**Int. j. adv. multidisc. res. stud.** 2022; 2(6):818-823

**Received:** 20-10-2022
**Accepted:** 30-11-2022

**International Journal of Advanced Multidisciplinary Research and Studies**

**ISSN: 2583-049X**

# Determination of Physico-Chemical, Heavy Metals and Health Risk Assessment of Santa Barbara River Niger Delta, Nigeria

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**Abstract**

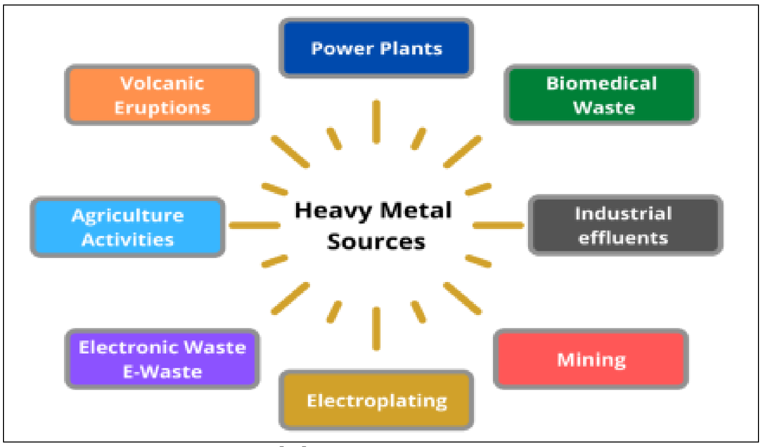
Water is an important component to human life. It contains environmental contaminants such as heavy metals that affect physicochemical parameter. The major aim of the present work is to assess the heavy metal pollution and health risk assessment of surface water from Santa Barbara River, Niger Delta. The present study focusses to bring an awareness among the people about the toxicological impact of oil spill on surface water and Physico – Chemical analysis of surface water. This analysis result was compared with the WHO standards of drinking water quality parameters for heavy metals such as Lead, Chromium, Nickel, Mercury and water quality parameters namely pH, Electrical conductivity, Total dissolved solids, Biological Oxygen Demand Dissolved oxygen, Nitrate, Sulphate etc. Various chemical methods was employed to investigate the extent level of pollution in surface water and health risk assessment was calculated for carcinogenic and non-carcinogenic risk index.

