. In both seepage and exploratory soils, the values of Mn, Fe, Pb, and As are typically higher than the equivalent bitumen values. As a result, these heavy metals may pose health

risks in addition to possible environmental hazards. This is because Ediagbonya and Adesokan (2019) and Briffa *et al.* (2020), and Ediagbonya *et al.* (2022) found that heavy metals, out of all the many kinds of pollutants, have been linked to a rising number of health problems, even at low concentrations, because of their dangerous capacity to bioaccumulate through food chains. As, Cd, Cr, Cu, Ni, Pb, and Zn are among the heavy metals in this study that the EPA has already designated as priority pollutants to manage (Chen *et al.*, 2015; Tóth *et al.*, 2016). The fact that the levels of heavy metals in seepage and exploratory soils were greater than those in bitumen suggests that the metals will initially build up in the soil before being transferred to the ecosystem's living things. For effective soil conservation, this will necessitate management actions to address the influence of heavy metals in soil.

Trace Heavy Metals in Bitumen Seepage, Exploratory, and Control Surface soils

The results of this investigation indicate that Mn, Cu, and Zn were significantly lower in the seepage and exploratory soils compared to the control soil; the only element significantly lower in the seepage soil compared to the control soil was Cd. This was in contrast to the findings of (Itodo *et al.*, 2018), who found no evidence of a significant difference for Zn, Pb, or Cd in the soil that was studied for asphalt in either the study locations or the control sites. According to (Ogunsusi and Adeleke, 2018) study, plants growing naturally in bitumen-polluted soils may be able to phytodegrade or rhizodegrade the metals, which could explain the decreased values of heavy metals in bitumen seepage soil for this study. Over time, a significant amount of Fe has been leached from bitumen into the corresponding surface soils, which may account for the statistically higher Fe in the

soils of bitumen seepage and exploratory sites compared to the control site. As the second most common metallic component in bitumen after vanadium (Asphalt Institute and Eurobitumen, 2015), Fe's value in seepage and exploratory soils was significantly higher than that of the control, which may have contributed to the metal's hyperaccumulation in these areas. Given that Fe is well known for its corrosive properties and propensity to produce soil acidity, this could have a significant detrimental impact on the conservation of soil in the research area. Furthermore, the disturbance brought on by the exploration efforts may have increased Fe's mobility and abundance. This corroborated (Adeyeye *et al.*, 2005) findings. The disturbance might have increased the metal's mobility, causing it to hyperaccumulate beyond the capacity of the deposit's native vegetation to replenish it. Given that iron and zinc are fundamental components of bitumen (Asphalt Institute and Eurobitumen, 2015), they may have leached into the surrounding exploratory soil, explaining the statistically higher concentration of these elements in the exploratory soil compared to the control. Specifically, the exploratory actions may have also softened and increased the mobility of the heavy metals. Consequently, the metal concentrations in the exploratory soil could have increased to such an extent (hyperaccumulation) that phytoremediation was no longer able to lower the metal levels in the soil. These heavy metals could be classified as extremely dangerous if hyperconcentration is equated with toxicity, as plants have not been able to phytoremediate them (Ogunsusi and Adeleke, 2018). Fe and V consequently pose a risk to soil conservation because they will likely raise the expense of rehabilitation. In seepage and exploratory soils, the concentrations of Mn, Cu, Zn, Pb, Ni, As, Cr, and Cd exceeded FEPA (1991)

standards (Table 4). Because of this, all of these heavy metals are highly dangerous to human health and the environment. These heavy metals are among those that the EPA has designated as priority pollutants to manage, according to (Chen *et al.*, 2015) and (Tóth *et al.*, 2016). Consequently, heavy metals pose a serious threat to soil conservation because they are priority pollutants.

Conclusion

- 1) Seepage soil had larger concentrations of five heavy metals—Mn, Fe, Pb, V, and As—than bitumen did.
- 2) Additionally, exploratory soil contained larger concentrations of seven heavy metals—Mn, Fe, Cu, Zn, Pb, As, and V—than bitumen.
- 3) Compared to bitumen, the mean value of V was substantially more concentrated in exploratory surface soil.
- 4) Both seepage and exploratory soils share Mn, Fe, Pb, and As, which were found in higher concentrations than their bitumen counterparts.
- 5) In comparison to control soil, Mn, Cu, and Zn concentrations were statistically lower in both seepage and exploratory soils. Only Fe was considerably more concentrated in seepage soil than in control soil, but iron and V were statistically more concentrated in exploratory soil than in control soil.
- 6) It is implied that heavy metals had leached from bitumen that has been explored into the related surface seepage and exploratory soils by the heavy metals that had higher values in seepage and exploratory soils than in bitumen and control soils. Thus, these metals may represent possible risks to the ecosystem and

soil preservation.

