Determination of Nickel in Selected Surface Waters of the Bonaberi Industrial Zone, Douala IV Council, Littoral Cameroon.

ABSTRACT

Aims: To assess the source and level of Nickel in selected surface waters and its impact on the community of the Bonaberi industrial zone.
Study design: Cross-sectional study design that involved semi-quantitative and qualitative data collection method.
Place and Duration of Study: This study was carried out in the area of Bonaberi industrial zone, Douala IV district between February 2019 to August 2020.
Methodology: 25 Different surface water samples were collected from 5 sampling sites. Water samples were collected in polyethylene bottles previously washed with deionized water and rinsed with sample to be collected from different sites and acidified with 5 ml concentrated nitric acid. The contents of the metal were analyzed using Colorimetric merck microquant procedure. Two way ANOVA test and a P-value (<0.05) was considered significant.
Results: Spring Water had a significant concentration of nickel in the various sites (0.06 mg/L), industrial waste (0.05 mg/L), River (0.04 mg/L), Well (0.03 mg/L), Tap waters (0.02 mg/L).
Conclusion: Nickel is one of the most toxic naturally occurring metal(s) that is very dangerous to environmental sustainability when present in high concentrations. The study justifies the need to ascertain the long-term effects of Nickel contaminant(s) at waste dumping sites. Strengthening waste management systems and water quality monitoring should be implemented in the watersheds to minimize the health effects and deterioration of the aquatic ecosystem. Adequate measures should be taken to educate the community on heavy metals pollution on surface water and their effects to health and environment.

Keywords: Heavy metal, Surface water, Nickel concentration, Water quality, Water Pollution

1. INTRODUCTION

Heavy metal pollution in surface water poses a significant health and environmental problems in the World. According to WHO (2017), about 1.5 billion of people in the world are suffering from drinking metals contaminated water [1], particularly in developing countries where water is hampered with multiple inappropriately discarded substances, objects made of heavy metals. Navarro and Vincenzo (2019) attributed to the fact that, most of the industries in the developing countries are discharging their wastes directly into the nearby streams, rivers, wells, oceans, lake, and open land without any treatment [2] [3]. This has led to pollution of the aquatic ecosystems with trace elements [4]. Some less developed countries for instance lack sufficient equipment and technical capabilities to detect and monitor water quality and are therefore exposed to heavy metal pollution [5] [6]. Excess trace elements in the water environment might occur through various processes and pathways by anthropogenic activities besides the natural processes [7] [8]. Multiple industrial, domestic, agricultural, medical and technological applications have led to a wide distribution of heavy metals in air, water and soil; raising concerns over their potential risk factor on human health and the environment [9]. Heavy metals have emerged out as imperious category of pollutants, showing inimical effects on both human physiology and the dynamism of terrestrial and aquatic life forms and ecosystems. Depending on their oxidation states, heavy metals can be highly reactive and, therefore, toxic to the simplest to most complex organisms. All life forms including fungi, bacteria, yeasts, plants, and animals may be affected due to toxic levels of heavy metals; however, their toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed organism. Naturally, vital heavy metals penetrate into the human body via food, air and water where they regulate numerous biological activities [10]. Microorganisms are the first entity that endures direct and indirect impacts of hazardous heavy metals. Several microbes have habituated and harbor potential tolerance to detoxify heavy metal-contaminated environments at cellular level different strategies through bioaccumulation, biosorption, biotransformation, etc. for ameliorating heavy metal-contaminated sites [11].

Nickel (Ni) known as a natural abundant element, hard, silvery-white metal whose strength, ductility and resistance to heat and corrosion make it extremely useful for the development of a wide variety of materials such as batteries, stainless steel, ceramic paint and as well as in the human body which is known as traced element [12]. However, the benefit of this heavy metal is generally overweighed by the hazard to health and the environment. The assumption that heaviness and toxicity are inter-related, Nickel emitted from both natural and anthropogenic sources into the atmosphere, is able to induce toxicity at low level of exposure and also cause many adverse effects on humans and causes allergies, nasal and lung cancer, kidney and cardiovascular diseases etc. [12] [13]. Generally, the levels of Ni is 5–40 ng m^{-3} in the air, 3–1000 mg kg^{-1} in agricultural soils, and less than 2 μg L^{-1} in fresh water and oceans [14].

