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Concentrations Of Heavy Metals And Polycyclic Aromatic Hydrocarbons In Surface And Groundwater From Communities In Soku Oil Field In Rivers State, Nigeria

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Abstract
The levels of heavy metals and Polycyclic Aromatic Hydrocarbons (PAHs) in Surface and Groundwater from communities in Soku Oil Field in Rivers State, Nigeria were determined in this study using Atomic Absorption Spectrophotometric technique for heavy metals and Gas Chromatography-Mass Spectroscopy for PAHs. The results for surface water samples showed mean levels of The results for surface water samples showed mean levels of Iron (7.417±0.428 mg/L), Chromium (0.152±0.007 mg/L), copper (0.948±0.025 mg/L), manganese (0.389±0.479 mg/L) and Lead (0.209±0.281 mg/L), Nickel (0.310±0.19 mg/L), and cadmium (0.056±0.047mg/L). The results for groundwater samples indicated maximum mean levels of Iron (7.537±0.428 mg/L), Chromium (0.147±0.007 mg/L), copper (0.945±0.025 mg/L), manganese (0.996±0.479 mg/L) and Lead (0.632±0.005 mg/L), Nickel (0.196±0.19 mg/L), and cadmium (0.056±0.047 mg/L). Nickel, Chromium, Manganese, Iron, Lead and Cadmium levels were above standard limits in all surface and groundwater stations. Total Polycyclic Aromatic Hydrocarbon above permissible limits. Carcinogenic Risk levels for exposure to lead, nickel, chromium and arsenic, were above the threshold value of 10^{-4} indicating high Carcinogenic Risk. The findings of this study showed that the water in the area requires adequate treatment for irrigation and recreation purposes. This study recommends that surface water in the study area should not be used for domestic and irrigation purposes as prolonged usage may result in health hazards.

Keywords: *Heavy Metals, Polycyclic Aromatic Hydrocarbons, Surface and Groundwater, Soku*

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I. Introduction

Soku as a community is referred to an ancient repository of oil and gas exploration and exploitation after Oloibiri oil field in the Niger Delta region of Nigeria (Inokoba and Imbua, 2010). The community is a host to three (3) flow stations (Ekulama I and II, and Soku). The Soku oil field and gas plant are the major oil field facilities that deliver the bulk of the gas to NLNG (The Nigeria Liquefied Natural Gas situated at Finima Town in Bonny Kingdom) (Ajayi and Oyharhe, 2016). The Creeks of Soku have unique ecological characteristics. Over the past few decades, pollution has caused a tremendous deterioration in the quality of the soil, water and sediment in the area. Special attention has been given to the area due to the ramifications of environmental pollution, growing needs of the population in terms of land and mineral resources (Inegbedion, 2010).

The aquatic environment is one component of the environment that has suffered from pollution due to the fact that it represents one of the receiving ends for varying degree of pollutants from different sources, especially heavy metals which are adsorbed in sediments and bioaccumulate overtime. The problem of water and sediment pollution has become a source of concern to all major stakeholders due to the degree of deterioration of the environment. Heavy metals are transported by runoff from industries, municipalities and urban areas; most of these metals end up accumulating in the soil and sediments of water bodies (Siegel, 2002). Contaminated water bodies can no longer support human use. Also, there is marked drift in the ability of contaminated water bodies to support its constituent biotic communities which include fishes and other aquatic organisms.

Water, a prime natural resource and precious national asset, forms the chief constituent of the ecosystem. Water sources may be mainly in the form of rivers, lakes, glaciers, rain water, ground water etc. Besides the need of water for drinking, water resources play a vital role in various sectors of economy such as agriculture, livestock production, forestry, industrial activities, hydropower generation, fisheries and other creative activities. The availability and quality of water either surface or ground, have been deteriorated due to some important factors like increasing population, industrialization, urbanization etc (Tyagi *et al,* 2013).