**Keywords:** Metals, AEEPCO, physicochemical parameter, Nigeria

## 1. Introduction

Water is an essential natural resource that sustains living organisms, maintains ecological balance for economic and developmental activities of all kinds. Life cannot exist cannot operate without water. Unlike many other raw materials there is no substitute for water in many of its uses. It is use in various sectors of the economy such as agricultural activities, livestock production, forestry, industrial activities, hydropower generation, fisheries and recreational activities. The quality of surface waters has been deteriorating due to increasing population, industrialization and urbanization threatening human and ecological health (Tyagi *et al*., 2013; Khatri and Tyagi, 2015; Adimalla and Qian, 2019; Deo *et al*., 2021) [2, 3, 4, 5].Water resources are the most exploited of the nature. Pollution of water bodies is increasing steadily due to rapid industrialization, urbanization and changing life styles. This alteration affects the physical, chemical and biological characteristics of water. Anthropogenic pollution from multiple sources releases contaminant such such as heavy metals into water making it harmful to humans and aquatic lives (Udhayakumar *et al*., 2016) [1]. These heavy metals actually affect all living organisms. Humans, an example of organisms feeding at the highest level, are more prone to serious health problems because the concentrations of heavy metals increase in the food chain (Masindi and Muedi, 2018) [16]. Water is the life-blood of the biosphere it can dissolve environmental contaminants such as heavy metal which contribute to marine pollution. Their sources can emanate from both natural and anthropogenic processes and end up in different environmental compartments (water, soil, air and their interface) (Ali *et al*., 2021; Masindi and Muedi, 2018 [16]). In surface water systems, pollution can come from natural, anthropogenic or geological sources. It includes volcanic eruptions, weathering of metal-containing rocks, sea-salt sprays, and forest fires. Natural weathering processes can discharge metals into the environment from through different sections (Sonone *et al*., 2020) [17]. One of the major challenges in Niger Delta is the shortage of potable and clean water due to environmental pollution particularly in rural communities that depends on rivers as their main source of domestic water supply. The deteriorating quality of water threatens sustainable living in these communities (Oseji *et al*., 2019; Omoigberale *et al*., 2013) [9, 13]. Sadly, rivers are been polluted by indiscriminate dumping of sewage, waste from industries, agricultural waste and other human activities, which in turn, affect the physicochemical characteristics of these water bodies. Ecologically, the environment is view as the physiochemical parameters of the habitat (Gazioğlu, 2018; Ülker *et al*., 2018) [10, 11]. The physiochemical parameters of surface water are environmental indicators for pollution determination. Santa Barbara River is an important fishing site in Nembe, Bayelsa State, is currently impacted by human activities such as boating activities, waste deposits, oil and gas exploration activities by the Aiteo Eastern Exploration and Production Company (AEEPCO), which operates OML 29 Wellhead at Santa Barbara South field in Nembe in Bayelsa State. Availability of clean and safe supply of water for aquatic organism is a requirement for sustainable growth and development (Ban, 2016) [6].Thus, the quality of water influences the wellbeing of any aquatic biota that uses it (Kashiwada and Itakura, 2020; Sachs *et al*., 2019) [7, 8].

Hence, an examination of water for physical and chemical characteristics is essential for public health studies. The assessment of water quality, usually carried out by determining its physico-chemical against a set of standards, is used to determine whether the water is safe for the environment (Adelagun *et al*., 2021; Chinedu *et al*., 2011) [15, 14]. The goal of this research was to determine the extent of anthropogenic influence on the Santa Barbara River in Nembe, Bayelsa State, Nigeria, by looking at the physical and chemical features of its surface water, and to provide baseline information on the impact of oil spills on surface water.