The dumping of municipal wastes, untreated wastes from various homes, factories and agrochemicals has reached an alarming situation in open water bodies and streams that continually increases the quantity of metals and deteriorates the quality of water [15] [16]. Due to their non-biodegradability and persistent nature, heavy metal Ni, accumulates in aquatic ecosystems, leading to pollution and accumulation to the top consumers through the food chain [17] [18]. Also, the poor management, lack of awareness and the absence of adequate solid and liquid waste treatment technologies in developing countries continuously leads to the waste generated from anthropogenic activities that is dumped into the nearby water bodies and rivers crossing cities and their boundaries [19][20]. Water bodies receive and absorb heavy metals mainly caused by the unplanned urbanization and industrialization of the Bonaberi industrial area that have adverse effects on the different water sources and sediment quality, as well as the diversity of aquatic fauna. [21] [22].

Bonaberi industrial zone is a considerably area of land located at the Douala IV district zone covering various operations such as steelwork, Agrifood, building and public works, breweries, cement works, car dealerships, fertilizers and pesticides, metallurgy, sawmills, tannery, car repair garages, car-wash, metal plating, laboratories, waste discharge etc. [23] However, the watershed has experienced rapid urbanization in recent years, potential sources of heavy metals pollution. This has led to an increasing ecological and global public health concern associated with environmental contamination by heavy metals. The high concentration of trace elements such as Ni, Cadmium (Cd), chromium (Cr), lead (Pb), and mercury (Hg) are discharged into the Douala IV district area.

Most of the studies conducted on water pollution focus on the investigation of mainly organic and common metals, thereby lacking information about the level of specific metals at a spatial scale along the course of the urban and semi-urban environments. This is highly relevant to devise a pollution control strategy. A study conducted in Cameroon showed that the degree of contamination and contamination factors of the groundwater in Kumba, had low values of trace metals [24]. However, a similar study conducted in Adamawa, Cameroon shows the concentration of some heavy metals in water sites were above the WHO standards and this pollution were mainly due to the mining operations at Djouzami (Adamawa, Cameroon) [25]. Because of their high degree of toxicity of some of these heavy metals, nickel is one of the prioritized metal that is of public health and environmental significance. These metallic elements are considered systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure [26]. The increments of metallic elements in the water bodies due to uncoordinated rapid urbanization with a lack of awareness in the water sources treatment methods also have a serious concern for the sustainable development of the city. The concentration of metallic elements in surface waters becomes relatively high due to significant anthropogenic metal loadings carried by tributary rivers and other water sources [27] [28]. Moreover, water quality characteristics, such as dissolved oxygen, pH, and organic matter content also affect the mobility and availability of these trace elements in the aquatic environment [29].

Despite the widespread environmental deterioration of the urban and semi-urban environment in most developing countries [30], such as Cameroon, the identification of pollution sources of specific heavy metals and their level is hardly available [31]. This study fills up the gap and covers the analysis of heavy metal nickel in surface waters within the Douala IV council area. Hence, this study is aim at assessing the level of concentration of heavy metal nickel and its impact on the health and environment in the selected surface waters in different sites of the Bonaberi industrial zone, Douala IV council area, Littoral Cameroon.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is located in the district area of Douala IV municipality with the surface area of about 886km^2. Bonaberi industrial zone is one of the two industrial zones of the city of Douala located at 4°04′ 02 N, 9°40′ 55 E with a surface area of 1.92km^2 [32]. The Douala IV council is situated in the estuary of Wouri River in the equatorial zone. It is bounded in the North by Mungo division, North-East by the Nkam, South – East by Sanaga – maritime Division, West by the Fako Division and South by the Atlantic Ocean with the surface area of about 886km^2. In this study, the targeted population were those in the industrial area and in small and medium size industries dealing with heavy-metals and those using the different sources of water involving home and environmental exposure[32] [33]. 150 participants were investigated in this research. The study area mainly contains the various sources of water which are tap, well, spring, river and industrial waste water. Each of these sources of water was collected at 5 different sites of the Bonaberi industrial zone which are Mabanda, Ndobo, Bepelle, Bonassama and Sodiko.

