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**Bitumen Seepage: Impact and Interaction on Heavy Metal Concentrations in Surface Water**

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**Abstract**

The association and interaction among metals in bitumen-polluted water may affect the availability of the metals even at toxic levels to the surrounding environment and biota that are dependent on such water. This study was carried out at Ode-Irele in Ondo State bitumen belt, Southwest of Nigeria, where there are bitumen seepages and at Ebute-Irele where there are no records of seepages to serve as a control. Composite samples of surface water were collected to a depth of 30 cm midstream in the sites and heavy metals- manganese, iron, copper, zinc, lead, chromium, cadmium, nickel, vanadium and arsenic, and alkali metals- calcium, magnesium, potassium, and sodium were determined using standard methods. The data of metal concentrations were analyzed using descriptive statistics and t-test at p < 0.05. The associations that exist among metals of surface water were determined using regressive correlation. The concentrations of the metals were compared with standards in the Federal Environmental Protection Agency and World Health Organisation Guidelines. The results show that nickel, calcium, magnesium, and sodium were higher in the seepage site than in the control, with only nickel in the seepage sites (0.40 ± 0.00 mg L-1) significantly different from the control (0.30 ± 0.00 mg L-1). Manganese, iron, copper, zinc, chromium, cadmium, nickel, vanadium, arsenic, and calcium concentrations were higher than the guideline levels. The correlation coefficients were positive and significant between iron and copper, manganese and vanadium, iron and sodium, calcium and magnesium, and between magnesium and sodium while the negative correlation between lead and zinc was significant. The metals whose concentrations were higher in the surface water of the seepage site and exceeded the guideline values, especially the component elements of bitumen (nickel, iron, manganese, vanadium, calcium, and sodium), would have toxic effects on the environment if not closely monitored during the bitumen development phase.

Keywords: Bitumen, heavy metals, concentration, toxicity, surface water

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**Introduction**

Bitumen, also known as asphalt, is a highly viscous liquid or semisolid material mainly produced from crude oil refinery process, and also present in some natural deposits (Rasoulzadeh *et al*., 2011). Asphalt composition can be divided into four generic groups: saturates, aromatics, resins, and asphaltenes (Rasoulzadeh *et al*., 2011). Also present in bitumen are the heteromolecules of sulphur, oxygen, nitrogen, and metals as well as combinations of alkanes, cycloalkanes, and aromatics (Read and Whiteoak, 2003). Asphalt Institute and Eurobitume (2015) gave the elemental analysis of bitumen from various sources as, % by weight, carbon (80.2-84.3), hydrogen (9.8-10.8), nitrogen (0.2-1.2), sulphur (0.9-6.6) and oxygen (0.4-1.0); and in mg kg-1, nickel (10-139), vanadium (7-1590), iron (5-147), manganese (0.1-3.7 ), calcium (1-335), magnesium (1-134) and sodium (6-159).

How bitumen functions have to do with how the molecules interact with each other as well as with other materials such as aggregate surfaces and water. The amount of hetero-molecules of sulphur, nitrogen, oxygen, and metals in some bitumen molecules makes them slightly polar. In bitumen chemistry, if the molecules contain hetero-atoms, they are better able to form molecular associations, and this has a great influence on the physical properties as well as the performance of bitumen (Goodrich *et al*., 1986). However, bitumen is very much insoluble in water because of its inert property (Kriech, 1990; Brandt and de Groot, 2001).

Bituminous products are often used in lining drinking water reservoirs and pipelines for the supply of drinking water; retention ponds are often coated with asphalt to prevent liquid industrial waste products from leaching into the soil; while bitumen is also used to line hazardous waste sites to prevent rainwater from leaching the wastes into groundwater (APA, 2011). The paving and roofing materials made from bitumen materials are subject to water runoff from rainfall. The heavy metal contamination of highway runoff water and roadside soils has been reported (Warren and Birch, 1987; Strecker *et al*., 1990; Pagotto *et al*., 2000; Lau *et al*., 2009) but Cooper *et al*. (1996) noted the source as the vehicles that plied the roads rather than from bitumen pavements.

