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ARTICLE

Comparative Assessment of Heavy Metals Pollution in Surface Water in Ikoli River and Epie Creek in Yenagoa Metropolis Using Geographical Information System

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ABSTRACT

The article is the investigation of heavy metals pollution on surface water in Ikoli River and Epie creek in Yenagoa, metropolis, Bayelsa State. Pb, Cd, Ni, Cr, Fe, Zn was determined and evaluated using a Geographical Information System. Zinc concentration was below the permissible limit of 3 mg/L in all the locations sampled. Iron is 77.78% below the limit of WHO 2011 of 0.3 mg/L while other heavy metals examined in Ikoli River and Epie creek are highly polluted. The pollution index for contamination index shows 11.11% sample is high and 88.89% are low while the evaluation of the heavy metal index and the pollution index load of the heavy metals contain 22.11% of the sample are low and 77.78% are high which imply that Ikoli River and Epie creek is polluted. Multivariate treatment of the result revealed a good correlation between the PCA and HCA, which showed activities of natural processes and man influenced environmental sources of the heavy metals which were mainly products of automobile exhaust, water tank leakages as well as dumping of radioactive wastes and burning. The study investigated successfully the potential use of GIS with the help of multiple criteria decision analysis to predict and characterize areas of high pollution, medium, and low pollution in the study area.

1. Introduction

Water pollution is situation whereby toxic materials from the environment are found in the water course, deter the quality of the given water body and also destroy the environment and health system of humanity [1]. Water is a vital resource that is widely accepted for a good number of purposes such as drinking and for so many industries' uses [2]. Water has been a powerful substance for the sustenance and balancing of the human ecosystem system. These practices have been widely used globally. Being a solvent that is occurring universally, It is also one medium that introduces infection to the

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end user if not properly treated. The World Health Organization (WHO) reported that about, 80% of diseases in the environment are waterborne. Most water that is used for drinking in the various Countries in the world does not meet the standards of WHO [3]. About 3.1% of deaths globally occur as a result of unhealthy bad and untreated water systems [4]. The underground system is fundamentally a recycling process due to its esteemed self-filtration and purification processes that took place in the soil. The interaction of water with other earthly materials is enormous and its constant exposure to human activities ie anthropogenic effects causes various routes of pollution forming mainly accumulating toxic metals such as lead, cadmium, and zinc. Deterioration of water quality as a result of the introduction of pathogens and other solutes is a notable challenge facing developing countries and industries around the world. The careless discharge of wastes domestic and industrial waste etc. to large water bodies has greatly destroyed both the quality of water and stampeding aquatic diversity, economic strangulation owing to increases in pollution pathways [5]. Rapid industrialization and the non-availability of clean freshwater resources and pollutants have become a worsening situation. Heavy metal pollution is mainly caused by the introduction of waste as effluents and domestic wastes, sullage, polluted river sedimentation, and atmospheric processes. Heavy metals can also enrich the environment; the microbes introduced into the natural environment cannot easily degrade. Finally, the food chain is also another medium (bioaccumulation) in which heavy metals are introduced into the human body system and directly or indirectly jeopardizes the human health system [6].

A statisitical approach with the incorporation of Geographic Information Syetems (GIS) as a method is fundamentally useful in realizing and determining groundwater quality as its assessment [7]. Hence Geographical Information Syetems a fundamental tool for data analysis, data management, display of spatial data, and also gathering of non-spatial data systems and also Geographic Information Systems (GIS) tools are reliable have proven integrity and could stand the test of time for data storage and management of data, spatial data display for water resources managements and assessments [8]. Today, GIS tools are also very productive and their method is increasing in the search for groundwater resource management. With an emphasis and understanding of the applications and the use of Geographical Information System for determining groundwater resources and water management. Similarly, its applications are aligning and this current study is deploying the inverse overlay method using the inverse weighted technique.

The results gotten from GIS applications have proven realistic in diverse fields of study for easy decision-making and storage of data [9]. GIS knowledge transfer has been a model for environmental studies site assessment, resources of the earth and also assessment of underground water potentials. In research studies of groundwater, underground water mapping, inventory site mapping date, analysis of site suitability, the vulnerability of groundwater site estimation with respect to the degree of contamination, solute transport modeling, infiltrations, under-groundwater flow mapping, and also assessment of groundwater quality index models [8,10,11]. Nitrate presence in water bodies suggests sewage pollution. Chloride concentration varies in aquatic systems which are related to the presence of mineral content. Usually seawater shows appreciable chloride concentrations and this can also be indicated by coastal aquifers. Effluents can also be a source of high chloride concentration especially from the disposal of their raw materials [12]. The lack of environmental enforcement protective laws by Nigerian government has worsened the disposal of effluents municipal wastes and other kinds of wastes etc into the water system [13]. Unhealthy waste disposal practices and untreated effluent disposal have led to deterioration of water quality. According to Tsai et al., (2003) heavy metals presence in surface water bodies indicates the human impact on the environment and in most cases depicts anthropogenic interplay thus destroying the physical environment [14]. Heavy metal pollution index (HPI) and metal index (MI) has profusely and often used as a creative tools for risk assessment of heavy metal's in global water systems [15]. Therefore, there is a need to assess the heavy metal concentration in the environment. The specific objective of the current study is to evaluate the concentration of heavy metal in Ikoli River and Epie Creek comparatively with the help of GIS as a determinant tool to unravel spectral distribution.

2. Study Location

The study area is part of the sedimentary basin of Niger Delta, Southern Nigeria (Figure 1). It is in the Capital City of Bayelsa State. The area shows within Latitude 5°3'30"N - 4°68'30"N and Longitude 6°15'0"E - 6°21'0"E. Good road network links make easy accessibility of the study area accessible.