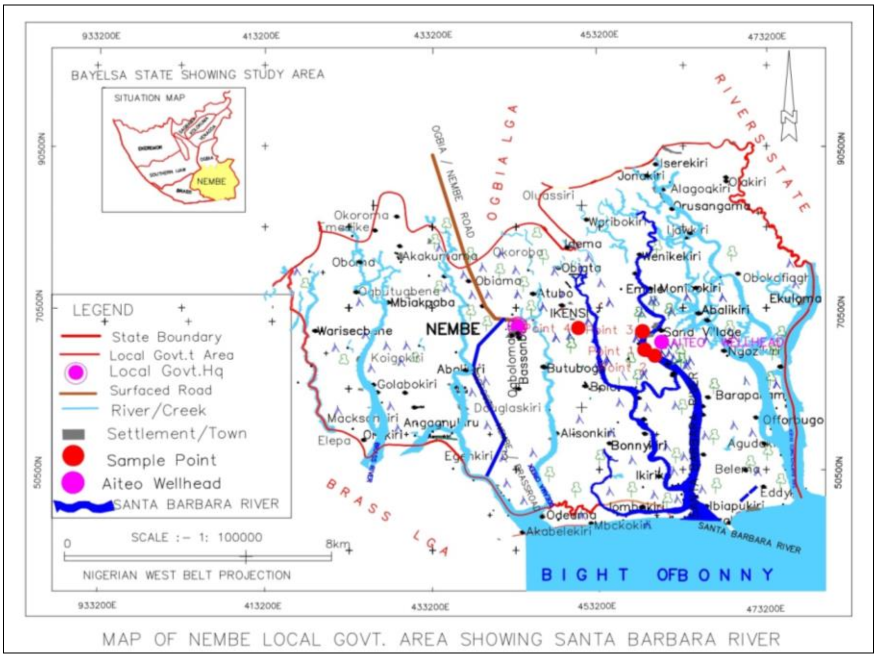

**Source:** Sonone *et al*., 2020 [17]

**Fig 1:** Different sources of contamination heavy metal in water

## 2. Materials and methods

### 2.1 Study Area

The research was carried out in the Nembe-Bassambiri kingdom's coastal area, notably the Santa Barbara River in Nembe Local Government Area of Bayelsa State, Nigeria. Nembe-Bassambiri is an oil-producing community with a majority of fishermen, traders, and farmers among residents. Nembe can be found between the latitudes of 4º32'12.85" N and 6º24'22.36" E. Throughout the river's course, the study area is surrounded by several types of mangrove flora. Its environments are made up of marine, brackish, and freshwater ecosystems. As a result, it has a low tide that is affected by seasonal changes in the environment. There are two major seasons in the area based on climate: wet or rainy seasons and dry seasons.




**Source:** Office of the Surveyor – General, Yenagoa Bayelsa State

**Fig 1:** Map representing the sampling sites of the present study

### 2.2 Sample collection and analysis

***Sample Collection:*** Samples were collected using glass bottles at 30 cm depth beneath the water surface according to the standard method (APHA, 2005). The bottles were covered with aluminum foil paper to prevent U.V light and photochemical degradation. Prior to their use, the bottles were thoroughly washed and rinsed with deionized water. Dissolved oxygen (DO) and Biochemical oxygen demand (BOD) bottles (250 ml) were used to collect water samples for dissolved oxygen and biological oxygen demand respectively. Precautions were taken to minimize the risk of contaminating the samples as they were being transported to the laboratory. The *insitu* measurement was carried out using a pH meter for pH, a benchtop multitek meter for temperature, salinity, TDS, and Conductivity of water respectively. Dissolved Oxygen were also measured insitu with an Optical Dissolve Oxygen meter with model number ODO200. While Biochemical Oxygen Demand were estimated using Winkler's method. The BOD was carried out after 5 days of incubation at 20°C. The other physical/chemical characteristics were examined using standard method (APHA, 1998).

### 2.3 Metal analysis

**Chemical and reagents**: All chemicals and reagents used for the study were of high analytical grade.

Preparation of standards**:** Instrumental calibration was carried out prior to metal determination by using standard solutions of metal ion prepared from salts. Commercial analar grade 1000ppm stock solutions of Zn2 +, Cr2 +, Pb2 +Fe2 + were diluted in 25cm3 standard flask and made up to the mark with deionized water to obtain working standard solutions of 2.0ppm, 3.0ppm and 4.0ppm of each metal ion.

Heavy metal determination**:** The sample water were digested using concentrated nitric acid $HNO_3$ and concentration of Lead (Pb), Zinc (Zn), Iron (Fe) and Chromium (Cr) measured with series atomic absorption spectrophotometer (AAS) (Williams *et al.*, 2007; Essien *et al.*, 2006; Adekoya *et al.*, 2006).

The essence of the digestion before analysis was to reduce organic matter interference and convert metal to a form that can be analyzed by AAS.

### 2.4 Statistical Analysis

One-way analysis of variance (ANOVA) test was used to compare the different sets of data collected along the course of the river to that of reference site; $P < 0.05$ was considered to show statistical significance, using SPSS v.25.0 software for Windows.

