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FACULTY OF AGRICULTURE

DEPARTMENT OF AGRICULTURAL PRODUCTION & SYSTEMS (APS)

Assessment of Water, Sediment and Fish quality in a Barachois for a potential mariculture project

BY

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Abstract

The study conducted below is about setting up a new aquaculture system in the south east part of Mauritius at Residence La Chaux at Mahebourg. 4 sites were selected for this analysis and they were compared in order to see which site is most suitable for the set up. Several test such as pH, salinity, phosphate nitrate and organic carbon in water and sediments. More important test that is heavy metal tests were carried out in water, sediments and fish samples. pH values of the samples ranged between 8.0 – 9.0 and salinity of the samples ranged between 28.0 to 35.0 ppt. The nitrogen, phosphorus and organic carbon content of the samples were higher. The value for nitrogen was 10.85- 15.61 mg/L. whereas the heavy metals content in the water, sediments and fish samples were high as compared to research work carried out. Only the concentration of cadmium was found in trace amount and the value was 0.0072 mg/L, which is it was found only in one sample. The contents of heavy metals in fish were lower than that of water and sediments. It can be concluded that the sites selected are suitable for the setup of aquaculture systems and hence more research work should be carried out to understand the ecosystem of the sites.

List of Abbreviations

% - percentage

AAS – Atomic Absorption Spectrum

Cr - Chromium

$CuSO_4$ – Copper Sulfate

FAO – Food And Agriculture Organisation

g – grams

H_2SO_4 – Sulfuric Acid

HCl – Hydrochloric Acid

KCl – Potassium Chloride

L – Litres

M – Molar

mg/g – milli gram per gram

mg/g – milligram per litre

ml – millilitre

NaOH – Sodium Hydroxide

ppb – parts per billion

ppm - parts per million

ppt – parts per thousands

WHO – World Health Organization

1. Introduction

1.1. Introduction

This project is about identifying whether the proposed site for Barachois is a suitable one to launch an aquaculture project for the culture of crabs, and oyster. There are several factors around the sites that can have an impact on the identified sites. Some factors are soil erosion, presence of a river mouth and habitat around the barachois. These factors have impacts on sulfur content, phosphorus content, nitrogen content, carbon content and heavy metal content of water, sediment and fish that are present in the barachois. With a growth rate of 10 % per year, Aquaculture is growing very fast around the world and thus is contributing a lot to reduce the scarcity of food around the world (Ministry of Agro-Industry and Fisheries, 2007). The occurrence of new aquaculture system will help in reducing poverty by the formation of new job scopes (Republic of Indonesia, 2003). The introduction of an aquaculture system may have a good impact on the environment as it will improve the infrastructure of certain proposed site. The aquaculture sector is one which is reducing famine, malnutrition and meeting the energy needs of the world population. The aquaculture sector should ensure security for the food supply that it is providing for the population (Funmilola, 2016).

Fish in diets has many benefits as it adds many nutrients and minerals and also brings lots of advantages to human health. Aquaculture is the only natural way through which the population is able to meet the requirements for omega-3-polyunsaturated fatty acids (Varela, 2008). The aquaculture has provided many job opportunities and has reduced the ratio of unemployment. A large amount of fish produced through aquaculture is exported to developing countries (Finegold, 2008). Another prominent farming is ornamental farming. It may help in maintaining and preserving many rare species in the sea. This type of farming requires specialized trainings. It can also benefit to the economy and become a tourist attraction spot (Tlusty, 2004).

There are factors that are affecting aquaculture. Firstly, the price and availability of fish meal is increasing. Aquaculture itself is considered as a pollution causing agent and hence the byproducts of aquaculture may lead to an increase in nutrients in water and hence it may cause eutrophication. Other polluting factors may be due to oil spills, household discharge and agricultural pesticides. There is a group of people who are against the practice of aquaculture. However the objectives of aquaculture are to provide the proteins through fish at a reasonable price, provide new species and maintaining natural species. One aim is to support recreational fishing. Moreover it may encourage the recycling of organic waste of humans and livestock (Jhingran, 1987). There are several systems used for aquaculture namely water based system, land based, recycling system and integrated farming (Smith and Philips, 2001).

1.2. Hypothesis

To test whether the proposed site is an appropriate one where an aquaculture project can be implemented with respect to water quality, sediments and fish quality.