Heavy metals including both essential and non-essential elements have eco-toxicological effects on living organisms (Storelli *et al*., 2015). The pollution of water by heavy metals is a serious global problem due to the toxicity and the ability to accumulate in the water and the subsequent consumers (Fabio *et al*., 2016). Heavy metal toxicity is one of the major current environmental health problems and is potentially dangerous because of bio-accumulation through the food chain (Aycicek *et al*., 2008) and this can cause hazardous effects on animal and human health (Aschner, 2002). The concentrations of heavy metals in the aquatic ecosystems are generally monitored by analyzing water, sediments and associated biota samples to assess the levels of accumulation (Camusso *et al*., [1995](https://tandfonline.com/doi/full/10.1080/23311843.2016.1140001)).

Several studies on the bituminous deposits in Ondo State, Nigeria have been carried out (Lameed and Ogunsusi, 2002a, b; Adebiyi and Asubiojo, 2008; Olajire *et al*., 2007, 2008; Olabemiwo *et al*., 2011; Fagbote and Olanipekun, 2013; Victor-Oji *et al*., 2017; Ogunsusi and Adeleke, 2019) with emphasis on the characteristic constituents, hydrocarbon content and metal toxicity of the mineral. There is the paucity of information on the quality of surface water bodies in the bitumen belt of Ondo State, Nigeria, particularly with regards to the inter-relationships of the heavy metals with one another. This study is aimed at evaluating the impact of bitumen seepage on the heavy metal concentration of the surface water in the bitumen belt of Ode-Irele, Ondo State, Nigeria, and how the metals associate with one another to influence their availability. The hypothesis is that the metal concentrations of surface waters in the seepage and control sites are not significantly different and that there are no associations between the levels of the metals.

**Materials and Methods**

***Study site***

The study was carried out at Ode-Irele in Ondo State, Southwest of Nigeria (Fig 1). Ode-Irele is located in the southern fringe of the state between latitudes 06º 16ʹ to 06º 40ʹN and longitudes 04º 47ʹ to 05º 10ʹE.

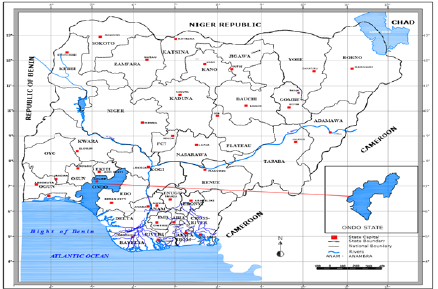


Fig. 1:Thebitumen exploration belt of Irele Local Government Area, Ondo State, Nigeria

Source:Ogunsusi and Adeleke (2017)

*Sampling Techniques*

Composite water samples were collected to a depth of 30 cm midstream at seepage sites in Loda (S1), Ludasa (S2), Petu (S3) and Omanira (S4); and at four locations (C1, C2, C3, and C4) in Ebute-Irele, about 12 km away from the seepage sites, which served as the control. The water samples were collected in plastic bottles, pre-rinsed at least three times with the sample water, and taken to the Department of Agronomy, University of Ibadan, Nigeria within 12 hours for analysis to determine the metal concentrations. The heavy metals - Fe, Mn, Cu, Pb, Cd, Cr, Ni, V, Zn, and As; and alkali metals- Ca, Mg, K, and Na were determined on an atomic absorption spectrometer (Perkin-Elmer, 1968).

*Data analysis*

The data of metals’ concentrations from the seepage and control sites were analyzed using descriptive statistics and t-test at p<0.05. The associations that exist among metals of surface water were analysed using regressive correlation. The values of the metals were compared between seepage and control sites, and with recommended Federal Environmental Protection Agency (FEPA, 1991; 2003), World Health Organization (WHO, 2004; 2010), and FEQGs (2016) guidelines. The standard guidelines are useful in assessing the risk of surface water pollution (Song *et al.*,2013) and for the proper management of water (Adhikary *et al*., 2010).