## 3. Result and discussion

**Table 1:** Physiochemical Parameter of Water sample Collected from Nembe community

| Water Samples | Temp (°C) | pH | Cond (S/m) | TDS (mg/L) | Salinity (g/L) | Turbidity (NTU) | DO (mg/L) | $BOD_5$ (mg/L) | Phosphate (mg/L) | Nitrate (mg/L) | Sulphate (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SWQ | $28.07\pm0.13^{b}$ | $7.79\pm0.09^{b}$ | $37.20\pm0.36^{a}$ | $37.37\pm0.26^{a}$ | $2.35\pm0.03^{b}$ | $12.00\pm1.16^{a}$ | $6.60\pm0.00^{a}$ | $0.47\pm0.03^{b}$ | $0.05\pm0.00^{a}$ | $0.33\pm0.00^{a}$ | $0.02\pm0.00^{a}$ |
| NEM 1 | $28.67\pm0.03^{b}$ | $8.83\pm0.06^{a}$ | $3914.33\pm1.86^{a}$ | $2928.33\pm0.33^{a}$ | $2.03\pm0.03^{b}$ | $19.40\pm0.26^{a}$ | $5.47\pm0.03^{a}$ | $0.77\pm0.03^{b}$ | $6.27\pm0.03^{b}$ | $0.87\pm0.03^{a}$ | $0.10\pm0.00^{b}$ |
| NEM 2 | $28.60\pm0.06^{b}$ | $7.82\pm0.02^{b}$ | $3501.00\pm66.01^{a}$ | $2655.33\pm0.88^{a}$ | $2.13\pm0.03^{b}$ | $232.00\pm1.00^{a}$ | $2.07\pm0.03^{a}$ | $1.27\pm0.03^{a}$ | $5.80\pm0.00^{b}$ | $0.80\pm0.00^{b}$ | $0.10\pm0.00^{b}$ |
| NEM 3 | $28.67\pm0.03^{b}$ | $7.47\pm0.07^{b}$ | $3589.67\pm20.85^{a}$ | $2671.67\pm16.3^{a}$ | $1.90\pm0.00^{a}$ | $285.67\pm1.20^{a}$ | $1.33\pm0.03^{a}$ | $0.47\pm0.03^{b}$ | $6.00\pm0.00^{b}$ | $1.13\pm0.06^{a}$ | $0.11\pm0.00^{a}$ |
| NEM 4 | $28.60\pm0.00^{b}$ | $7.17\pm0.02^{a}$ | $4575.33\pm22.18^{a}$ | $3482.00\pm20.03^{a}$ | $1.97\pm0.03^{a}$ | $5.05\pm0.03^{a}$ | $7.27\pm0.03^{a}$ | $0.47\pm0.03^{b}$ | $5.43\pm0.03^{a}$ | $0.90\pm0.00^{b}$ | $0.13\pm0.00^{b}$ |
| WHO/FAO | - | 7.0 - 8.5 | 300 | 500 | - | 5 | 6 - 8 | 3 | 12 | 50 | 200 |

Values represent Mean ± Standard Error of Mean (SEM). Mean in the same column with the same superscript alphabet are significantly different, while mean with different alphabet are not significantly different at $P \geq 0.05$, n=3

NEM – Nembe Water Sample, SWQ – Swali River Control Sample

Dunnett test was used to determine the observed significant difference.

**Table 2:** Heavy Metal Concentrations of Water Sample Collected from Nembe community

| Water Sample | Pb (mg/L) | Cr (mg/L) | Ni (mg/L) | Hg (μ/L) |
|---|---|---|---|---|
| SW Q 1 | BDL | BDL | BDL | BDL |
| Nembe 2 | BDL | BDL | BDL | BDL |
| Nembe 3 | $0.06 \pm 0.02^{a}$ | $0.06 \pm 0.00^{a}$ | $0.01 \pm 0.00^{bc}$ | BDL |
| Nembe 4 | $0.97 \pm 0.02^{a}$ | $0.52 \pm 0.00^{a}$ | $0.33 \pm 0.00^{a}$ | BDL |
| Nembe 5 | $0.00 \pm 0.00^{bc}$ | $0.60 \pm 0.12^{bc}$ | $0.15 \pm 0.03^{bc}$ | BDL |
| WHO | 0.01 | 0.05 | - | 0.001 |

Values represent Mean ± Standard Error of Mean (SEM). Mean in the same column with the same superscript alphabet are significantly different, while mean with different superscript alphabet are not significantly different at $P \geq 0.05$, n=3, BDL – Below Detectable Limit, SWQ 1- Swali Water. Dunnett test was used to determine the observed significant differences.