- 7) In seepage and exploratory soils, the values of Mn, Cu, Zn, Pb, Ni, As, Cr, and Cd surpassed the guidelines set by FEPA (1991). As a result, the soil and the biota that depend on it in the ecosystem could be seriously threatened by the heavy metals stated above.
- 8) By comparing the concentration of heavy metals in the soil between bitumen seepage and exploratory sites with the control and the FEPA standard criteria, one may evaluate the danger of soil pollution in the vicinity of bitumen-laden soils and implement appropriate management practices for such soil globally.
- 9) Vanadium should be closely monitored since it can provide major hazards to the environment and human health.
- 10) Since Mn, Fe, Pb, and As are more concentrated in soils than bitumen and are hence very toxic, they should be closely monitored.
- 11) More research on Mn, Cu, and Zn is needed to determine why their concentrations are statistically lower in seepage and exploratory soils than in control soil.
- 12) Because Mn, Cu, Zn, Pb, Ni, As, Cr, and Cd exceeded FEPA essential levels, there should be close monitoring of these elements during bitumen exploitation.
- 13) Studies on these heavy metals ought to be carried out to ascertain their degrees of immobility in soil.

References

- Abdullahi, A., Lawal, M. A. and Salisu, A. M. (2021). Heavy metals in contaminated soil: source, accumulation, health risk, and remediation process. *BAJOPAS*, 14(1): 1-12.

- Akinsulore, A. and Akinsulore, O. (2021). Sustainable Development and the Exploitation of Bitumen in Nigeria: Assessing the Environmental Laws Faultlines. *Beijing Law Review*, 12: 113 - 138. doi: [10.4236/blr.2021.121007](https://doi.org/10.4236/blr.2021.121007).
- Alabi, O.O., Sedara, S. and Awolere, S. Y. (2019). Assessment of concentrations of heavy metals in soils around espro asphalt production and quarry site, Wasinmi, Osun State Southwest Nigeria. *Journal of Geography Environment and Earth Science International*, 22(3): 1-10. DOI: [10.9734/jgeesi/2019/v22i330148](https://doi.org/10.9734/jgeesi/2019/v22i330148)
- Alengebawy, A., Abdelkhalek, S. T., Qureshi, S. R. and Wang, M. (2021). Heavy Metals and Pesticides Toxicity in Agricultural Soil and Plants: Ecological Risks and Human Health Implications. *Toxics*, 9(3):42. doi: [10.3390/toxics9030042](https://doi.org/10.3390/toxics9030042).
- Angon, P. B., Islam, M. S., Shreejana, K. C., Das, A., Anjum, N., Poudel, A. and Suchi, S. A. (2024). Sources, effects and present perspectives of heavy metals contamination: Soil, plants and human food chain. *Heliyon*, 10(7): e28357. ISSN 2405-8440. <https://doi.org/10.1016/j.heliyon.2024.e28357>.
- Asphalt Institute and Eurobitumen (2015). The bitumen industry: a global perspective: production, chemistry, use, specification, and occupational exposure. 3rd edition. 58pp. <http://www.eurobitume.eu/publications>.
- Briffa, J., Sinagra, E. and Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon*, 6(9): e04691. ISSN 2405-8440, <https://doi.org/10.1016/j.heliyon.2020.e04691>.
- Chen, H., Teng, Y., Lu, S., Wang, Y. and Wang, J. (2015). Contamination features and health risks of soil heavy metals in China. *Sci. Total Environ.*, 512, 143-153.
- Chokor, A. A and Ediagbonya, T. F. (2024). Profile, health risk assessment and source apportionment of polycyclic aromatic hydrocarbons (PAHs) in terrestrial snails and some aquatic species consumed in parts of Ogbia LGA, Bayelsa, Nigeria. *Ovidius University Annals of Chemistry*; 35(1): 58-66.
- Duffus, J. H. (2002). Heavy metals-a meaningless term? *Pure Appl Chem.* 74(5):793-807.
- Ediagbonya, T. F., Ogunjobi, A. J., Odinaka, V.C. and Adenikinju, A.C. (2022). Bioaccumulation of elemental concentrations in sediment and frog (*Pyxicephalus edulis*) in Igbekebo River, Ondo State, Nigeria. *J Afr Chem.* 2022;5(3):790-803.
- Ediagbonya, T. F., Omotade, E.T. and Ihuma K.S (2024) Health risk associated with polycyclic aromatic hydrocarbons (PAHs) in dumpsites in southwestern Nigeria. *Environmental Nanotechnology, Monitoring & Management*, 22(3):28-60.
- Ehis-Eriakha, C. B. and Akemu, S. E. (2022). Impact of Heavy Metal Pollution on the Biotic and Abiotic Components of the Environment. *South Asian Journal of Research in Microbiology*, 13(3): 38-54.
- Huang, L., Rad, S., Xu, L., Gui, L., Song, X., Li, Y., Wu, Z. and Chen, Z. (2020). Heavy Metals Distribution, Sources, and Ecological Risk Assessment in Huixian Wetland, South China. *Water*, 12(431):