**Results**

***Heavy metal concentrations in surface water***

The mean concentrations of the metals in the surface water of bitumen seepage site and the control are shown in Table 1. The concentrations of Ni, Ca, Mg, and Na were higher in the seepage site but only Ni showed a significant difference between the surface water of the seepage site (0.40 ± 0.00 mg L-1) and the control (0.30 ± 0.00 mg L-1). The contents of Mn, Fe, Cd, V, and As were the same while the control contained higher Zn, Pb, Cr, and K which were not significantly different.

**Table 1: Heavy metals and alkali metals in surface water of the bitumen belt in Ondo State**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Metal | Mean mg L-1 | | t-value | Df | P | SD | | FEPA (1991) | FEPA (2003) | WHO (2004) | WHO (2010) | FEQGs (2016) |
| Seepage Site | Control Site | Seepage | Control | mg L-1 | mg L-1 | mg L-1 | mg L-1 | mg L-1 |
| Mn | 12.00 | 12.00 | 0.26 | 6 | 0.81 | 0.0030 | 0.0010 |  | 0.03 |  | 0.40 |  |
| Fe | 2.10 | 2.10 | 0.38 | 6 | 0.71 | 0.0000 | 0.0000 |  | 0.03 |  | 0.30 |  |
| Cu | 0.65 | 0.60 | 1.00 | 6 | 0.36 | 0.0006 | 0.0008 |  | 0.03 |  | 2.00 |  |
| Zn | 1.50 | 1.70 | 0.83 | 6 | 0.44 | 0.0001 | 0.0004 |  | 0.012 |  | 3.00 |  |
| Pb | 0.05 | 0.07 | 0.30 | 6 | 0.77 | 0.0000 | 0.0000 |  | 0.06 |  | 0.01 |  |
| Cr | 0.05 | 0.07 | 2.18 | 6 | 0.10 | 0.0000 | 0.0000 | 0.05 |  |  | 0.05 |  |
| Cd | 0.03 | 0.03 | 0.66 | 6 | 0.54 | 0.0000 | 0.0000 |  | 0.04 |  | 0.003 |  |
| Ni | 0.40\* | 0.30\* | 2.45\* | 6 | 0.05\* | 0.0000\* | 0.0000\* | 0.1-0.2 |  |  | 0.07 |  |
| V | 0.30 | 0.30 | 0.47 | 6 | 0.66 | 0.0002 | 0.0001 |  |  |  |  | 0.12 |
| As | 0.01 | 0.01 | 0.00 | 6 | 1.00 | 0.0000 | 0.0000 | 0.01 |  |  | 0.01 |  |
| Ca | 141.30 | 137.50 | 0.75 | 6 | 0.48 | 0.0090 | 0.0141 |  |  | 150 |  |  |
| Mg | 57.80 | 53.00 | 1.96 | 6 | 0.10 | 0.0039 | 0.0029 |  |  | 150 |  |  |
| K | 3.00 | 4.00 | 1.73 | 6 | 0.13 | 0.0008 | 0.0008 |  |  | 200 |  |  |
| Na | 13.30 | 4.00 | 1.00 | 6 | 0.36 | 0.0185 | 0.0008 |  |  | 200 |  |  |

NB: marked t-value is significant at P < 0.05000

***Heavy metal concentrations and the permissible limits***

The Mn level across all locations sampled ranged from 9.80 to 16.20 mg L-1 (Table 2). The range of Mn values exceeds the WHO (2010) guideline of 0.40 mg L-1 and FEPA (2003) guideline of 0.03 mg L-1. The Fe level ranged between 1.80 and 2.20 mg L-1 and was higher than the WHO (2010) guideline of 0.3 mg L-1 and FEPA (2003) guideline of 0.03 mg L-1. The Cu level ranged between 0.60 and 0.70 mg L-1 and was lower than the WHO (2010) limitation guideline of 2.0 mg L-1 but higher than FEPA (2003) limitation guideline of 0.3 mg L-1. The Zn level varied between 1.50 and 1.70 mg L-1 being below the WHO (2010) guideline of 3.0 mg L-1 but less than the FEPA (2003) guideline of 0.012 mg L-1. The Pb content was between 0.005 and 0.05 mg L-1 and far below the WHO (2010) guideline at 0.01 mg L-1 and FEPA (2003) guideline of 0.06 mg L-1.