Rivers are indispensable freshwater systems that are essential for the continuation of life. They are resources of great importance across the globe. The benefits of these systems to all living organisms cannot be over emphasized as they remain one of the most vital human needs (Edwin & Murtala, 2013).

The quality of any surface water body is a function of either or both natural influences and human activities. Of all the human activities, industrial waste is the most common source of water pollution in recent times. The quantum of these pollutants is such that rivers receiving these effluents cannot give dilution needed for their continued existence as good quality water sources (Edwin & Murtala, 2013).

Surface water sources in pristine environments are always of better quality when compared to those prone to anthropogenic influences. Surface waters are the best sinks for several point and non-point sources of pollution such as wastewater from agricultural and industrial processes, storm runoff amongst others (Edokpayi *et al,* 2017, Odiyo *et al,* 2012).

Groundwater is often the first alternative choice of many consumers due to its perceived cleanness and safeness. However, many studies have shown that groundwater can appear clean but houses a wide variety of pathogenic organisms (Olasoji *et al,* 2019). The safety of groundwater (shallow and deep groundwater sources) depends on a number of factors amongst which are (I) the geology of the area (II) human activities/land use activities of the area (III) environmental and meteorological conditions of the area (Olasoji *et al,* 2019).

Rural dwellers rely basically on hand-dug wells for potable water supply as the streams usually dry up in dry season. These resources are under threat from pollution either from human life style manifested by the low level of hygiene practiced in the developing nations (Adekunle *et al,* 2007; Punmia & Jain, 1998; Ikem *et al,* 2002; Akujieze *et al*, 2003). The neglect of rural areas in most developing countries in terms of basic infrastructures such as pipe-borne water and sanitation facilities exposes the villagers to a variety of health-related problems such as water – borne diseases (Sridhar, 2000).

Groundwater pollution is mainly due to the process of industrialization and urbanization that has progressively developed over time without any regard for environmental consequences (Longe and Balogun, 2010).

Heavy metals can be from natural and anthropogenic origin. The anthropogenic origin of heavy metal greatly influences all components of the ecosystem presenting serious danger to all forms of life. The effect of anthropogenic activities has substantively intensified the presence of heavy metals concentrations in the environment (Lu *et al*., 2015). This is as human activities have been found to contribute more to environmental pollution due to the everyday manufacturing of goods to meet the demands of the large population (Goudie, 2018).

Heavy metals are naturally found in the earth's crust. They are mainly elements that have a high atomic number and a density at least five (5) times greater than that of water (Mishra *et al*., 2019)**.** Despite the fact that these metals are natural constituents of the environment and are wide spread, they are considered as contaminants when they have exceeded the permissible limits or concentrations. Their multiple applications in the industrial, domestic, agricultural, medical and technological use have led to their availability and distribution in the environment; raising concerns on potential effects on human health and the environment at large (Horrigan *et al*., 2002). Heavy metal contamination of the coastal communities continues to attract the attention of environmental researchers due to the increased input contributed to coastal water (Zhuang and Gao, 2014).

Polycyclic aromatic hydrocarbons (PAHs) are organic pollutants produced by anthropogenic activities associated with industrialization and urbanization, as well as through natural activities (Qiao *et al.,* 2018). PAHs in the environment are primarily of pyrogenic, petrogenic, and biologic origin (Hąc-Wydro *et al.,* 2019). Most PAHs are believed to originate from pyrogenic sources such as volcanoes and the combustion of petroleum products and plant materials (Gennadiev and Tsibart, 2018). PAHs of diagenetic or biogenic origin include those formed by plants, algae, microorganisms and phytoplankton or during slow alterations of organic matter (Rocha and Palma, 2019). PAHs are derived from the incomplete combustion of organic matter, such as transportation fuel, emissions from power plants and petroleum spills, coal mining, and other anthropogenic sources. Mostly PAHs are hydrophobic and lipophilic and therefore very difficult to biodegrade (Kronenberg *et al.,* 2017).