**Table 3:** Acceptable Daily Intake (ADI) of Water from Nembe Community

| Water Sample | Pb (mg/L) | | Cr (mg/L) | | Ni (mg/L) | | Hg (μg/l) | |
|---|---|---|---|---|---|---|---|---|
| | Adult | Child | Adult | Child | Adult | Child | Adult | Child |
| SWQ 1 | - | - | - | - | - | - | - | - |
| Nembe 2 | - | - | - | - | - | - | - | - |
| Nembe 3 | 1.89E-03 | 3.91E-05 | 5.14E-03 | 3.91E-05 | 3.14E-04 | 7.60E-05 | - | - |
| Nembe 4 | 3.05E-02 | 6.32E-04 | 4.46E-02 | 3.39E-04 | 1.04E-02 | 2.51E-03 | - | - |
| Nembe 5 | - | - | 5.14E-02 | 3.91E-04 | 4.71E-03 | 1.14E-03 | - | - |

**Table 4:** Hazard Quotient of Water from Nembe Community

| Water Sample | Pb (mg/L) | | Cr (mg/L) | | Ni (mg/L) | | Hg (µg/l) | |
|---|---|---|---|---|---|---|---|---|
| | Adult | Child | Adult | Child | Adult | Child | Adult | Child |
| SWQ 1 | - | - | - | - | - | - | - | - |
| Nembe 2 | - | - | - | - | - | - | - | - |
| Nembe 3 | 5.388E-01 | 1.303E-01 | 1.71E+00 | 1.52E-01 | 1.57E-02 | 3.80E-03 | - | - |
| Nembe 4 | 8.710E+00 | 2.106E+00 | 1.49E+01 | 1.32E+00 | 5.19E-01 | 1.25E-01 | - | - |
| Nembe 5 | - | - | 1.71E+01 | 1.52E+00 | 2.36E-01 | 5.70E-02 | - | - |

USEPA, 2011
Maximum Permissible Limit (Values in bold denote the above Maximum Permissible limit).
HQ: 1

**Table 5:** Hazard Index of Water from Nembe Community

| Water Sample | HI | |
|---|---|---|
| | Adult | Child |
| SWQ 1 | - | - |
| Nembe 2 | - | - |
| Nembe 3 | 2.27E+00 | 2.86E-01 |
| Nembe 4 | 2.41E+01 | 3.55E+00 |
| Nembe 5 | 1.74E+01 | 1.58E+00 |

USEPA, 2011
Maximum Permissible Limit (Values in bold denote the above Maximum Permissible limit).
HI: 1

**Table 6:** Life Cancer Risk (LCR) of Water from Nembe Community

| Water Sample | Pb (mg/L) | | Cr (mg/L) | | Ni (mg/L) | | Hg (µg/l) | |
|---|---|---|---|---|---|---|---|---|
| | Adult | Child | Adult | Child | Adult | Child | Adult | Child |
| SWQ 1 | - | - | - | - | - | - | - | - |
| Nembe 2 | - | - | - | - | - | - | - | - |
| Nembe 3 | 1.60E-05 | 3.32E-07 | 2.57E-03 | 1.95E-05 | 2.64E-04 | 5.47E-06 | - | - |
| Nembe 4 | 2.59E-04 | 5.37E-06 | 2.23E-02 | 1.69E-04 | 8.71E-03 | 1.81E-04 | - | - |
| Nembe 5 | - | - | 2.57E-02 | 1.95E-04 | 3.96E-03 | 8.21E-05 | - | - |

USEPA, 2011
Maximum Permissible Limit
LCR: $1 \times 10^{-6}$ to $1 \times 10^{-4}$