The range of values for Cr was between 0.02 and 0.07 mg L-1 with the lower limit below the WHO (2010) and FEPA (1991) guideline of 0.05 mg L-1 while the upper range was higher. The Cd varied between 0.02 and 0.03 mg L-1 and was higher than the WHO (2010) guideline of 0.003 mg L-1 but lower than FEPA (2003) guideline of 0.4 mg L-1. The range of nickel was 0.004 to 0.40 mg L-1 with the lower limit below the WHO (2010) guideline of 0.1mgL-1 and FEPA (1991) 0.1-0.2 mg L-1 but the upper value was higher. The range of V was 0.03 to 0.4 mg L-1 with the lower value less than FEQGs guideline of 0.12 mg L-1 while the upper value was higher. The level of As ranged between 0.01 and 0.02 mg L-1 which is within the WHO (2010) and FEPA (1991) guideline of 0.01 mg L-1.

**Table 2: Heavy metals in the surface water at various locations in the bitumen belt of Ondo State**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Location | Elements (mg L-1) | | | | | | | | | |
|  | Mn | Fe | Cu | Zn | Pb | Cr | Cd | Ni | V | As |
| S1 | 12.20 | 2.20 | 0.60 | 1.50 | 0.06 | 0.06 | 0.03 | 0.4 | 0.30 | 0.01 |
| S2 | 9.90 | 1.80 | 0.70 | 1.50 | 0.04 | 0.05 | 0.02 | 0.4 | 0.40 | 0.01 |
| S3 | 16.20 | 2.20 | 0.60 | 1.60 | 0.005 | 0.02 | 0.02 | 0.4 | 0.03 | 0.02 |
| S4 | 9.80 | 2.00 | 0.70 | 1.50 | 0.04 | 0.06 | 0.03 | 0.4 | 0.40 | 0.01 |
| Mean | 12.00 | 2.10 | 0.65 | 1.50 | 0.04 | 0.05 | 0.03 | 0.3 | 0.3 | 0.01 |
| C1 | 11.20 | 2.00 | 0.60 | 2.20 | 0.04 | 0.06 | 0.03 | 0.3 | 0.3 | 0.02 |
| C2 | 12.00 | 1.90 | 0.50 | 1.60 | 0.03 | 0.07 | 0.3 | 0.2 | 0.4 | 0.01 |
| C3 | 13.30 | 2.20 | 0.70 | 1.80 | 0.05 | 0.08 | 0.02 | 0.4 | 0.3 | 0.01 |
| C4 | 9.90 | 2.30 | 0.60 | 1.20 | 0.04 | 0.07 | 0.03 | 0.3 | 0.3 | 0.01 |
| Mean | 12.00 | 2.10 | 0.60 | 1.50 | 0.04 | 0.05 | 0.03 | 0.3 | 0.3 | 0.01 |
| FEPA(1991) |  |  |  |  |  | 0.05 |  | 0.1 - 0.2 | - | 0.01 |
| FEPA(2003) | 0.03 | 0.03 | 0.30 | 0.0123 | 0.06 |  | 0.04 |  | - |  |
| WHO(2010) | 0.40 | 0.3 | 2.00 | 3.00 | 0.01 | 0.05 | 0.003 | 0.01 | - | 0.01 |

***Alkali metal concentrations and the permissible limits***

The concentrations of alkali metals and their permissible limits are as presented in Table 3. The Ca level ranged between 132 and 152 mg L-1 in seepage site with the lower limit less than the WHO (2004) guideline at 150 mg L-1 but the upper limit higher than the guideline. Mg ranged between 55 and 62 mg L-1 and the values were lower than the WHO (2004) guideline of 150 mg L-1. The range of K was between 2 and 4 mg L-1 which was lower than the WHO (2004) guideline of 200 mg L-1. The Na ranged between 4 and 41 mg L-1 and lower than WHO (2004) guideline at 200 mg L-1.