The USEPA has categorized 16 of the PAHs as priority contaminants based on their possible for human exposure, toxicity, frequency of occurrence at hazardous waste sites, and the extent of information available (Bojes and Pope, 2017). PAHs are widespread organic contaminants in the environment that are recognized to have carcinogenic and mutagenic effects, and to bioaccumulate in human and animal tissue (Adjiboye *et al.,* 2019). PAHs also have detrimental impacts on the fauna and flora of affected habitats, ensuing in the uptake and accumulation of toxic chemicals via food chains (biomagnification), and in some instances, serious health issues and/or genetic defects in humans (Chauhan *et al.,* 2008).

Heavy metals can be further ploughed back into the food chains through the bioaccumulation potentials in organisms such as plankton and invertebrate to fishes and finally biomagnified in man, upon consumption (Feelisch *et al.*, 2022). The impact on the food chains and food webs which represents the relationship and interdependence of one organism on another for food becomes impacted negatively. Humans, who feed at the highest level, are more prone and susceptible to serious health hazards owing to increased concentrations of heavy

metals in the food chain (Feelisch *et al.*, 2022). The disturbance on food chains can culminate into food insecurity, malnutrition, hunger and all impeding dangers facing the coastal population in the area (Siegel, 2002). It is therefore, significant to regularly assess heavy metal concentrations in surface water and groundwater to enable detection of changes in the creeks.

II. Methodology

Description of the Study Site and Sampling Techniques

The study site, Fig. 1, is located in Akuku Toru Local Government Area, Rivers State, Niger Delta region. Soku as a community is referred to as an ancient repository of oil and gas exploration and exploitation after Oloibiri oil field in the Niger Delta region of Nigeria**.** The community is a host to three (3) flow stations (Ekulama I and II, and Soku, and Oil Ream Development Project (ORD). The Soku oil field and gas plant are the major oil field facilities that deliver bulk of the gas to the Nigeria Liquefied Natural Gas (NLNG) situated at Finima, town in Bonny kingdom for exportation. Increase in oil exploitation and exploration activities had culminated into increase incidences of oil spills within the area. Spills had occurred accidentally and through the deliberate activities of the local populace who engage in illegal/artisanal refining (bunkering or kpoo fire) or protested against the operations of multinational oil companies operating within the area**.** The oil field and the gas plant are surrounded by a number of tidal estuarine water bodies from the Sombrero and Saint Bartholomew estuaries. The shorelines and creeks of these estuaries are occasionally inundated by spilled oil from oil spillage when it occurs. The building of the Abonnema- Degema Bridge contributed its share of toxic heavy metals; the heavy metal contaminants may be released from the sediment into the water column; leading to the possible contamination of benthic organisms living in contact with them and finally of all the benthic food chain (Ideriah *et al.,* 2012). In recent times, the activities of oil bunkering and the practice of dumping domestic wastes by the river/creek side has further worsened the contamination load of nearby surface water bodies in the Niger Delta. The ultimate discharge of effluents by industries and other anthropogenic activities in and around creeks and rivers constitute a major environmental challenge particularly in developing areas such as the Niger Delta in Nigeria (Moslen and Daka, 2013). These practices no doubt deteriorates the water quality and alters the natural dynamics of the aquatic ecosystem. It is therefore, necessary to regularly assess surface water bodies to enable detection of changes in aquatic systems.