The study area is characterized by high rainfall during the rainy season and a short duration of the dry season which is about four (4) months. The average annual rainfall is about 4000 mm [16] and this serves as the major source of groundwater recharge. There are two (2) major seasons that defined this region. They are the dry and wet seasons. The dry season lasts from November to early March and the rainy season begins from late March to October. A short break in the rainy season is observed around mid-August. The mean monthly temperature varies between 25 °C and 32 °C. The annual mean temperature is constant within Bayelsa State. The organic debris which originates in these swamps, assist in the sedimentation of this region's climate, vegetation root, types of trees, shrubs, of four ecological zones which supports luxuriant fast-growing swamps forest. These are fresh water swamp, mangrove forests, coastal barrier island forests and lowland rain forests. These types of vegetation are connected with the different soil units in the area, and they are part of the Niger Delta complex ecosystems. The region is characterized by low lands with topography or contour which is part of the surface and it shows the altitude nature of the terrain. Contour lines shown in Figure 2 with areas of equal elevation it was generated at 2 m intervals. The spot height indicates the direction in which water flows through. The areas are drained mainly by the creeks Epie creeks and tend to slope gently into Ikoli River which drains into the Atlantic Ocean. Due to the poor drainage of the area, it tends to flood during the rainy season.

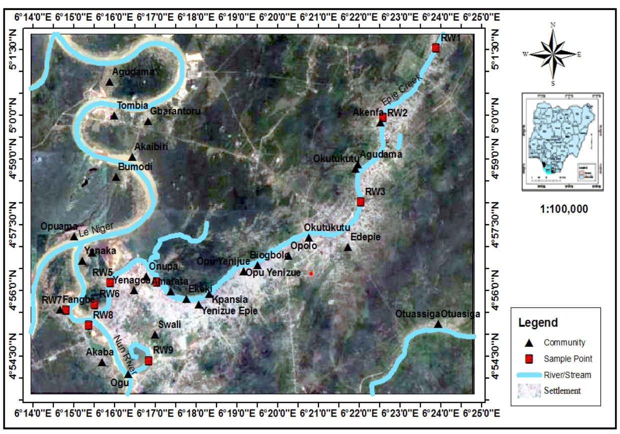

Figure 1. Google map showing sample point for surface water

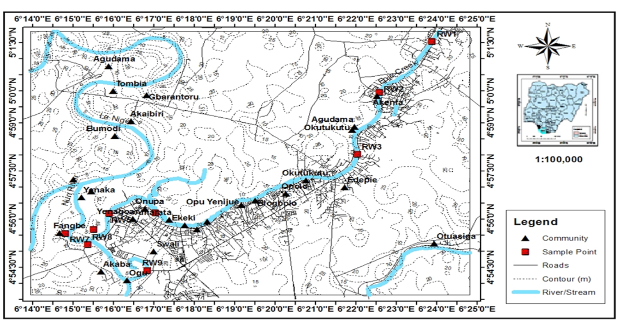

Figure 2. Contour map of the study area

The digital information showing on the topographic architecture in the current study area is pointing too low and high elevations showcasing the digital terrain of the area. The DEM of the current study ranges from 2.00 m to 22.60 m shown in Figure 3. It is used to determine area that is liable to flooding especially during the rainy season [17]. The yellow coloration is indicating flood plain and this is also a reliable pointer to site suitability and for flood relief centers and other similar projects and can also determine rice farming potentials for a peculiar terrain.

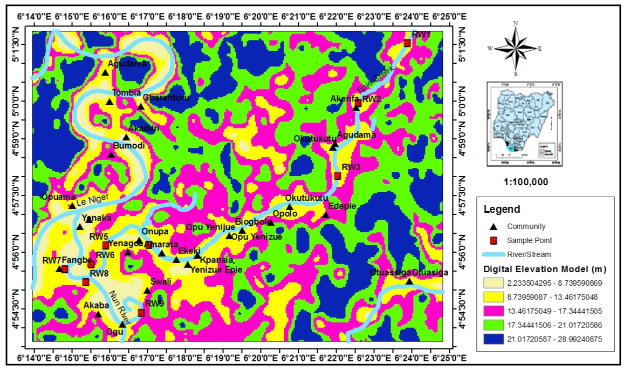

Figure 3. Digital Elevation map of study area

3. Geology of Study Area

Reyment (2018) geologically described the current study area as cutting across the South-Western side of the Niger Delta Region of Nigeria. The formation of the Niger Delta Basin was basically due to rifting of failed arm known as Aulacogen which was a manifestation of a basin that was pulled -apart from the South American plate from the African plate [18]. The initial rifting was initiated during the late Jurassic period and ended during the Cretaceous. Faulting especially thrust faulting was predominant. According to Reijers (2011) the landmass of the Niger Delta basin is about 105,000 km^2 was recorded in the delta [19].

Notable structures of the delta are facies of the Agbada formation, and facies of the pro-delta Akata Formation. The continental Benin Formation constitutes delta top facies with sand and aquiferous potentials. According to Reyment (2018) and Etu–Efeotor (1997) the Paleocene to Holocene Akata Formation is purely marine and is the basal lithostratigraphic unit found in the Niger Delta basin.

It contains marine pro-delta mega facies and are thick shales, turbidite sands, and small amounts of silt and clay. High pressure, low density, and deep marine deposits containing of plant relics characterize the Akata formation and is overlying the Agbada formation [18,20]. Over 50 percent of planktonic foraminifera and the rich micro fauna and benthonic assemblage are found in the Agbada Formation [21].

This assemblage shows a depositional shallow marine shelf environment. Presumably the materials such as the sand streak and silt were deposited within the ambit of high energy delta conditions which advanced into the sea. About 0-6000 meters is the approximate range of thickness. The formation is not visible at the shore and crops out and changes towards the sea at the outer delta area [20].

4. Materials and Method

4.1 Data Collection

A total of nine sampling points were identified for surface water sample collection in Ikoli River and Epie creek in the current study area. The prevailing creeks serve as refuse depositing channels for individuals, marketers and households residing around them. Coordinates were also taken using Global Positioning System (GPS); the collection of the samples was within a distance of 10 cm to 15 cm depth using polypropylene decontaminated bottles. The acidification was done with concentrated nitric acid to a pH below 2.0 to reduce precipitation and adsorption on the walls of the container. The samples were then kept within 4 ºC in an ice-container and were taken to the laboratory for analysis. The samples were analyzed for Pb, Zn, Fe, Cd, Ni and Cr using atomic absorption spectrophotometer. Also Shuttle Radar Topographical Mission (SRTM) from USGS explore were determined before spatial locations of some Communities in the study area were also acquired by the use of Garmin72 GPS, and extracted using TCX, DNRGPS software including downloading of a satellite image from google earth in 2020 with the aid of universal map downloader. An administrative map from where political boundaries and roads were digitized.