**Table 3: Available alkali metals in surface water of the bitumen belt in Ondo State**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Elements (mg L-1) | | | |
| Ca | Mg | K | Na |
| S1 | 132.00 | 54.00 | 2.00 | 4.00 |
| S2 | 145.00 | 60.00 | 3.00 | 4.00 |
| S3 | 136.00 | 55.00 | 3.00 | 4.00 |
| S4 | 152.00 | 62.00 | 4.00 | 41.00 |
| Mean | 141.00 | 58.00 | 3.00 | 13.00 |
| C 1 | 125.00 | 55.00 | 3.00 | 4.00 |
| C 2 | 145.00 | 51.00 | 5.00 | 5.00 |
| C3 | 121.00 | 50.00 | 4.00 | 3.00 |
| C 4 | 149.00 | 56.00 | 4.00 | 4.00 |
| Mean | 135.00 | 53.00 | 4.00 | 4.00 |
| WHO (2004) | 150 mg L-1 | 150 mg L-1 | 200 mg L-1 | 200 mg L-1 |

***Associations between the metals***

The correlation coefficients of the associations between the metals in surface water of the bitumen belt are presented in Table 4. The positive correlations are: Fe with Cu, Mn, Pb, Cr, Ni, V, and Zn, and Ca, Mg, K and Na but only Cu and Na were significant (P<0.05); and Mn with Cu, Pb, Cr, Ni, V, and Zn; Ca, Mg, K, and Na but only V was significant (P<0.05). The other metals had positive correlations: V with Cu, Pb, Cr, Ni, As, Zn, Ca, Mg, K and Na but only Mn was significant. Cu with Pb, Cr, Ni, Zn, and Na; Ni with Pb, Cr, As, Zn and Na; Pb with Ca, and Na; Cr with Cd, As and Zn; Cd with As, Zn, Ca, Mg and K; As with Zn, Mg, and K; Zn with Ca, Mg and K; Ca with Mg and K; Mg with Ca, K and Na; and K with Na. The negative correlations are Cd with Fe, Cu, Mn, Pb, Ni, V, and Na but the association between Pb significant (p<0.05); As with Fe, Cu, Mn, Pb, Ca and Na; Cu with Cd, As, Ca, Mg, and K; Pb with Cr, Zn, Mg and K; Cr with Ca, Mg and K; and Ca with Na.

Table 4: Correlation matrix of the relationships between the metals in the surface water of the bitumen belt in Ondo State