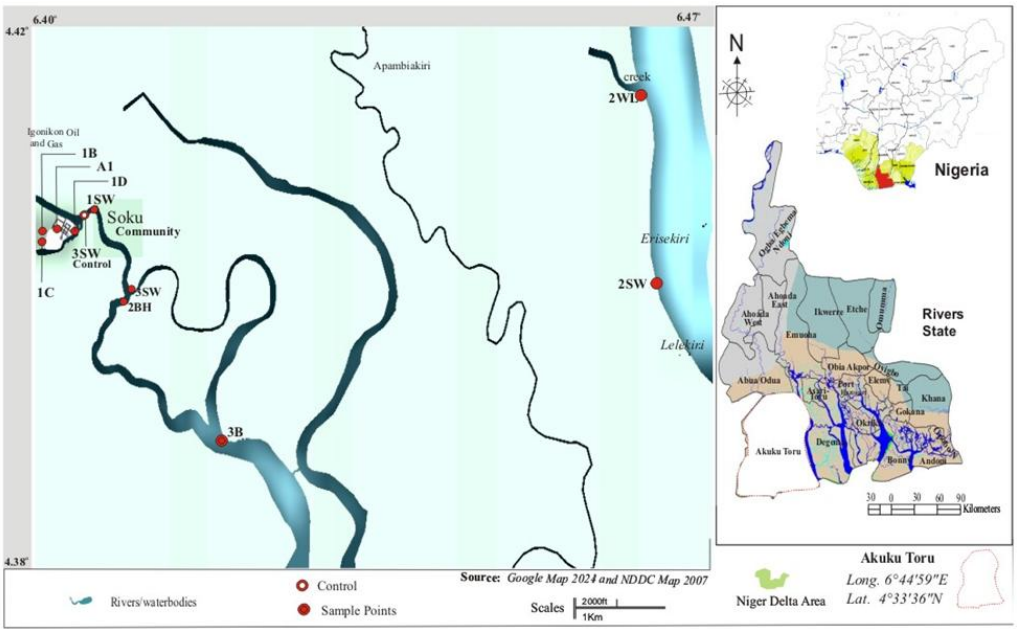

Figure 1: Map of the Study Area showing sampling points

Sampling Techniques

Surface and Groundwater samples at different locations were collected into glass bottles for PAH determination. Samples were also taken from site about 10km from the study site to represent control. Analysis of the samples were conducted in accordance with the American Public Health Association (APHA, 2005) for water and waste water analysis.

Surface water samples for heavy metal analyses were collected with nitric acid pre rinsed 1 liter plastic container and treated with 2ml nitric acid.

Determination of Heavy Metals

For the determination of heavy metals, the Atomic Absorption Spectrophotometry (Buck Scientific Model 200A spectrophotometer) was used. Two grams of the air-dried sediment was weighed and transferred to a conical flask. To each sample, 10 ml of nitric acid and 2 ml of perchloric acid was added and heated in a water bath to dryness. The solution was allowed to cool, and filtered into a 50 ml volumetric flask using a Whatman 42 filter paper and was made up to the mark with distilled water and used for the determination of the heavy metal concentrations.

Determination of Polycyclic Aromatic Hydrocarbons

The respective samples were raised into micro vials (100 microlitres) and preserved in the refrigerator until they are injected into the Gas Chromatography – Mass Spectrometer (GC-MS) instrument. The PAHs extracts were analyzed by using a 3800 Varian Gas Chromatography Coupled to a Varian Saturn 2200 Mass Spectrometer, equipped with a 30m x 0.25 mm i.d (inner diameter) WCOTCP-Sil 8 CB column. The GC – MS will be operated under the following conditions: the initial column temperature was 70 °C. After an initial holding time of 1 min, the temperature was programmed to rise to 300 °C at a rate of 10 °C /min for 30mins.

The injector and detector temperatures were 25 °C and 300 °C respectively. Helium was used as the carrier gas at a flow rate of 2 ml/min. The method will be according to the established procedure by the EPA method 8270D. PAHs concentrations were identified based on their retention time and confirmed by comparing their mass spectra with the reference standard.