4.2 Data Analysis

Multivariate statistical analysis was performed using SPSS 21 for Windows 10. The PCA was used to reduce data and the data were extracted to analyze the relationship between the analyzed heavy metals in the water samples and the likely possible similarities of these metals in the water. The cluster analysis CA was used to classify the heavy metals on the basis of their similarities based on their chemical properties. While the hierarchical agglomerative cluster analysis was used to provides an intuitive similarity relationship between the sample and the data set using the dendrogram which gives a visual of the clustering process. Finally, the correlation coefficient matrix was used to measure how the variance picture of each constituent can be explained by its relationship with each other. The multivariate technique was also used to predict the origin of the analyzed metallic ions in the analyzed surface water samples in addition to various assessments of water were analyzed using heavy metals pollution indices such as the Contamination index, heavy metal evaluation index and heavy metal pollution index.

4.3 GIS Data Processing

Arc GIS 10.6, TCX, DNRGPS, SPSS, Google Earth Pro and Microsoft Excel 2013 software for sample parameter spreadsheet preparation. The collection data was handheld with Global Positioning System (GPS) in degree, minute, second and imported into Microsoft Excel where the data was converted to degree decimal and transferred to Geographical Information System environment in Data Base in Arc GIS 10.6 using Arc map tools and add various layers such as road, Community, River to generate sample location map, Geologic map. Spatial analyst extension tools in Arc GIS 10.6 using hydrological tools to generate the height information from SRTM to produce Digital Elevation Model, Contour, drainage and watershed. Similarly, the spatial distribution maps for assessment of contamination for water quality of selected heavy metals were produced using Arc GIS 10.6 software in Arc tool box to generate surfaces in spatial analysis tool using the inverse distance Weighted method IDW for heavy metals in water in other to generate various assessment of contamination in water such as Contamination index map, Heavy metal pollution map, Heavy metal evaluation index map. Thus, GIS provides the basis for us to look inward into the possible cause and outline the relationship using visual presentation.

5. Results and Discussion

The results from the analysis were collated for surface water presented in Table 1. The parameters analyzed are heavy metals which are chromium, Cobalt, Lead, Zinc iron, nickel and cadmium. The results were compared with the World Health Organization (WHO) standard. Also, statistical treatments were carried out on the samples including basic descriptive statistics, correlation and cluster analysis with assessment of contamination which was incorporated into the environment of geographical information systems using spatial analysis tool with Inverse Distance Weightage (IDW) method for environmental modeling for prediction of pollution zone base of pollution index on heavy metal, evaluation index and contamination index of heavy metal.

The descriptive statistics in Table 1 of the heavy metal in the water show that the surface water in the study areas is the order of abundance in increasing order of the heavy metals as follows: Cr<Ni<Pb<Cd<Zn<Fe and their Mean, Minimum, Maximum, values are show in the table above.

Table 1. Descriptive Statistics for surface water in the study area.

Long	Lat	SAMPLE Point	Pb	Cd	Ni	Cr	Fe	Zn
6.39825	5.02563	RW1 IGBOGENE	0.036	0.014	0.024	0.003	0.271	0.162
6.37654	4.99913	RW2 AKENFA	0.023	0.01	0.016	0	0.206	0.107
6.36729	4.96704	RW3 AGUDAMA	0.017	0.014	0.004	0.003	0.244	0.185
6.28393	4.93666	RW4 AMARATA	0.011	0.08	0.02	0	0.165	0.067
6.2651	4.9363	RW5 FMC	0.032	0.016	0.027	0.007	0.32	0.21
6.25865	4.9281	RW6 FAMGBE	0	0.001	0.01	0.001	0.126	0.055
6.24685	4.92577	RW7 OGBOGORO	0.001	0	0.001	0.001	0.164	0.048
6.25608	4.92012	RW8 SWALI	0.022	0.024	0.024	0.01	0.268	0.24
6.28062	4.90669	RW9 YENAGOA	0.032	0.016	0.027	0.007	0.32	0.21
		Min	0	0	0.001	0	0.126	0.048
		Max	0.036	0.08	0.027	0.01	0.32	0.24
		Mean	0.019	0.023	0.016	0.004	0.23	0.14
		WHO (2011)	0.003	0.01	0.07	0.05	0.3	3
		NSDWQ (2007)	0.003	0.01	0.07	0.05	0.3	3

The Pearson correlation coefficients surface of water samples. As shown in Table 2. Strong correlation among the heavy metals of Ni-Pb, Fe-Pb, Fe-Ni, Fe-Cr, Zn-Pb, Zn-Cr, and Zn-Fe while the rest are weak correlation and also the matrix is not positive definite.

Table 2. Pearson correlation coefficients between heavy metals concentrations in Surface water samples

	Pb	Cd	Ni	Cr	Fe	Zn
Pb	1					
Cd	0.008	1				
Ni	0.782*	0.331	1			
Cr	0.547	–0.106	0.592	1		
Fe	0.901**	–0.093	0.681*	0.782*	1	
Zn	0.775*	–0.08	0.603	0.892**	0.916**	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

The result of HCA in a dendrogram is shown in Figure 4 and Figure 5. The distance cluster expresses the degree of association between sampling sites. The lower the distance value of the cluster, the more significant association. Values of 0 and 25 were restricted between the total cluster distances in this study currently comparing the HCA results and sampling locations Icicle diagram and R-mode Cluster actualize that there is a relation between geographical locations and total heavy metal concentrations with Cluster 1 (5 and 9) at Euclidean distance of 1, Cluster 2 (6 and 7) at Euclidean distance of 6, Cluster 3 (1 and 3) at Euclidean distance of 7, Cluster 8 (5, 9, 8, 1 and 3 also 6, 7, 2) at Euclidean of 25.