doi:10.3390/w12020431.
<http://www.mdpi.com/journal/water>.

- Itodo, A., Ubimago, M. and Wuana, R. (2018). Environmental impact of abandoned asphalt production site on soil, water, and vegetables from near farmlands. *J. of Geosc. and Env. Protec.*, 6(4): 107-122. doi: [10.4236/gep.2018.64007](https://doi.org/10.4236/gep.2018.64007).
- Khan, S. N., Nafees, M. and Imtiaz, M. (2023). Assessment of industrial effluents for heavy metals concentration and evaluation of grass (*Phalaris minor*) as a pollution indicator. *Heliyon*, 9(9): e20299. ISSN 2405 - 8440 , <https://doi.org/10.1016/j.heliyon.2023.e20299>.
- Mansoor, S., Ali, A., Kour, N., Bornhorst, J., AlHarbi, K., Rinklebe, J., Moneim, D. A. E., Ahmad, P. and Chung, Y. S. (2023). Heavy Metal Induced Oxidative Stress Mitigation and ROS Scavenging in Plants. *Plants (Basel)*, 12 (1 6) : 3 0 0 3 . <https://doi.org/10.3390/plants12163003>
- Ogunsusi, K. and Adeleke, B.O. (2018). Exploiting phytoremediation as a technique for conservation of bitumen polluted soil. *Journal of Tropical forest Resources*, 34: 10-23.
- Ogunsusi, K. and Adeleke, B.O. (2019). Bitumen seepage: Impact and interaction on heavy metal concentrations in surface water. *Journal of Researches in Agricultural Sciences*, 7 (1) : 1 - 1 1 . <http://faculty.eksu.edu.ng/agric.office/published-volumes>
- Ogunsusi, K., and Adeleke, B. O. (2017). Abundance of Birds in Six Selected Habitats. *J. of Res. in For., Wildl.andEnv.*, 9(3): 61-75. ISBN: 2 1 4 1 - 1778. <http://www.ajol.info/index.php/jrjwe>
- Onojake, M. C., Osuji, L. C. and Ndubuka, C. O. (2017). Characterization of bitumen samples from four deposits in southwest, Nigeria using trace metals. *Egyptian Journal of Petroleum*, 26(2): 547-552. <https://doi.org/10.1016/j.ejpe.2016.08.002>.
- Tóth, G., Hermann, T., Szatmári, G. and Pásztor, L. (2016). Maps of heavy metals in the soils of the European Union and proposed priority areas for detailed assessment. *Sci. Total Environ.* 565: 1054–1062.
- Yuan, R., Li, S., Che, Y., He, J., Song, J. and Yang, B. (2021). A critical review on extraction and refining of vanadium metal. *International Journal of Refractory Metals and Hard Materials*, 101: 105696. ISSN 0263-4368, <https://doi.org/10.1016/j.ijrmhm.2021.105696>.
- Yuan, X., Xiong, T., Wang, H., Wu, Z., Jiang, L., Zeng, G. and Li, Y. (2018). Immobilization of heavy metals in two contaminated soils using a modified magnesium silicate stabilizer. *Environ Sci Pollut Res Int*, 25(32):32562-3 2 5 7 1 . <https://doi.org/10.1007/s11356-018-3140-6>
- Zhao, F., Liu, Y., Lu, N., Xu, T., Zhu, G. and Wang, K. (2021). A review on upgrading and viscosity reduction of heavy oil and bitumen by underground catalytic cracking. *Energy Reports*, 7: 4249–4277.