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Fe | Cu | Mn | Pb | Cr | Cd | Ni | V | As | Zn | Ca | Mg | K | Na |
| Fe | 1.0 | 0.8\* | 0.8\* | 0.6 | 0.0 | -0.7 | 0.2 | 0.4 | -0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.8\* |
| Cu | 0.8\* | 1.0 | 0.6 | 0.5 | 0.2 | -0.6 | 0.4 | 0.2 | -0.2 | 0.3 | -0.3 | -0.4 | -0.4 | 0.7 |
| Mn | 0.8\* | 0.6 | 1.0 | 0.6 | 0.4 | -0.7 | 0.6 | 0.9\* | -0.1 | 0.3 | 0.2 | 0.1 | 0.0 | 0.8 |
| Pb | 0.6 | 0.5 | 0.6 | 1.0 | -0.3 | -1.0\* | 0.3 | 0.4 | -0.8\* | -0.5 | 0.1 | -0.3 | -0.2 | 0.5 |
| Cr | 0.0 | 0.2 | 0.4 | -0.3 | 1.0 | 0.1 | 0.8\* | 0.6 | 0.8\* | 0.6 | -0.6 | -0.2 | -0.3 | 0.3 |
| Cd | -0.7 | -0.6 | -0.7 | -1.0\* | 0.1 | 1.0 | -0.4 | -0.4 | 0.7 | 0.4 | 0.1 | 0.4 | 0.3 | -0.6 |
| Ni | 0.2 | 0.4 | 0.6 | 0.3 | 0.8\* | -0.4 | 1.0 | 0.8\* | 0.3 | 0.2 | -0.6 | -0.4 | -0.4 | 0.5 |
| V | 0.4 | 0.2 | 0.9\* | 0.4 | 0.6 | -0.4 | 0.8\* | 1.0 | 0.2 | 0.2 | 0.1 | 0.3 | 0.2 | 0.6 |
| As | -0.4 | -0.2 | -0.1 | -0.8 | 0.8\* | 0.7 | 0.3 | 0.2 | 1.0 | 0.7 | -0.3 | 0.2 | 0.0 | -0.1 |
| Zn | 0.3 | 0.3 | 0.2 | -0.5 | 0.6 | 0.4 | 0.2 | 0.2 | 0.7 | 1.0 | 0.0 | 0.3 | 0.1 | 0.3 |
| Ca | 0.2 | -0.3 | 0.2 | 0.1 | -0.6 | 0.1 | -0.6 | 0.1 | -0.3 | 0.0 | 1.0 | 0.9\* | 0.7 | -0.0 |
| Mg | 0.1 | -0.4 | 0.1 | -0.3 | -0.2 | 0.4 | -0.4 | 0.3 | 0.2 | 0.3 | 0.9\* | 1.0 | 0.9\* | 0.1 |
| K | 0.1 | -0.4 | 0.0 | -0.2 | -0.3 | 0.3 | -0.4 | 0.2 | 0.0 | 0.1 | 0.7 | 0.9\* | 1.0 | 0.3 |
| Na | .8\* | 0.7 | .8\* | 0.5 | 0.3 | -0.6 | 0.5 | 0.6 | -0.1 | 0.3 | -0.0 | 0.1 | 0.3 | 1.0 |

\* Correlations are significant at P < 0.05000

**Discussion**

The mean concentrations of the metals in the surface water were not significantly different between the bitumen seepage and the control sites. This suggests that the levels of these metals in bitumen are probably not enough to bring about their release to cause accumulation in the water sources. However, the concentrations of Ni, Ca, Mg, and Na was higher in the seepage site probably in relation to the elemental analysis of bitumen samples which has shown the preponderance of Ni, V, Fe, Mn, Ca, and Na (Asphalt Institute and Eurobitume, 2015). These metals might have leached from the bitumen and may be potential environmental threats if allowed to accumulate in surface water. This is, however, not in agreement with Elinge *et al*. (2011) who reported higher levels of some metals (Ca, Mg, Na, and K) in the control site than this seepage site.

The higher levels of some metals than the WHO (2010) and FEPA (2003) guidelines point to the possible levels of toxicity in the surface water impacted by bitumen seepage. The higher level of Mn may not be unconnected with its wide distribution as one of the most abundant elements in the earth's crust. It is an essential trace element with many biological functions but toxic at higher doses (Erikson *et al*., 2005). Zhang *et* al. (2014) noted that very high mean concentrations of Mn in drinking water are correlated with cancer incidences and mortality. Since Mn is a component of bitumen (Asphalt Institute and Eurobitume, 2015), the potential toxicity in the study area would be from bitumen seepage. Fe as one of the elemental components of bitumen was higher than the WHO (2010) and FEPA (2003) guidelines and this may pose a potential environmental threat. This toxicity might have resulted from the transportation of the metal from bitumen seepage to the nearby surface water.

The Cu level was lower than WHO (2010) guideline but higher than FEPA (2003) standard such that the upper limit may pose a potential environmental threat. Although man can adapt to excessive exposure to Cu from water by decreasing the absorbed fraction (Turnlund *et al.*, 1989; Uauy *et al*., 1998), its consumption above 5-6 mg L-1 results in nausea, vomiting, and diarrhoea (WHO, 2003). The Zn level was higher than FEPA (2003) guideline and can be a potential environmental threat. It has poor mobility in anaerobic environments such that severe contamination can occur in surface water primarily near a point source of its release ([Barceloux](https://www.tandfonline.com/author/Barceloux%2C+Donald+G) and [Barceloux](https://www.tandfonline.com/author/Barceloux%2C+Donald+G), 1999). The exposure to excess Zn compounds has been implicated in cases of irritation and corrosion of the gastrointestinal tract, acute renal tubular necrosis, and interstitial nephritis.