Figure 4. Icicle diagram for heavy metals in surface water Sample in the study area

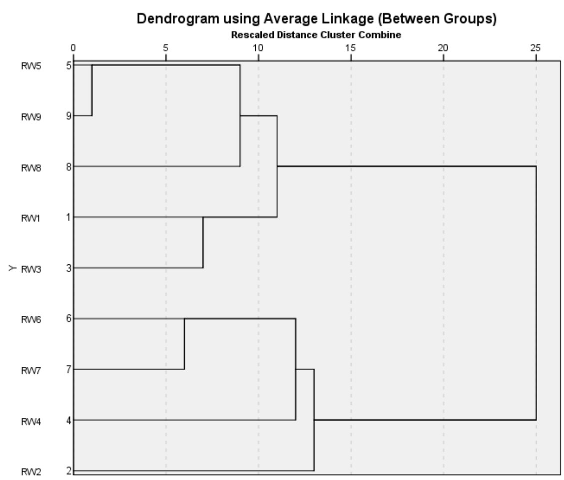

Figure 5. Dendrogram of sampling locations in terms of heavy metals concentrations in surface water (R-Mode)

The Principal Component Analysis output in Table 3, Figures 6 and 7 in surface water. Extraction of two principal components was identified, which explained 86.677% of the total variance. These results explain two main sources of heavy metals in the soil samples. The first principal component explained 66.718% of the total variance. This component was significantly loaded of Ni and Pb with loading values of, an almost similar pattern in Table 4. The second principal component explained 19.959% of the total variance, which was mainly loaded by Fe, Cd, Cr and Zn and from Table 4.

5.1 Iron (Fe) Content

Iron concentration in the surface water explicitly varies from 0.13 mg/L to 0.32 mg/L in Table 1 in the current study. Compared with the tolerable limit for iron is given by the WHO (2011) standard for drinking water of 0.30 mg/L, the water is acceptable for drinking and also can be used for industrial purposes (e.g. in the bakery) except location RW 5 in FMC and RW 8 in Yenagoa in Figure 8. Higher concentration of iron may have some human health implications. The presence of iron can also manifest corroding in the water usually with an indication of offensive coloration with obvious smell and color in the water, making it unacceptable for drinking. The possible higher concentration of iron may be inferred from high refuse dumps of solid industrial and domestic wastes discharge to the Ikoli River which also is flowing into Epie creek. Significantly, the water from the creeks is of good use to humans in the surrounding study area because there is an abrupt scarcity of clean water accessibility for household use in this area.

Table 3. Total Variance Explained for surface water sample of study area

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.003	66.718	66.718	4.003	66.718	66.718
2	1.198	19.959	86.677	1.198	19.959	86.677
3	0.494	8.241	94.918			
4	0.251	4.188	99.107			
5	0.046	0.762	99.869			
6	0.008	0.131	100.000			

Extraction Method: Principal Component Analysis.

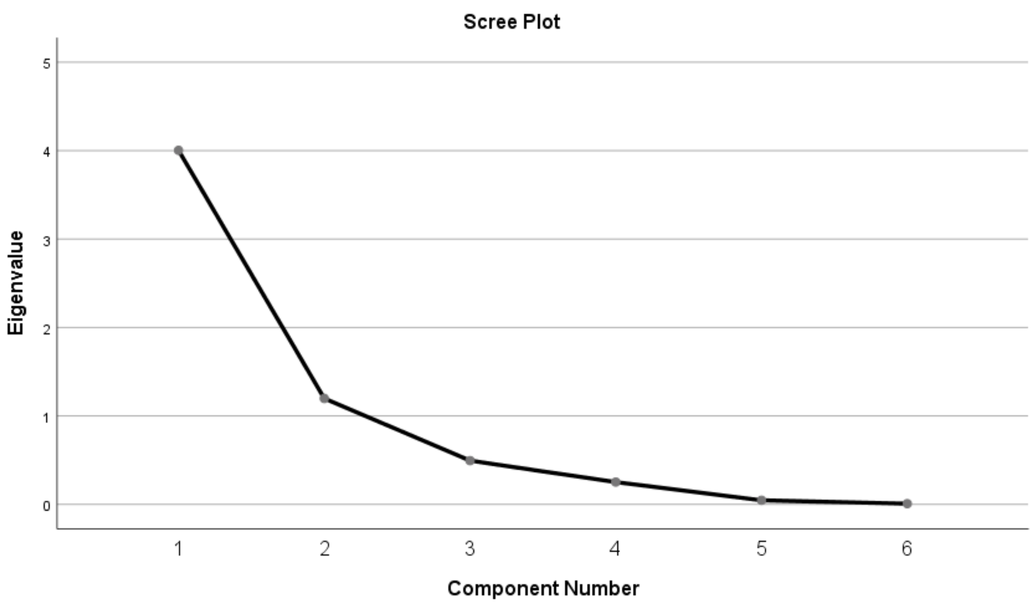

Figure 6. Eigenvalue vs Component Number in Surface water sample

Table 4. Component Transformation Matrix for surface water sample of study area

	Component	
	1	2
Pb	0.898	0.075
Cd	0.007	0.961
Ni	0.810	0.438
Cr	0.853	–0.191
Fe	0.962	–0.116
Zn	0.942	–0.163
Extraction Method: Principal Component Analysis.		
a. 2 components extracted.		

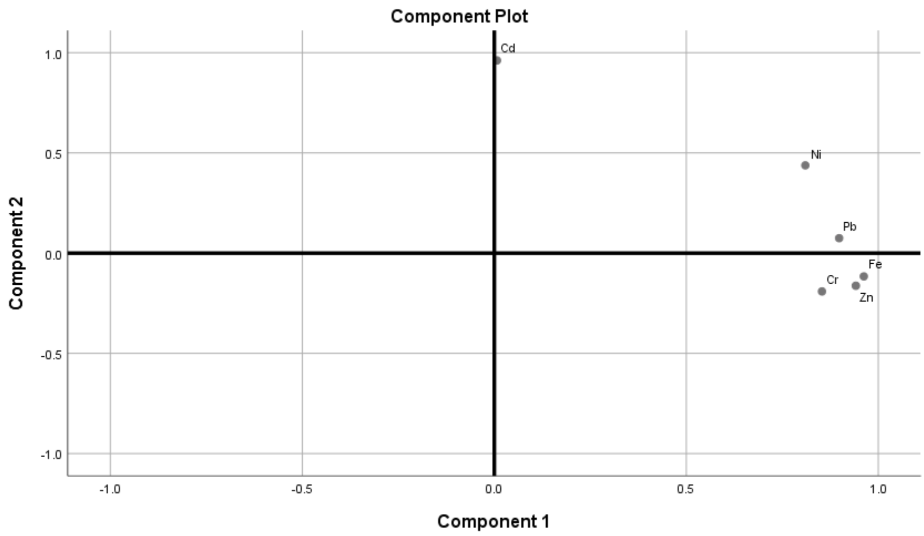

Figure 7. Loadings of principal components of heavy metals concentrations in surface water samples