Major anthropogenic activities at each sampling site along the course of the Douala IV District are described in Table 1. Samples of surface water were collected from Sodiko (S1, S2, S3, S4, S5), Mabanda (M1, M2, M3, M4, M5), Ngwelle (D1, D2, D3, D4, and D5), Ndobo (N1, N2, N3, N4, and N5), and Bonassama (B1, B2, B3, B4 and B5) water sources. The letters and numbers represent the various sites of collection. The map on Figure 1 shows the location of the various sites of sample collection in the Douala IV council area.

Table 1: Various anthropogenic activities in each site

Water sources	Sampling code	Major anthropogenic activities of the site

Sodiko	S1- Well	Domestic activities, Washing and fetching water for household consumption
	S2- Tap	Fetching water for household consumption, car washing, public institutions, biological laboratories and construction sites
	S3- Spring	Agricultural activities, washing clothes and bathing, swimming, fetching water for household consumption.
	S4- River	Bridge, industrial and commercial activities, Crossing road and high vehicle traffic
	S5- Industrial waste water	Institutional waste, waste dump sites
Mabanda	M1-Well	Domestic activities, Washing and fetching water for household consumption
	M2- Tap	Fetching water for household consumption, car washing, metal works and fabrications, public institutions, biological laboratories and construction sites
	M3-Spring	Agricultural activities, washing clothes and bathing, swimming, fetching water for household consumption.
	M4-River	Bridge, industrial and commercial activities, Crossing road and high vehicle traffic
	M5- Industrial waste	Institutional waste, waste dump sites Metal works and fabrication
Bonasama	B1-Well	Domestic activities, Washing and fetching water for household consumption
	B2- Tap	Fetching water for household consumption, car washing, public institutions, hospitals and biological laboratories and construction sites
	B3-Spring	Agricultural activities, washing clothes and bathing, swimming, fetching water for household consumption.
	B4-River	Bridge, industrial and commercial activities, Crossing road and high vehicle traffic
	B5- Industrial waste	Institutional waste, waste dump sites
Ngwelle	D1-Well	Domestic activities, Washing and fetching water for household consumption
	D2- Tap	Fetching water for household consumption, car washing, public institutions, biological laboratories and construction sites
	D3-Spring	Agricultural activities, washing clothes and bathing, swimming, fetching water for household consumption.
	D4-River	Bridge, industrial and commercial activities, Crossing road and high vehicle traffic
	D5- Industrial waste	Institutional waste, waste dump sites
Ndobo	N1-Well	Domestic activities, Washing and fetching water for household consumption
	N2-Tap	Fetching water for household consumption, car washing, public institutions, biological laboratories and construction sites

	N3- Spring	Agricultural activities, washing clothes and bathing, swimming, fetching water for household consumption.
	N4-River	Bridge, industrial and commercial activities, Crossing road and high vehicle traffic
	N5- Industrial	Institutional waste, waste dump sites

Source: From Author (2020).