III. Results And Discussion

Mean levels of heavy metals in the groundwater samples are shown in figure 2. Manganese levels ranged from <0.002±0.00 - 0.996±0.479 mg/L; Chromium levels ranged between 0.136±0.006 - 0.147±0.007 mg/L; Iron levels were between 6.633±0.262 and 7.537±0.428 mg/L; Lead levels ranged from 0.013±0.003 - 0.242±0.005 mg/L; Nickel levels ranged between <0.009±0.000 and 0.196±0.19 mg/L; Copper levels ranged from 0.872±0.004 - 0.945±0.025 and Cadmium levels ranged from 0.018±0.034 - 0.056±0.047 mg/L. The mean levels of heavy metals in the Surface water samples are shown in figure 3. Manganese levels ranged from 0.208±0.00 - 0.389±0.479 mg/L; Chromium levels ranged between 0.134±0.006 - 0.152±0.007 mg/L; Iron levels were between 6.476±0.262 and 7.417±0.428 mg/L; Lead levels ranged from 0.152±0.003 - 0.632±0.005 mg/L; Nickel levels ranged between 0.154±0.000 and 0.310±0.19 mg/L; Copper levels ranged from 0.879±0.004 - 0.948±0.025 and Cadmium levels ranged from 0.045±0.034 - 0.056±0.047 mg/L.

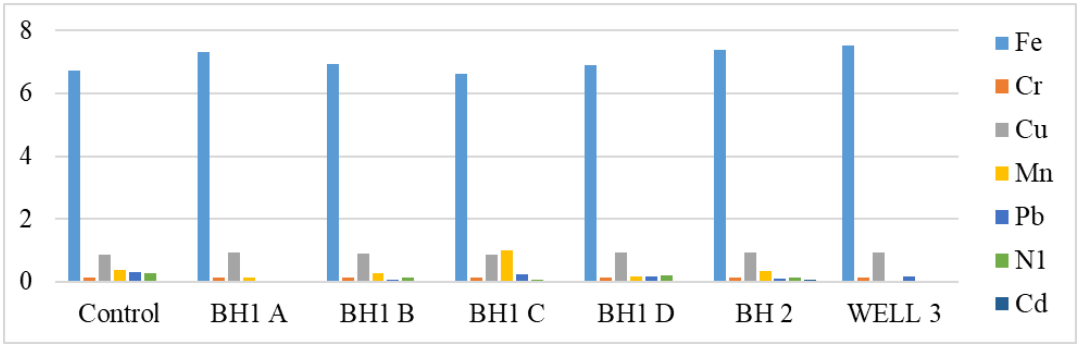

Figure 2: Variations in Levels of Heavy Metals in Groundwater

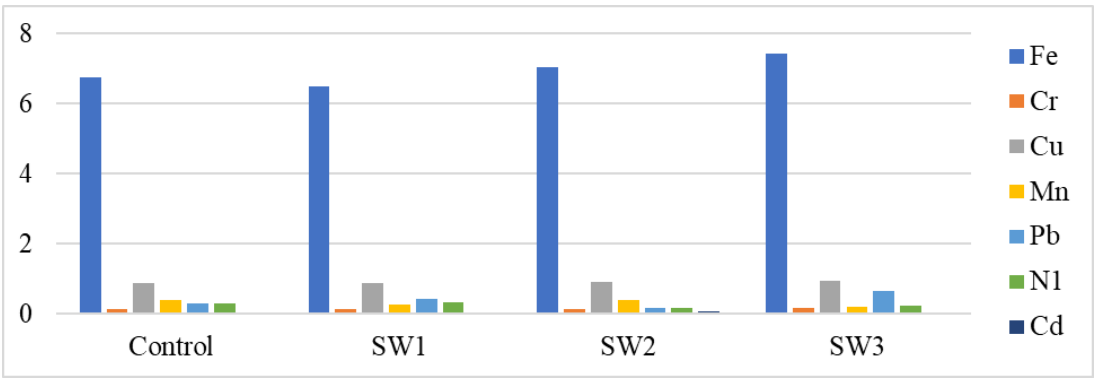

Figure 3: Variations in Levels of Heavy Metals in Surface Water

The acceptable limits for nickel by WHO and NSDWQ are 0.07 mg/L and 0.02 mg/L respectively. surface and groundwater samples in all the stations highly exceeded the set standard limits. The highest nickel level of 0.310 mg/L was recorded at station SW1 (surface water).