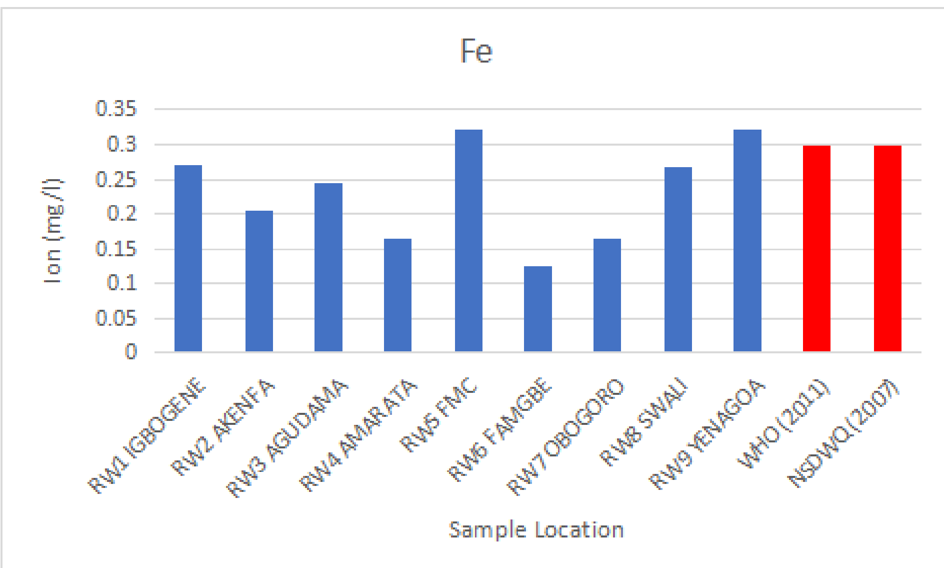

Figure 8. Concentration of Iron in surface water

5.2 Zinc

Zinc concentration in all the samples of the surface water sample varies from 0.05 mg/L to 0.24 mg/L (Figure 9) compared with the tolerable WHO limit of drinking water, the analyzed values were below the permissible limit given by WHO 2011 standard of 3.00 mg/L. which explicitly states that the water is safe for drinking. Zinc is a useful metal that can facilitate or boost female reproduction excessive concentration of zinc in the environment is considered poisonous.

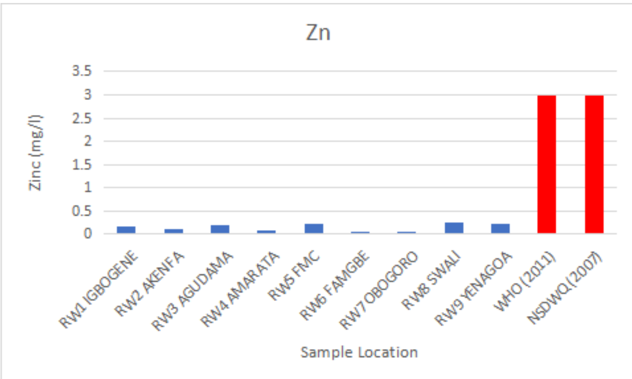

Figure 9. Concentration of Zinc in surface water

5.3 Chromium (Cr)

Chromium (Cr^{6+}) concentration in the surface water indicating from 0.00 mg/L to 0.01 mg/L (Figure 10) with 0.04 as the mean value and when compared with the given limit of (WHO 2011 and NSDWQ 2007) of 0.05 mg/L, the analyzed values is lower than the standard thus indicating that the water is not affected by chromium toxicity. Excessive concentration of chromium is poisonous to the environment especially to an aquatic environment.

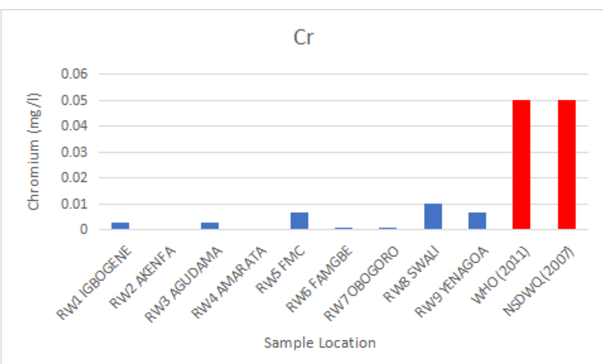

Figure 10. Concentration of Chromium in surface water

5.4 Nickel (Ni)

Nickel concentration in the samples of the surface water varies between 0.001 mg/L and 0.027 mg/L in Table 1. Looking forward the analyzed values of sampled location with the allowable limit of WHO standard for nickel concentration in the surface water samples make clear that the water samples concentrated values were below the given limit of WHO 2011 of 0.07 mg/L which clearly marks that nickel concentration of the water in the study area is minimal. The plotted values of nickel concentration against the regulatory bodies are shown below in Figure 11. Excessive concentration of nickel in the environment is injurious to human health.