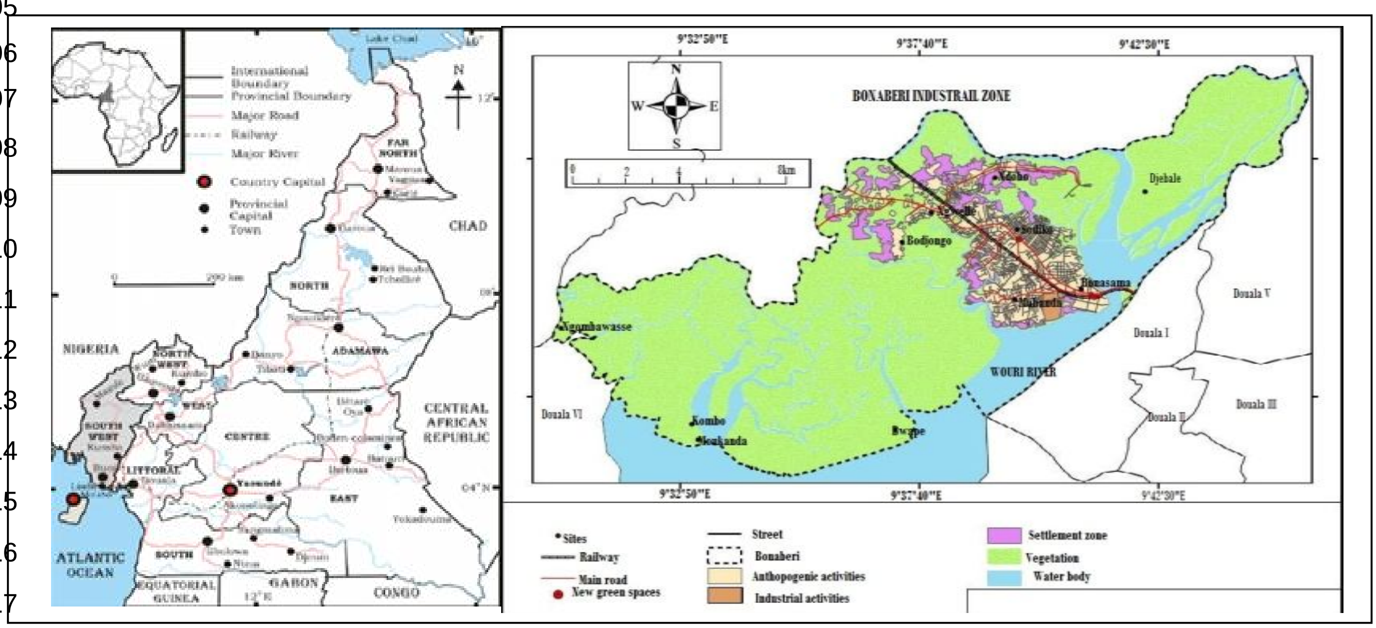

Figure 1: Map of Bonaberi industrial Zone, Douala IV council

2.2. Study Design and Data Sources

The study was a cross-sectional fieldwork and laboratory based study design approach that involved both semi-quantitative and qualitative data collection methods carried out from February 2019 to August 2020. Both primary and secondary data collected from different sources were used. Primary data were gathered from the different water samples collected from the Bonaberi Industrial zone and self-administered questionnaires were used. Ethical clearance was sought from the Institutional Ethics Committee for Research on Human Health of the University of Douala. Administrative clearances for the study were acquired from the Littoral regional delegation for public health, mission order from the Mayor of the Douala IIV council area and some directors of institutions. The study was commenced only after obtaining due authorizations from necessary authorities. Only waste handlers and workers/individuals who gave their consent were recruited into the study. For confidentiality purposes, no name was required from research participants and only unique identification codes were used to identify participants.

2.3. Data Collection and Processing

Self-administered questionnaire and interviews were used for data collection on knowledge and awareness of the heavy metal nickel pollution in surface water and its effects. There were prepared in English and pretested. Then the questionnaires were distributed to the respondents after modification was made.

Polyethylene plastic bottles were rinsed thoroughly with deionized water after being washed in dilute nitric acid (HNO_3). In the field, these bottles were rinsed several times with the water from each source and 250ml was collected. The water samples were acidified with concentrated nitric acid and preserved. The sample was collected in the early hours in polyethylene plastic bottles. And 250ml of each sample was collected. The acid pre-treatment ensured that heavy metals (Nickel) did not get absorbed to the surface of the container during transportation and storage. The samples were labeled immediately transported to the laboratory using cold box maintained at 4 degree Celsius using ice blocks.

25 samples of surface water were collected. In each site (Sodiko, Mabanda, Ndobo, Bonassama, and Ngwelle), five different sources of water were collected for nickel concentration determination.

2.3. Procedure (Technique)

The Merck Microquant technique involves two Ni determination reagents where 6ml of the sample from each surface water sample was inserted into the test tube with Ni reagent 1 added drop wise to the sample till a slightly yellow coloration is obtained. It was allowed to stand for 60seconds till the yellow coloration was stable. Later on, 6ml of Ni Reagent 2 was added to the mixture and allowed to stand for 3 minutes before inserted into the colorimetric apparatus and the values were recorded.

2.4. Data Analyses

2.4.1. Physical Analysis

The measurement of physiochemical properties (pH, temperature etc.) were done on the site using a Calibrated portable multipara meter probe. Other parameter such as odour, turbidity and analysis of nickel was determined at the laboratory of the Faculty of Medicine and Pharmaceutical Science, University of Douala. The pH and temperature of each water from each site was determine to verify if these properties do affect the Ni concentration in the various surface waters.