**Table 7:** Total Life Cancer Risk (TLCR) of Water from Nembe Community

| Water Sample | TLCR | |
|---|---|---|
| | Adult | Child |
| SWQ 1 | - | - |
| Nembe 2 | - | - |
| Nembe 3 | 2.85E-03 | 2.53E-05 |
| Nembe 4 | 3.13E-02 | 3.55E-04 |
| Nembe 5 | 2.97E-02 | 2.78E-04 |

USEPA, 2011
Maximum Permissible Limit
LCR: $1 \times 10^{-6}$ to $1 \times 10^{-4}$

## 4. Discussion

***Physiochemical Parameter of Water sample Collected from Nembe community***

This present study shows the different physiochemical properties of water. Temperature is known to influence the pH, alkalinity and DO concentration in the water (Matta, 2014). The temperature of water is reflective of the quality in that aquatic life has a set threshold of temperatures in which it can survive. The conductivity of water were seen to very high and was above WHO permissible limit of 750 S/m and FAO persmissible limit of 3000 S/m respectively. The high level in conductivity may be due to the presence of inorganic dissolved solids from the crude pollution thereby influencing the physiochemistry of Santa Barbara River, while the control sample (SWQ) was found to be significantly different from the both study area. In addition, the TDS were extremely high in Nembe study area compared to the control sample, this may be due to natural environmental features such as carbonate deposits, salt deposits, and sea water intrusion. The value in this study surpasses the standards of WHO (500) and FAO (2000) mg/L respectively as shown in Table 4.1. According to Raimi *et al.*, (2022) and Kwamboka, (2018), in river bodies, higher levels of total dissolved solids often harm aquatic species. The TDS changes the mineral content of the water, which is important to survival of many animals. Also, dissolved salt can dehydrate the skin of aquatic animals, which can be fatal. In this study, there were observed significant differences in the corresponding value obtained for turbidity which were high. The turbidity of water can affect the growth of phytoplankton and aquatic organism. However, when compared with scholarly research work of Oseji *et al.*, (2019) [9], surface water from River Niger, Illushi, Edo State turbidity value were 107.28±30.9 NTU which was slightly lower to samples in this study area. According to World Health Organization (WHO) and the United State Environmental Protection Agency (USEPA), the recommended limit for turbidity levels must not exceed 5 NTU (WHO, 2017; US EPA, 2019). The dissolve oxygen levels in this study area were found to be very low, which was due to the impact of the oil spill impact on Santa Barbara River. The USEPA acceptable limit for dissolve oxygen in water ranged between 6.5 - 8 mg/L. The biochemical oxygen demand (BOD) of sampled water from this study was low indicating the presence of pollution and there were observed significant difference from the study areas. Connor (2016) reports on the United Nations World Water Development states that a river may be considered severely polluted when the BOD values exceeds 8mg/L. BOD is a quantitative indicator of the biologically degradable organic substances in water. It is widely used to assess strength of pollutants in aquatic system. Commonly, higher values of BOD in drinking water may cause serious health impact. The WHO standard for BOD in water is 3 mg/L. The nutrient level such as phosphate, nitrate and sulphate in water from this study were significantly different among each other which is due to influence by human activities in the environment. USEPA has established a recommended limit of 0.1 mg/L for total phosphorus in flowing waters. While the recommended stipulated limit of nitrate in drinking water is 10 mg/L as stated by WHO. The natural level of nitrate in surface water is typically low (less than 1 mg/L). However, sulphate salts can be major contaminants in natural waters when they are present in excess amount (Simeon *et al.,* 2019).

***Heavy metal in water***

In this study, the heavy metal concentrations in water were statistically significant with the control sample from Swali river station was found to be below detectable limit (BDL). However, Dunnett test was used to determine the observed significant in this study. Pb and Cr were above WHO maximum permissible limit for the both study areas (Table 2). Ali *et al*. (2021) in their studies on environmental pollution with heavy metals: a public health concern reported that Pb can also create different health problems. Young infants are more sensitive to Pb poisoning than adults. Mishra and Bharagava (2016) stated on their research that chromium is known as highly toxic heavy metal as it can cross the cell membrane via sulfate transport system and causes denaturation and mutation of nucleic acids and proteins. It also creates critical health issues like skin problems, nasal irritation, hearing impairment and lung carcinoma.