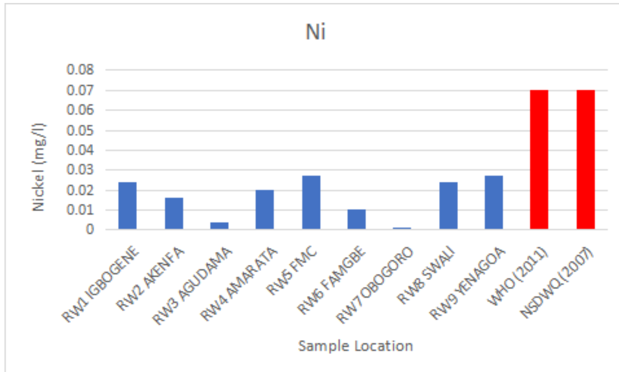

Figure 11. Concentration of Nickel in surface water

5.5 Cadmium (Cd)

Cadmium concentration varies from 0.00 mg/L to 0.08 mg/L in Table 1. The level of cadmium in surface water in sample location RW 6 in Famgbe, RW 2 and RW 7 at Ogbogoro is below the detection limit of WHO 2011 standard given as 0.01 mg/L while other samples location is above the stipulated limit. The occurrence of cadmium is mostly in association with zinc and percolates into the water and also from the corrosion of zinc-coated materials. At higher concentrations, it is known to have a potential toxic effects. Possible sources of cadmium in the environment are through industrial activities; the metal is widely used in making pigments electro plating, plastics, stabilizers and battery industries. Cadmium is highly toxic and can cause high blood pressure, and kidney failure at higher concentrations, etc. Plot of cadmium against the regulatory bodies is shown below. Excessive concentration of Cadmium in the human body and environment can cause an illness called Itai-itai meaning brittle or fragmented bones.

5.6 Lead (Pb)

The concentration of lead in surface water samples varies from 0.00 mg/L to 0.04 mg/L (Figure 13) when compared with the given standard lead concentration was below the stipulated limit of 2.00 mg/L for drinking water given by WHO 2011 standard in samples location RW6 in Famgbe and RW7 in Ogbogoro. While the rest samples were above the permissible limit given by WHO 2011 and are about 77.78% which implies that Ikoli River and Epie Creek are highly polluted by lead toxicity. Plot of lead concentration against the regulatory is given below. Excessive concentration of lead in the environment and the human body affects the IQ of infant babies and also attacks the peripheral nervous system of humans.

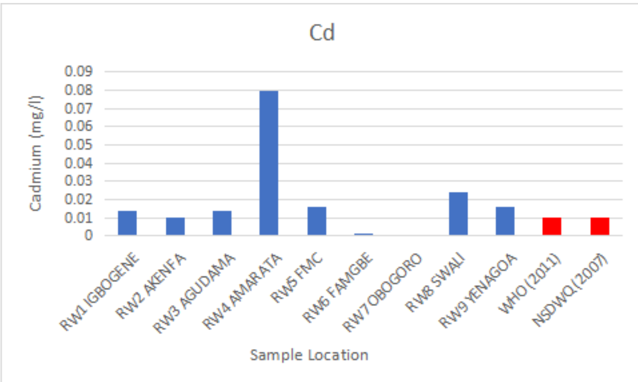

Figure 12. Concentration of Cadmium in surface water

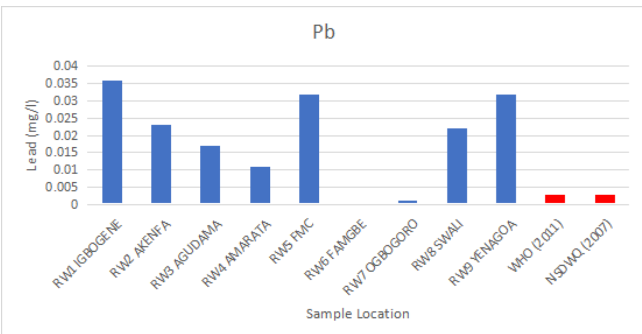

Figure 13. Concentration of Lead in surface water

5.7 Heavy Metals Pollution Assessment Indexes

The computed indexes for this research are presented in Table 5. Three quantitative methods were used in assessing the risk level of heavy metal concentration contamination in the samples: Contamination Index, Heavy Metal Pollution Index (HPI) and Heavy Metal Evaluation Index (HEI).

5.8 The Contamination Index

The contamination index which is also the degree of contamination for the study area was calculated using the concentration values of selected metals Fe, Zn, Pb, Cd, Ni and Cr with minimum and maximum values shown in Table 7, the mean Cd value was found to be –1.62224 and only sample location RW4 in Amara exceeds the critical pollution index value of 1 and the value of Cd average in the current research showed that the area has low contamination in terms of the Contamination index in Figure 13. In this current study the adoption after Backman et al., 1997 and Edet and Offiong 2012 was used for the grouping which indicated thus, low (Cd < 1) medium (Cd 1-3) and high (Cd >3) [22,23].

Table 5. Groundwater quality classification based on adopted and modified pollution indices classes the table is referenced after Backman et al., 1997: Edet and Offiong 2012 and Kwala et al., 2017 [22-24]

Index Method used	Class source	Classes	Degree of Pollution
Cd	Adopted	<1 1-3 >3	Low Medium High
HEI	Modified	<5 5-20 >20	Low Medium High
HPI	Modified	<100 100-150 >150	Low Medium High

Table 6. Adopted Standard for computed indices

Heavy metal	Wi	S	I	MAC
Pb	100	0.003	0.003	0.003
Cd	333.33	0.01	0.01	0.01
Ni	14.29	0.07	0.07	0.07
Cr	20	0.05	0.05	0.05
Fe	3.33	0.3	0.3	0.3
Zn	0.33	3	3	3

MAC: maximum admissible concentration/upper permissible
Wi: Weightage (1/MAC)
S: Standard permissible
I: Highest permissible

Table 7. Assessment of Contamination results

Long	Lat	SAMPLE Point	Cd	HEI	HPI
6.39825	5.02563	RW1 IGBOGENE	–2.23981	14.76019	408.3911
6.37654	4.99913	RW2 AKENFA	–3.0491	9.617571	285.7462
6.36729	4.96704	RW3 AGUDAMA	–2.60786	8.05881	471.28
6.28393	4.93666	RW4 AMARATA	3.858048	12.52471	1910.695
6.2651	4.9363	RW5 FMC	–1.73762	13.92905	447.6419
6.25865	4.9281	RW6 FAMGBE	–4.29881	0.70119	24.39231
6.24685	4.92577	RW7 OGBOGORO	–4.40305	0.930286	2.63746
6.25608	4.92012	RW8 SWALI	–1.08381	11.24952	615.0358
6.28062	4.90669	RW9 YENAGOA	–1.73762	13.92905	447.6419
		Minimum	–4.40305	0.70119	2.63746
		Maximum	3.858048	14.76019	1910.695
		Mean	–1.62224	9.196524	593.3449