The mean levels for chromium in all the surface and groundwater samples exceeded the permissible limit of 0.05 mg/L set by WHO and NSDWQ. SW1 (surface water) recorded the lowest level of 0.134 mg/L while the highest level of 0.152 mg/L was recorded at SW3 (groundwater). Chromium ions in water may have an erythropoietin impact, such as an expanded event of goiter among people and animals (Oyeku and Eludoyin, 2010).

The mean levels of manganese in all stations fell above the permissible limit of 0.2 mg/L set by NSDWQ and the WHO limit 0f 0.05 mg/L. Except for BH1A (0.132 mg/L), BH1D (0.185 mg/L) and WELL3 (<0.002 mg/L) (groundwater) which were below the set limits. The permissible limit for iron, as set by WHO and NSDWQ, is 0.30 mg/L and all surface and groundwater samples had iron levels above the set limit. The highest level of 7.537 mg/L was recorded in station SW1 (surface water), while the lowest limit of 6.476 mg/L was recorded at station WELL3 (groundwater). Water containing an excessive concentration of iron has been reported to constitute a human health hazard leading to hemochromatosis, whose signs include fatigue and eventually, heart disease, liver complications, and diabetes (Nwachukwu *et al*., 2014).

The mean levels for lead in all the surface and groundwater samples exceeded the permissible limit of 0.01 mg/L as set by USEPA and NSDWQ. Station SW3 (groundwater) recorded the highest level of 0.632 mg/L while the lowest level of 0.013 mg/L was recorded at station BH1A (groundwater).

The acceptable limit for Cadmium in surface and groundwater, as set by WHO and NSDWQ is 0.003 mg/L. Surface and groundwater samples from all the stations had cadmium levels above the acceptable limits.

Copper levels ranged between 0.865 mg/L in Control to 0.948 mg/L in station SW3 (surface water). The levels of Cu in the water samples were below the NSDWQ and WHO acceptable limits of 1.0 mg/L and 2.0 mg/L respectively. These values observed in this study is in agreement with observations of Akankali and Davies (2021). However, the observed level of Cu in this study was low when compared to those reported by Edokpayi *et al.* (2016).

Surface water samples recorded higher concentrations of heavy metals such as iron (Fe), lead (Pb), and cadmium (Cd), primarily due to industrial discharge, surface runoff, and atmospheric deposition. These metals were more bioavailable in surface water, increasing their toxicity to aquatic organisms and human consumers. In contrast, groundwater had lower but still significant heavy metal contamination, likely from leaching through soil and rock layers, corrosion of underground pipes, and geological formations. Though partially filtered, some boreholes and wells exhibited metal concentrations exceeding WHO/NSDWQ limits, posing long-term health risks.

Result of the PAH analysis of the surface and groundwater samples is shown in Table 1. The levels of the various PAH within detection limit are as follows: Naphthalene levels ranged between 0.000 – 0.108 ppm; Acenaphthene levels ranged between 0.000 – 0.118 ppm; Acenaphthylene levels ranged between 0.000 – 0.028 ppm; Fluorene levels ranged between 0.000 – 0.028 ppm; Phenanthrene levels ranged between 0.000 – 0.016 ppm; Anthracene levels fell between 0.000 – 0.027 ppm; Fluoranthene levels fell between 0.000 – 0.023 ppm; Pyrene levels fell between 0.000 – 0.225 ppm; Benz(a)anthracene levels fell between 0.000 – 0.093 ppm; Chrysene levels fell between 0.000 – 0.097 ppm; Benzo(b)fluoranthene levels fell between 0.000 – 0.080 ppm; Benzo(k)fluoranthene levels fell between 0.000 – 0.016 ppm; Benzo(a)pyrene levels fell between 0.000 – 0.025 ppm; Indeno(1,2,3-c,d))pyrene levels fell between 0.000 – 0.087 ppm; Dibenz(a,h)anthracene levels fell between 0.000 – 0.034 ppm while Benzo{g,h,i)perylene levels fell between 0.000 – 0.014 ppm. Total PAH levels ranged between 0.082 and 0.648 ppm across all sampling stations.