1.3. Aim

The aim of this investigation is to assess the quality of sediment, water and fish in view of a potential mariculture project from different sites at Barachois

1.4. Objectives

The Objectives are:

- To identify potential sites for a mariculture project and collect samples
- To evaluate the nutrients content such as nitrogen, phosphorus and carbon in water and sediments
- To test for heavy metals in water, sediments and fish samples
- To select appropriate sites to set up an aquaculture system.

2. Literature Review

2.1. Aquaculture

The alternative way to meet up the daily food requirement all around the world is Aquaculture *(*Fisheries.noaa.gov, 2018*)*. Aquaculture is the new growing field which is giving a helping hand in the socioeconomic growth of many countries. There are several types of culture technologies like cages in open sea, in land culture, ponds, lakes, rivers, and barachois. Barachois culture is one popular culture that is growing in this sector. The barachois culture comprises mostly of oyster farming and crab farming. There are many sites that have been identified where aquaculture projects can be set up. A site, a barachois, to set up an aquaculture project was identified in the south east part of Mauritius, namely Residence La Chaux, Mahebourg. Thus test are to be carried out to investigate whether it is a potential site to set up the aquaculture system.

The identified site consists of 7 different barachois where 4 places were chosen for the analysis to be done.

Fig 1.1 site of sampling

(Source: Google earth)

2.2.Site description

Site 1

Site 1 is one of the large ponds that are found in that location. The pond is surrounded by a barrier of rocks. On one side of the pond there is another large pond named site 3 and on another side, it meets the sea. A part of the pond is surrounded by land.

Site 2

Site 2 is a pond that is found in a remote place. The pond is surrounded by mangrove.

Site 3

Site 3 is another big pond which is found next to site 1. Next to the site, there is a river mouth.

Site 4

Site 4 is a small pond and found in the middle and surrounded by land. There is a lot of pollution around this site.

2.3. Erosion from agricultural land

Soil erosion is a lethargic impact that results in soil particles due to the activity of wind and water causing degradation in soil. This phenomenon is becoming more and more frequent around the world and is carrying away soil nutrients to rivers. Through rivers the nutrients are landing in the sea thus affecting the costal ecology. On agricultural lands, the use of pesticides, insecticides and plant nutrients are used. The excessive use of these agricultural medicines ends up in the sea through soil run off and also affects aquatic animals (Schultz, 2011).

2.4.Pollution

Pollution is defined as the introduction of substances by man into the aquatic environment, resulting in such deleterious effects which is harmful to living resources, are hazards to human health and cause obstruction in the marine environment (Waldichuk, 1974). There are several sources of pollution such as boat activities, disposal of waste, sewage and habitat. Through these types of pollution, the normal concentrations of certain heavy metals are exceeding the amount needed. According to Henry (2012), there is 20% Mercury, 8% Copper and 68% Lead entering the ocean.

2.5. River mouth

The river mouth is a place where there is deposition of sediments. These sediments consist of many nutrients, pesticides, insecticides. The run off of soils on upper land often end up in rivers. Rivers also bring waste to the river mouth which changes the salinity gradient (Kazungu, 2018).

2.6. Nitrogen cycle

Nitrogen cycle is a biogeochemical cycle that occurs in nature with respect to changes with nitrogen compounds. Nitrogen is an essential element for most biological processes. Nitrogen cycle comprises of Ammonification, Immobilization, Nitrogen fixation, Nitrification and Denitrification. According to researchers from Kiel Germany, nitrogen that are in the ocean, deposits there as a consequence of runoff from upper lands through rivers and thus relates terrestrial and marine nitrogen cycle (G. Capone, 2008).

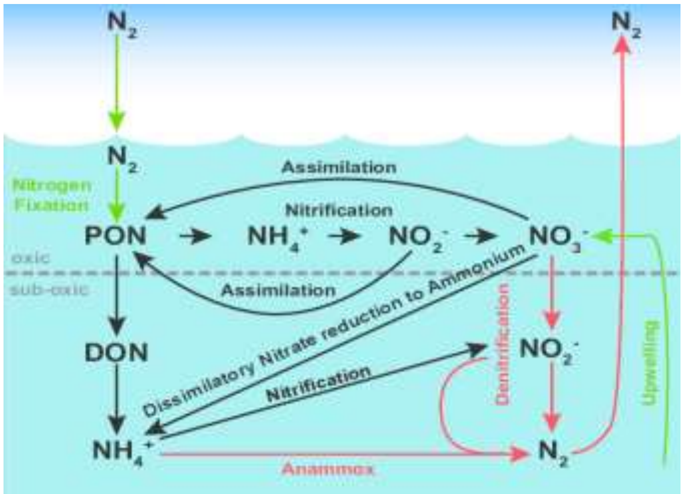


Fig 1.2 Nitrogen cycle

(Source: Research gate, Arrigo, 2005)

2.7. Phosphorus Cycle

Phosphorus is an important component of life (White and Dyhrman, 2013). Phosphorus is an important content for primary productivity in the aquatic environment (FROELICH et al., 1982). This nutrient helps phytoplankton to grow and maintain it and is regained upon decomposition of organic matter Phosphorus is found in sediments as phosphate salts (Sundby et al, 1992).