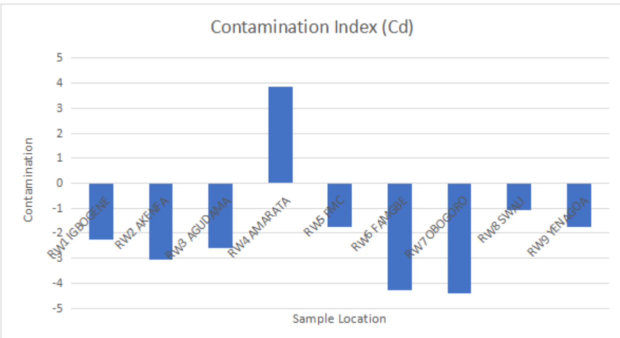

Figure 14. Concentration of Contamination Index in surface water

5.9 Heavy Metal Evaluation Index

Heavy metal evaluation computation indexes (HEI) of the current study areas give a mean value of 9.196524 with minimum and maximum values of 0.70 and 14.76 respectively. Adopting the procedure used after Edet and Offiong 2012 [23], the values of HEI computations were divided into 3 classes using a mean value multiplication. The three classes demarcated are HEI < 5 low, HEI 5-20 medium and HEI > 20 high. Based on these, 2 locations which represent 22.22% of all the locations had low HEI values, while 9 locations covering 77.78% of the sample waterfalls within the medium class in the study in Figure 15.

5.10 Heavy Metal Pollution Index

The pollution index for heavy metals in the study areas were done with a calculation using the concentration values of (Pb, Zn, Fe, Cd, Ni and Cr); the mean value of HPI was found to be 593.34 (Table 7) which extends the critical pollution index value of 100 exceptions of RW6 in Famgbe and RW7 in Ogbogoro which were below. This outline that the study areas (Ikoli River as well as Epie creek), are recorded with very high concentrations of heavy metals which were the critical pollution index. HPI values for all sampled locations were observed to be greater than the tolerable limit (HPI>100) with the highest value of (1910.69) recorded at RW4 in Amarata and the lowest value (2.64) observed in (Figure 14 and Table 7). Although RW6 and RW 7 are characterized by non-industrial activities in the area other adjourning areas may have been connected to possible dilution effects from the discharge point towards the area of Epie creek due to solid waste disposal in the river. The HPI indicated that metal concentration decreases for distance increasing away from the pollutant emission sources.

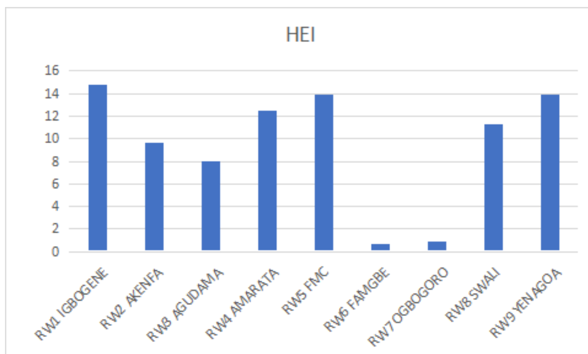

Figure 15. Concentration of Heavy Metal Evaluation Index in surface water

5.11 Interpolation of Water Contamination

The spatial distribution of contamination in surface water contamination surfaces created by using Inverse Distance Weighted (IDW) method and the techniques of GIS mapping was applied to produce distribution of spatial maps of the Contamination Index, Heavy Metal Evaluation Index and Heavy Metal Pollution Index surfaces created by using IDW method.

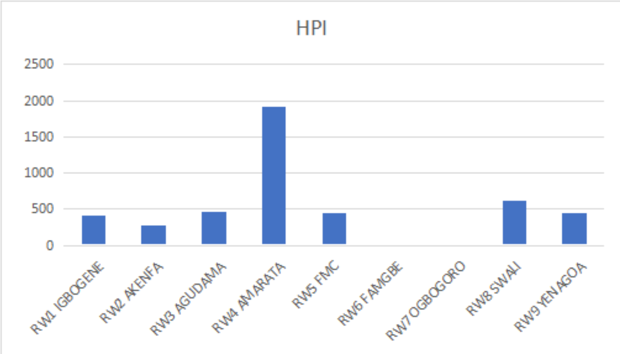

Figure 16. Concentration of Heavy Metal Pollution Index in surface water

5.12 Contamination Index Map

From Figure 17 the spatial distribution map of Contamination Index for surface water reveals that the area with blue colour has a low contamination index, likewise area with yellow colour contains a medium contamination index and the area with red colour reflects high contamination index.

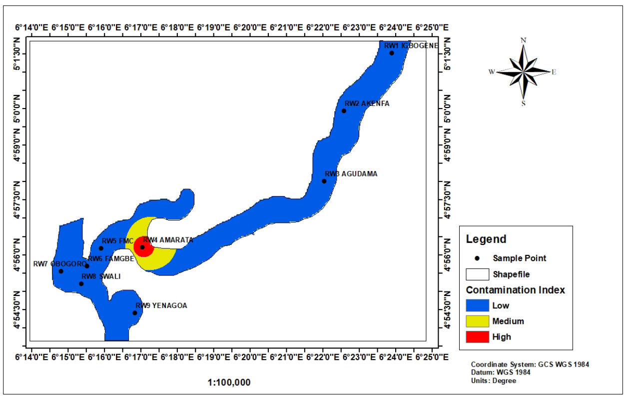

Figure 17. Contamination Index Map in surface water

5.13 Heavy Metal Evaluation Index

The distribution spatial map of evaluation of the heavy metal index in Figure 18 reveals that blue colour contains a low degree of pollution and red indicates a medium degree of pollution when compared with Table 5.

5.14 Pollution Index of Heavy Metal

The spatial distribution map of pollution of heavy metal index for the surface in Figure 19 reveals that the area with blue colour indicates a low Degree of pollution likewise area with yellow contains medium Degree of pollution and the area with red colour is High Degree pollution when compared with Table 5.