Table 2: Characteristics of the water sources

N°	Water site	Temperature	Turbidity	Colour	Odour	pH
1	Tap	35.1°	Clear	Colourless	Odourless	7.0
2	Industrial waste	38.0°	Turbid	Grey	Odour	5.8
3	Well	36.2°	Turbid	Brownish	Odour	6.2
4	Spring	35.0°	Clear	Colourless	Odourless	7.3
5	Wouri river	37.5°	Clear	Colourless	Odourless	6.9

According to the analysis procedure, merck microquant colometric method was used within the study.

2.4.2. Statistical Analysis

The means and standard deviations of the metal concentrations in water were calculated. The differences of heavy metal concentrations among the surface water in the different collection site were analyzed with a two-way ANOVA, followed by merck microquant tests. The statistical analysis was performed using SPSS version 2.0 statistical software and a significance level of 0.05 ($P < 0.05$) was considered as statistically significant. This method was performed to determine the differentiation of Nickel concentration in each source of water at the various sites based on the WHO standard for drinking water.

3. Results and Discussion

3.1 Concentration of Nickel

the sample solutions were placed in the colorimetry apparatus and a direct reading of the metal concentration in each water source of each quarter was made. The concentration averages of nickel calculated are presented in the table below displaying the mean value and standard deviation (Table 3). These concentrations represent mean values of all data collected in this study at every sampling site selected.

Table 3: Concentration of nickel of the various waters in the different sites

Sites|Types of water	Well (mg/L)	Tap(mg/L)	Spring(mg/L)	River wouri(mg/L)	Industrial waste water(mg/L)	Mean/mg/L	standard deviation
Sodiko	0.01	0.02	0.07	0.03	0.07	0.04	0.01
Mabanda	0.02	0.02	0.03	0.03	0.05	0.03	0.01
Ngwelle	0.03	0.01	0.05	0.04	0.05	0.04	0.01
Bonassama	0.05	0.02	0.08	0.05	0.07	0.05	0.01
Ndobo	0.03	0.03	0.09	0.05	0.04	0.05	0.00
Mean	0.03	0.02	0.06	0.04	0.05		

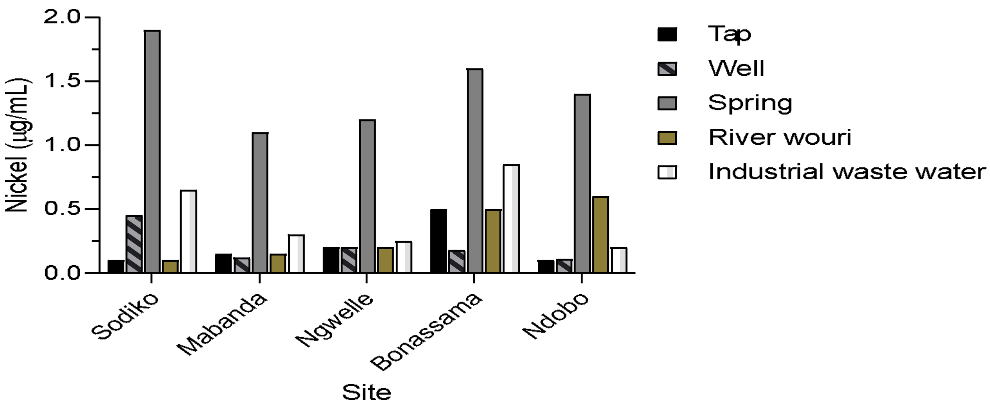

Figure 2: Nickel concentration in the various surface water and sites

The nickel concentrations in the surface water samples from the sites ranged between 0.01 mg/L and 0.07 mg/L. The concentrations of nickel increased at the level of discharge in spring in the various sites (Table 3). Although, the least concentration is at the level of tap waters in the various sites, these sites are an indicator of excessive nickel intake. Overall, spring water stands as the highest concentration of nickel in all the sites mentioned in this study. The sites variation may be attributed to agricultural and industrial activities dealing with engineering goods, chemicals etc. This is also due to the consideration that the water table in the spring water sites are high, and the fact that there are many companies and industries, garages that deal with heavy metals, nickel inclusive, the release of nickel into the environment by power plant, metal factories and waste incinerators spill into the water and absorbed into the ground as well.