The Pb level was lower than WHO (2010) and FEPA (2003) guidelines and may not pose a serious threat to the environment. However, Pb accumulation in surface water should be avoided because chronic exposure can result in mental retardation, brain damage, and kidney damage in man (Martin and Griswold, [2009](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4427717/#CIT0051)).

The upper limit of Cr was higher than WHO (2010) and FEPA (1991) guidelines. The potential environmental threat relates to its high solubility in water, high mobility, and ease of reduction. Excessive exposure to Cr can affect the respiratory tract, liver, kidney, gastrointestinal and immune systems, and the blood, and also cause dermatitis and ulceration of the skin (Saha *et al*., 2011). The higher Cd level than WHO (2010) guideline has the potential to pose environmental threats. Jaishankar et al. (2014) observed that Cd is highly soluble in water which would enhance its bioaccumulation and bioavailability. The long-term exposure causes morpho-pathological changes in the kidneys. Although Ni is naturally-occurring in surface water, the upper limit higher than the WHO (2010) and FEPA (1991) guidelines might have come from bitumen (Asphalt Institute and Eurobitume, 2015) and this accumulation can pose a potential threat to the environment. The upper limit of V was higher than FEQGs (2016) guideline which can pose threats to livestock and human health. A variety of health problems have been reported in humans exposed to high doses of V, even as food supplements (EFSA, 2004). The As upper value was higher than the WHO (2010) and FEPA (1991) guidelines and may pose potential environmental problems to livestock and man. Smith et al. ([2000](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4427717/#CIT0086)) and IARC (2004) have provided pieces of evidence linking long-term As exposure and intake from drinking water with nausea and vomiting, reduced production of erythrocytes and leukocytes, etc.

The total cationic content of natural water comes from Ca2+, Mg2+, K+, and Na+. The levels of these alkali metals below WHO (2004) and FEPA (1991) guidelines in this study show their low environmental pollution potentials. The Ca level would be beneficial to human and animal consumption through its contribution to the hardness of water which is one of the natural characteristics that enhances its palatability and consumer acceptability. Mortality rates and heart diseases are lower in areas with hard water (Tiwari *et al*., 2015). The upper limit which was higher than the WHO (2004) guideline could have been due to leaching from the bitumen (Asphalt Institute and Eurobitume, 2015). Mg also contributes to total hardness in water but it is not a potential environmental threat despite being one of the elemental components of bitumen (Asphalt Institute and Eurobitume, 2015). K is the least abundant of the four cations in natural water (Tallin, 2010) and the potential threat of its low concentration is to limit the distribution of aquatic organisms. The low Na level in the study area may not pose a potential environmental threat even as van Dam *et al*. (2014) noted that replacement of Ca and Mg with Na ion did not cause toxicity but increased the reproduction in an aquatic organism.

**Conclusion**

The concentrations of some metals determined in surface water samples collected from the bitumen belt of Ondo State, Nigeria showed that Ni, Ca, Mg, and Na were higher in seepage sites than in the control site with only the Ni significantly different. The ranges of values of the metals- Mn, Fe, Cu, Zn, Cr, Cd, Ni, V, As, and Ca were higher than WHO (2004; 2010) and FEPA (1991; 2003) guidelines. The levels of these metals, especially Ni, should be monitored to avoid hyperaccumulation in surface water during the actual development of bitumen.

The metals with which Fe, Mn, Ni, V, and Ca had positive correlations and especially where significant should be closely monitored during the bitumen development phase. This is because the metals, apart from being at higher concentrations than the guidelines, are elemental components of bitumen whose exploitation can speed up the seepage and accumulation of the metals in surface water and raise their toxicity levels

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