**Health Risk Assessment**

***Acceptable Daily Intake (ADI) of Water from Nembe Community***

In this study, the acceptable daily intake of water sample collected from Nembe for Pb, Cr and Ni were present except Hg which was not detected in the water sample, while the control sample Swali River was below detectable limit for Pb, Cr, Ni and Hg as shown in Table 3. It was observed to be significantly higher than that the control sample collected from Swali River, as their respective Pb, Cr and Ni were below detection limit. These findings support the report of Mgbenu *et al*. (2019) on the hydrogeochemical signatures, quality indices and health risk assessment of water resources in Umunya district, southeast Nigeria. More so, the acceptable daily intake of water sample collected from the study area for showed that children are more vulnerable to Pb, Cr and Ni. Also, the Pb, Cr and Ni in water samples collected from both communities.

***Target hazard quotient (THQ)***

The target hazard quotient (HQ) for Pb and Cr in water collected from Nembe was observed to be highest followed by Ni while Hg was not detected. The adult and children population showed higher risk for Pb, Cr and Ni (Table 4). Also, the target hazard quotient values for Pb, Cr and Ni were observed to be on the extreme especially in Nembe 3 and Nembe 4 sampling point, Pb and Cr values, which were higher than the USEPA limit of 1. The significantly increased Pb, Cr, Ni and Hg in water samples collected from the study areas could be attributed to anthropogenic activity in the coastal areas. This result agrees with the research of Ekere *et al*. (2019) on levels and risk assessment of polycyclic aromatic hydrocarbons in water and fish of Rivers Niger and Benue confluence Lokoja, Nigeria.

***Hazard Index (HI)***

The hazard index (HI) of water collected from Nembe community was higher for adults and children population, while the HI for the control sample in Swali River (SWQ 1) were below detectable limit for adults and children population respectively. However, the Hazard Index (HI) in this study was observed to be high and exceeded the threshold value stipulated by United State Environmental Protection Agency (USEPA). The toxicity effect of the HI in the different sampling point arranged in increasing order are Nembe 4 > Nembe 3 > Nembe > Nembe 5 > Nembe 2 > SWQ 1 (Table 5).

***Life Cancer Risk Ingestion (LCR)***

The Life Cancer Risk Ingestion (LCR) values for Cr and Ni were predominant for adults and children population while that of Hg values in water was not detected for adults and children population (Table 6). Also, the life cancer risk ingestion (LCR) for Cr and Ni in adults and children varied from one sampling point to another which were leading in values for adults and children population, while Hg value in water were not detected for adults and children population (Table 4.21.4). The LCR for Cr and Ni in samples this study was significantly higher in levels when compared to the control sample (Swali River) and exceeded the acceptable limit of USEPA for some sampling point. The acceptable limit for cancer risk ranged from $10^{-4}$ to $10^{-6}$.

***Total Life Cancer Risks (TLCR)***

The total life cancer risks (TLCR) of water were high for adults and children population (Table 7). The findings of this study disagree with the report of Ihunwo *et al.* (2021) on ecological and human health risk assessment of total petroleum hydrocarbons in surface water and sediment from Woji Creek in the Niger Delta Estuary of Rivers State.

**5. Conclusion**

In this study the effects of heavy metal and health risk assessment from oil spill on Santa Barbara River, Niger Delta were investigated. While some of the physiochemical parameter was above WHO regulatory limits; they were significantly higher than baseline condition of rivers. Turbidity, TDS, conductivity and heavy metals (Pb, Cr, Ni) were in breach of the international regulatory limits for drinking water and ecological health. The health risk assessment showed high carcinogenic and non-carcinogenic risk for surface water from Santa Barbara River.

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