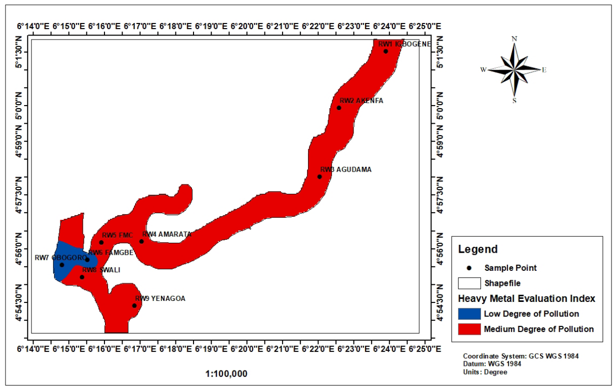

Figure 18. Heavy Metal Evaluation Index Map in surface water

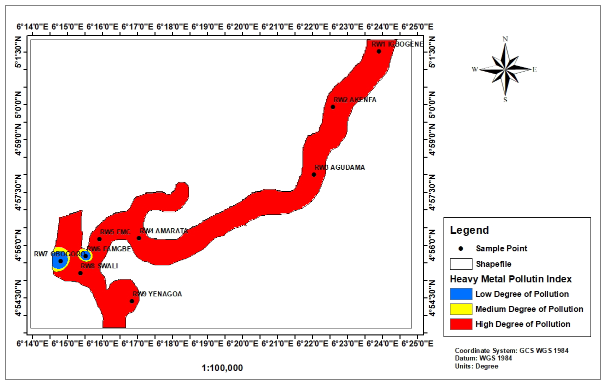

Figure 19. Heavy Metal Pollution Index Map in surface water

5.15 Analysis of GIS Using Weighted Overlay Method

In the final prediction of the pollution zones, and the evaluating criteria were needed to give a better understanding. GIS applications were assessed using the weighted Overlay method which gives a set of map classes referencing each input. The maps were given values of different scores and provisions of different weights. Limiting the criteria compromises the accuracy of the proposed approach the multiple criteria decision analysis (MCDA) methods for the importance weighting of various environmental criteria will increase the accuracy of ranking potential pollution indices. This method was accurate and resolved multi-criteria problems in many fields of study by integrating GIS and MCDA to help tackle the real-world problem [25].

The pollution indices are used to denote the heavy metal evaluation index, Contamination index, and heavy metal pollution index. The scores given for the three pollution index for each map class was assigned along with the map weightings entered as attribute data and also the percentage of influence the on weightage of the spatial maps based on the class provided below.

Table 8. Multiple criteria decision analysis for ranking of pollution in study area

S/N	Pollution	% of Influence	Rank
1	Contamination index	20	2
2	Heavy metal evaluation index	40	5
3	Heavy metal pollution index	40	5

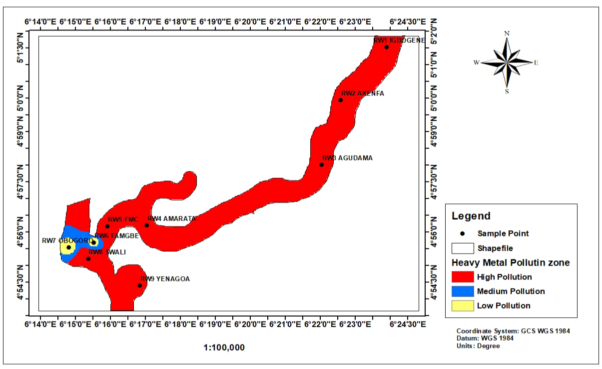

Figure 20. Heavy Metal Pollution Map in surface water.

The heavy metal pollution Map using Multiple criteria decision analysis reveals that Ikoli River, Epie creek is polluted which is due to careless dumping of industrial wastes and domestic wastes and, also attributed to leakages from marine dumping wastes, water tanks, radioactive waste, and atmospheric deposition are some of the known causes of water pollution. Heavy metals that are disposed of in industrial waste can accumulate in lakes and rivers, proving harmful substances to the ecosystem. These harmful toxins released into the environment especially effluents aggravate and suppress the human immune system, and causes reproductive failure, and acute poisoning. Some diseases causing infections such as cholera, and typhoid fever [26], and other diseases gastroenteritis, diarrhea, vomiting, skin, and kidney problem are spreading through polluted water [27]. Human health systems are directly damaged due to poor environmental management. Water pollutants are degrading marine environmental plants and animals such as seaweeds, mollusks, marine birds, fishes, crustaceans, and other sea organisms that serve as food for humans. Poor usage of insecticides such as DDT releases harmful concentrations into the environment which is deteriorating the food chain.

6. Conclusions

In the evaluation for the Heavy metal concentration and pollution statute, out of all the metals detected and evaluated, Zinc concentration was below the required and permissible limit of 3 mg/L in all the locations samples of 9, and iron is 77.78% below the stipulated limit by WHO 2011 of 0.3 mg/L while other heavy metal in Table 1 reveals Ikoli River and Epie creek to be highly polluted. The calculated pollution index for contamination index gives 11.11% sample are high and 88.89% are low while both heavy metal evaluation index and the heavy metal pollution index contain 22.11% of the sample are low and 77.78% are high which implies the Ikoli River and Epie creek is polluted. Also, multivariate treatment of the result revealed a good correlation between the PCA, and HCA, which showed geogenic and anthropogenic sources of the Heavy metals to be the products of automobile exhaust, leakage from water tanks, marine dumping, radioactive waste, and burning. From Figure 17 this study investigated successfully the use of the application of GIS weighted overlay method with the help of Multiple Criteria Decision Analysis to predict and characterize areas of high pollution, medium and low pollution in Ikoli River, and Epie creek in Yenagoa. Consequently, recommendations such as sustainable development of wastewater resources and public law and awareness campaigns should be emphasized. Environmental law and public awareness should be placed high. The study contributed to knowledge by using geographical Information Systems and Remote Sensing technology has the potential to store, analyze, monitor, and use for mapping of pollution in water resource management for better visualizing the environmental policy.

Conflict of Interest

There is no conflict of interest.

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