Nickel is seldom found in natural waters, but is often present in industrial wastewater as a direct product of metal plating baths, and as a corrosion product of stainless steel, nickel alloys. Nickel is the fifth most plentiful element by weight following oxygen, magnesium, silicon and iron. This is a well-established Class 1 human carcinogen. Prolonged exposure to low doses of nickel may produce severe pathologic effects, including dermatitis, asthma, lung fibrosis and respiratory tract cancer [13], [34]. The toxicity of nickel to aquatic life varies widely and is influenced by species, pH, temperature, synergetic effects, and other factors. Statistical analysis showed significant differences between the mean values of the surface waters in their various quarters and the main value of tap water which is within the acceptable standard limits *($P < .05$)*(Table 4).

Table 4: Two-way ANOVA analysis for Ni metal in different water sources

Two-way ANOVA	*Ordinary*				
Alpha	.05				
Source of Variation	% of total variation	P value	P value summary	Significant?	
Samples sites	7.213	.0561	ns	No	
Water type	82.81	<.0001	****	Yes	
ANOVA table	SS	DF	MS	F (DFn, DFd)	P value
Samples sites	.4731	4	.1183	F (4, 16) = 2,891	P=.0561
Water type	5.431	4	1.358	F (4.16) = 33.19	P<.0001
Residual	.6546	16	.04091		
Dunnett's multiple comparisons test	Predicted (LS) meandiff,	95.00% CI of diff,	Significant?	Summary	Adjusted P Value
Sodiko					
Tap vs. Well	-0,002000	-.3484 to .3444	No	Ns	>.9999
Tap vs. Spring	-1,230	-1.576 to -.8836	Yes	****	<.0001
Tap vs. River wouri	-0,1000	-.4464 to .2464	No	Ns	.8486
Tap vs. Industrial waste water	-0,2400	-.5864 to .1064	No	Ns	.2252
Mabanda					
Tap vs. Well	-.002000	-.3484 to .3444	No	Ns	>.9999
Tap vs. Spring	-1.230	-1.576 to -.8836	Yes	****	<.0001
Tap vs. River wouri	-.1000	-.4464 to 0.2464	No	Ns	.8486
Tap vs. Industrial waste water	-.2400	-.5864 to .1064	No	Ns	.2252
Ngwelle					
Tap vs. Well	-.002000	-.3484 to .3444	No	Ns	>.9999
Tap vs. Spring	-1.230	-1.576 to -.8836	Yes	****	<.0001

Tap vs. River wouri	-.1000	-.4464 to .2464	No	Ns	.8486
Tap vs. Industrial waste water	-.2400	-.5864 to .1064	No	Ns	.2252
Bonassama					
Tap vs. Well	-.002000	-.3484 to .3444	No	Ns	>.9999
Tap vs. Spring	-1,230	-1.576 to -.8836	Yes	****	<.0001
Tap vs. River wouri	-.1000	-.4464 to .2464	No	Ns	.8486
Tap vs. Industrial waste water	-.2400	-.5864 to .1064	No	Ns	.2252
Ndobo					
Tap vs. Well	-.002000	-.3484 to .3444	No	Ns	>.9999
Tap vs. Spring	-1.230	-1,576 to .8836	Yes	****	<.0001
Tap vs. River wouri	-.1000	-.4464 to .2464	No	Ns	.8486
Tap vs. Industrial waste water	-.2400	-.5864 to 1.064	No	Ns	.2252

The mean and standard deviation values of heavy metal Nickel, investigated are presented in Table 3. The mean value of spring, industrial waste, river and well investigated, exceeded the acceptable standard limit in some sites. Spring water values varied between 0.03 and 0.09 mg/L; higher mean value was recorded in Ndobo (0.09 mg/L), while the lowest (0.03 mg/L) was recorded in Mabanda. All values recorded in all water collection sites for spring water exceeded 0.02mg/L which is the standard limit set by WHO (2017), for drinking water. The main reason for high concentration is due to the fact that the water table was high in combination with waste discharged from anthropogenic activities practiced in the sites(waste discharge from laboratories and dental clinic, car maintenance garages, car-wash, agrochemicals (phosphate fertilizers), pesticides, the emission of fossil fuels, batteries, open incineration of both organic and inorganic wastes etc.