Table 1: Levels of Polycyclic Aromatic Hydrocarbon

PAH COMPONENT (ppm)	control	SW1	SW2	SW3	BH1A	BH1B	BH1C	BH1D	BH2	WELL1	USEPA (2007)
Napthalene	0.000	0.070	0.002	0.063	0.000	0.000	0.000	0.000	0.108	0.000	**-**
Acenapthene	0.118	0.103	0.105	0.092	0.006	0.018	0.103	0.024	0.007	0.000	**0.002**
Acenaphthylene	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.028	0.000	**0.002**
Fluorene	0.007	0.028	0.025	0.025	0.000	0.013	0.028	0.025	0.014	0.000	**0.1**
Phenanthrene	0.006	0.006	0.008	0.006	0.010	0.009	0.006	0.016	0.004	0.000	**0.1**
Anthracene	0.014	0.000	0.005	0.000	0.004	0.000	0.000	0.000	0.027	0.000	**0.005**

Fluoranthene	0.023	0.010	0.017	0.009	0.015	0.002	0.007	0.011	0.000	0.000	**0.005**
Pyrene	0.225	0.000	0.032	0.000	0.000	0.021	0.030	0.140	0.016	0.000	**0.005**
Benz(a)anthracene	0.006	0.000	0.004	0.000	0.029	0.007	0.003	0.006	0.004	0.093	**0.0002**
Chrysene	0.097	0.000	0.026	0.000	0.012	0.008	0.016	0.000	0.049	0.000	**0.005**
Benzo(b)fluoranthene	0.080	0.003	0.008	0.003	0.003	0.045	0.006	0.000	0.015	0.014	**0.0002**
Benzo(k)fluoranthene	0.014	0.016	0.014	0.015	0.000	0.015	0.012	0.012	0.012	0.008	**0.0002**
Benzo(a)pyrene	0.021	0.006	0.015	0.005	0.000	0.000	0.025	0.000	0.004	0.009	**0.0002**
Indeno(1,2,3-c,d) pyrene	0.000	0.012	0.000	0.011	0.003	0.000	0.000	0.000	0.080	0.087	**0.0002**
Dibenz(a,h)anthracene	0.023	0.025	0.023	0.023	0.000	0.004	0.023	0.000	0.022	0.034	**0.0002**
Benzo{g,h,i)perylene	0.012	0.006	0.007	0.005	0.000	0.000	0.006	0.013	0.007	0.014	**0.0002**
Total PAHs	**0.648**	**0.285**	**0.265**	**0.257**	**0.082**	**0.142**	**0.265**	**0.263**	**0.397**	**0.259**	

Acenapthene levels were above the USEPA (2007) permissible limit of 0.002 ppm in control, SW1, SW2, SW3, BH1A, BH1B, BH1C, BH1D and BH2 stations. Well1 station recorded level below the permissible limit while levels were undetected in other stations. Acenaphthylene levels were above the USEPA (2007) permissible limit of 0.002 ppm in BH1D and BH2; other stations recorded acenaphthylene levels below the permissible limit. Fluorene and Phenanthrene levels were below the USEPA (2007) permissible limit of 0.01 ppm across all stations. Anthracene levels were above the USEPA (2007) permissible limit of 0.005 ppm in Control and BH2 stations. Fluoranthene levels were above the USEPA (2007) permissible limit of 0.005 ppm in Control, SW1, SW2, SW3, BH1A, BH1B, BH1C and BH1D stations. Pyrene levels were above the USEPA (2007) permissible limit of 0.005 ppm in Control, SW2, BH1B, BH1C, BH1D and BH2 stations. Benz(a)anthracene levels were significantly above the USEPA (2007) permissible limit of 0.0002 ppm in Control, SW2, BH1A, BH1B, BH1C, BH1D, BH2 and WELL1 stations. Chrycene levels were significantly above the USEPA (2007) permissible limit of 0.0002 ppm in Control, SW2, BH1A, BH1B, BH1C and BH2 stations. Benzo(b)fluoranthene levels were significantly above the USEPA (2007) permissible limit of 0.0002 ppm in Control, SW1, SW2, SW3, BH1A, BH1B, BH1C, BH2 and WELL1 stations. Benzo(k)fluoranthene levels were significantly above the USEPA (2007) permissible limit of 0.0002 ppm in all the sampling stations, except BH1A which is below the limit. Benzo(a)pyrene levels were significantly above the USEPA (2007) permissible limit of 0.0002 ppm in Control, SW1, SW2, SW3, BH1C, BH2, WELL1 stations. Indeno(1,2,3-c,d) pyrene levels were significantly above the USEPA (2007) permissible limit of 0.0002 ppm in SW1, SW3, BH1A, BH2 and WELL1 stations. Dibenz(a,h)anthracene levels were significantly above the USEPA (2007) permissible limit of 0.0002 ppm in Control, SW1, SW2, SW3, BH1B BH1C, BH2 and WELL1 stations. Benzo{g,h,i)perylene levels were significantly above the WHO (2007) permissible limit of 0.0002 ppm in Control, SW1, SW2, SW3, BH1C, BH1D, BH2 and WELL1 stations. The total PAH levels in all surface and groundwater samples exceed the limit of 5.0×10^{-4} ppm as recommended by USEPA (2007), and this poses serious environmental concerns as the consumers of the water from the sample area are liable to health risks due to bioaccumulation of these PAH compounds. The health effects of PAH compounds are not stereotyped; individual PAH compounds have different health effects (Rengarajan *et al.,* 2015). Many PAH compounds have mutagenic, carcinogenic, teratogenic, and immunotoxic effect on humans. Some chronic health effects of these PAH compounds include eye cataracts, kidney and liver damages, breathing problems, decreased immune function, lung malfunctions, and asthma-like symptoms (Abdel-Shafy and Mansour, 2016). Naphthalene, if ingested or inhaled in high concentrations, can cause the breakdown of red blood cells (Rengarajan *et al.,* 2015).

Surface water samples (SW1, SW2, and SW3) exhibited higher total PAH concentrations compared to most borehole and well samples. This suggests a more direct exposure to contamination sources. Groundwater samples, while also contaminated, displayed relatively lower PAH levels than surface water, except for BH2 and WELL1, which had comparable contamination levels to surface water samples. Surface water samples had a broader spectrum of PAH contamination, with a prevalence of fluoranthene, pyrene, and benzo (b) fluoranthene. Groundwater stations, on the other hand, were notably contaminated with benz (a) anthracene, dibenz (a,h) anthracene, and benzo(a)pyrene, which are more hydrophobic and persistent, suggesting possible subsurface leaching. Given the persistence and toxicity of PAHs, the presence of these contaminants in both surface and groundwater poses significant health risks. Surface water, being more exposed, is at risk of continuous contamination, while groundwater contamination raises concerns about long-term leaching and bioaccumulation.

IV. Conclusion

The assessment of surface and groundwater from the locations in the study area revealed all stations recorded high levels of lead, cadmium, manganese, chromium, nickel and iron; all above permissible limits which pose probable high toxic and carcinogenic risks. This study has contributed data to scarce information on Soku Oil Field.

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