The mean values of industrial waste water showed significant variation, with higher mean values in Sodiko and Bonassama (0.07 mg/L) and the lowest was in Ndobo (0.04 mg/L). The mean values recorded were higher when compared with the standard limit (0.02 mg/L) stipulated by WHO(2017).The findings were not deviated from the reports of other studies, attributed to the fact that Ni is one of the most abundant transition trace metal on earth [34], [35].

The mean values of River water had its range values between 0.03 and 0.05 mg/L, with higher mean value (0.05 mg/L) in Sodiko and Mabanda. The mean value recorded in Sodiko and Mabanda were above the standard limit (0.02mg/L), suggested to unregulated and intense application of pesticide and other related agrochemical at the farmland near the water body which suddenly get into the water through runoff process. The findings affirm the report of Ileperuma (2000) that high content of Nickel in aquatic ecosystem linked to agricultural activities with intense application pest control chemical in a farm near water bodies [36].

Well water had its ranged values from 0.01 to 0.05 mg/L, with the highest mean value recorded in Bonassama (0.05 mg/L), while the lowest value of 0.01 mg/L was recorded in Sodiko. The slightly observed value in Bonassama above the

0.02 mg/L recommended by WHO 2017, attributed to domestic waste discharge and leaching from waste treatment plans during raining season.

The ranged values of tap water in this study is between 0.01 and 0.03 mg/L, with the highest mean value 0.03 mg/L in Ndobo, that exceeded recommended limits by WHO (2017). The significant values recorded in these sites may attribute to impact of precipitation and human activities around the sites.

The elevated values recorded in spring, industrial waste, River and well surface waters are also attributed to accumulation of domestic wastes rich in Ni at the banks of the water. High concentration Ni in drinkable water when consume/absorbed may leads to loss of hair in the body, cardiovascular, lung and kidney diseases. The average Nickel concentration obtained in this study is much higher than those obtained at Betare-Oya and Batouri [37].

3.2 Temperature of Water samples

Temperature values in the various sites at different water collection point had no significant change. It ranged between 35.5 °C to 38.1°C. The temperature variation is similar in different areas and had no influence on the concentration on Ni. Similar results from the studies,

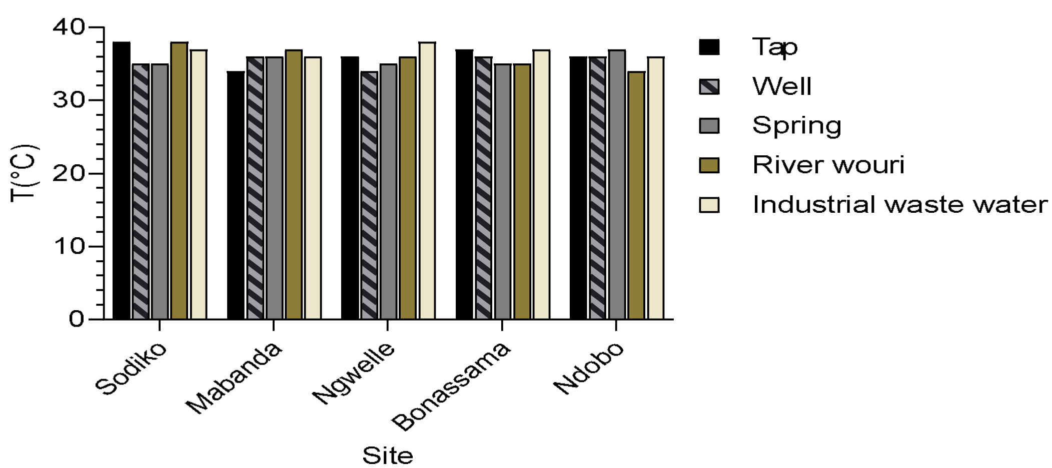

Figure 3: Temperature of the different waters at their various sites

3.3. pH of the Water samples

The pH value of most of the water sites in the study area ranged from 5.2 – 6.9 as in the figure 4. The value of the water is recognised as an index of classifying groundwater as acidic < 5.5, slightly acidic 5.5 -6.4, neutral 6.5 – 7.5, slightly alkaline 7.5 – 8.0, moderately alkaline 8.0 – 9.0 and alkaline > 9. This clearly shows that the tap, river, spring and well water is neutral, while industrial waste water is slightly acidic. Similar research conducted by Karthikeyan (2007), shows nickel accumulation was significantly influenced by pH and hardness in water. The results showed an accumulation of nickel significantly increased at a higher pH=9.0 than at pH=6.0[38].

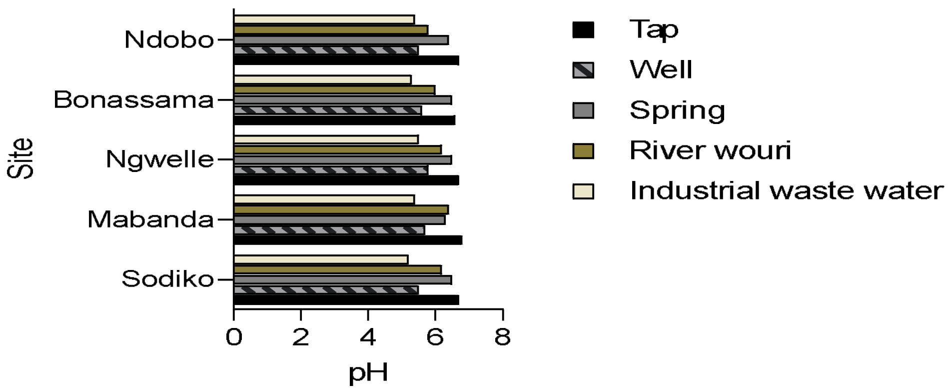

Figure 4: pH of the different waters at the various sites

From the analysis of the data obtained for all the sampling campaigns, the results (Table 3) show proficiency classes that vary from good to bad class for the Bonaberi industrial zone. Ni concentrations were relatively high beyond surface water quality standards, demonstrating a considerable potential environmental risk during a long term exposure [21]. From all the measured concentration from the various sources, Ni shows the highest in spring water of all the selected sites, whereas tap water had the lowest concentration. The absence of treatment of wastewater from the discharge results in high levels of metals Nickel inclusive. The origin of heavy metal contamination can be linked to different inputs: wastewater discharge from domestic sources; industrial waste water; wastewater discharge from hospital sources; discharges related to the maintenance of road vehicles, discharge from hospital sources; discharges related to the maintenance of road vehicles. These observations reveal an important contribution of the anthropogenic activities. These observations reveal that spring, industrial waste water, river, well are unsuitable for drinking in some sites in the Bonaberi Industrial zone.

The environment of the Bonaberi at the sites analyzed has increased in its population and industrialization which treatment of surface water has been ignored which makes is hazardous for mankind and environment.

4. Conclusion

Contact with soluble and insoluble nickel compounds can cause a variety of side effects on human health. Human exposure to Ni may occur through food, water or air. Workers in Ni producing and processing industries are exposed by inhalation, and to a lesser extent, dermal contact. The nervous system is one of the main target organs for Ni toxicity; in fact, it can be accumulated in the brain. Allergy to nickel and metals is caused by the materials used in our daily life; therefore, the chances of triggering the onset of allergic reactions are high. This metal can cause an allergy that manifests as contact dermatitis, headaches, gastrointestinal and respiratory manifestations.

Finally, this study justifies the need for further studies to ascertain the long-term effects of heavy metal contaminants at waste dumping sites and investigations on water chemistry. The water in the area requires bioremediation as per environmental quality criteria and regular monitoring of heavy metals such as nickel in the various water types. Strengthening integrated waste management systems and river quality monitoring should also be implemented in the watershed streams to minimize the health effects and deterioration of the aquatic ecosystem. Adequate measures should be taken to educate the community on heavy metals pollution on surface waters and their effects to health and the environment and prompt transportation of municipal and biomedical wastes should be encouraged.

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COMPETING INTERESTS

Authors have declared that no competing interest exists.

CONSENT

Written informed consent was obtained from each participant before their enrollment into the study.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the Institutional Ethics Committee for Research on Human Health of the University of Douala, regional ethical committee approvals and the Mayor of the Douala IV council. The Institutional Ethics Committee for Research on Human Health of the University of Douala Project number is 1254/IEC-UD/03/2019/M.

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