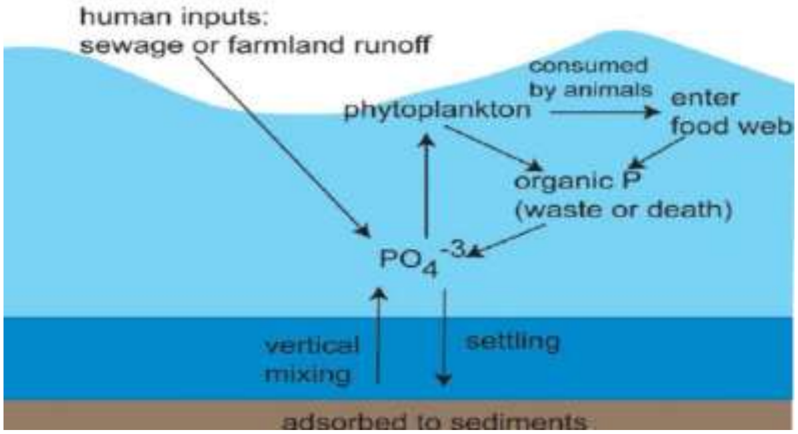


Fig 1.3. phosphorus cycle

(Source: Research gate, 2016)

2.8. Carbon cycle

The sea takes up more carbon than it releases to the atmosphere. Atmospheric carbon dioxide dissolves in sea water. Small photosynthetic plants, such as phytoplankton take up atmospheric carbon dioxide, and convert it in to organic carbon. Some organisms in the oceans, has the ability to transform carbon into rocks. Carbon enters into aquatic organisms in the form of organic carbon and calcium carbonate (Science Learning Hub, 2010).

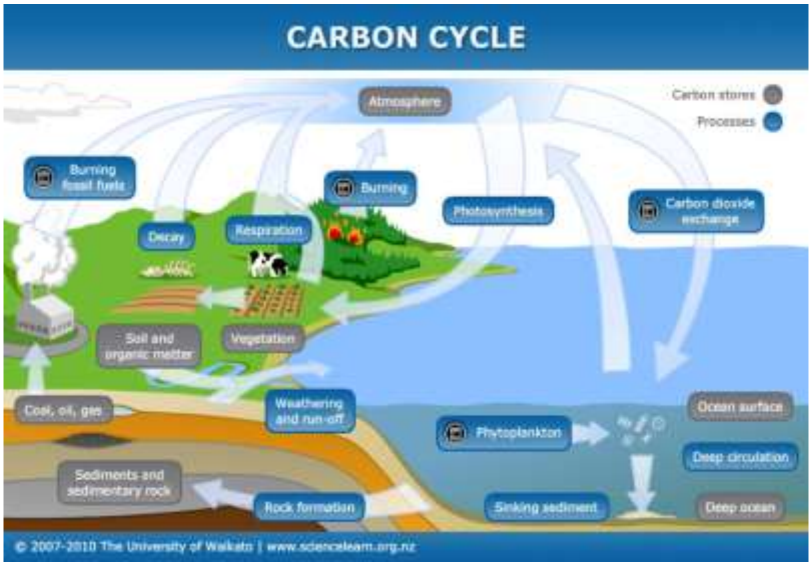


Fig1.4. The Carbon cycle

(Source: science learning hub)

2.9.The sulfur cycle

Sulfur is an element that gets involve in many biogeochemical reactions that have an impact on carbon cycle and oxygen cycles. Sulfur is an important element for the formation of lipids and eventually proteins (Hurtgen, 2012). As sulfur content increases in sediments, toxicity of sediments increases (Monika et al.., 2017). The sea gives a smell of rotten cabbage which shows that hydrogen sulfide and thus sulfur is present in the sea and mostly in sediments as it comes from decaying organism in the sea. The smell of hydrogen sulfide may affect the earth organisms as it is toxic (Science Daily, 2003).

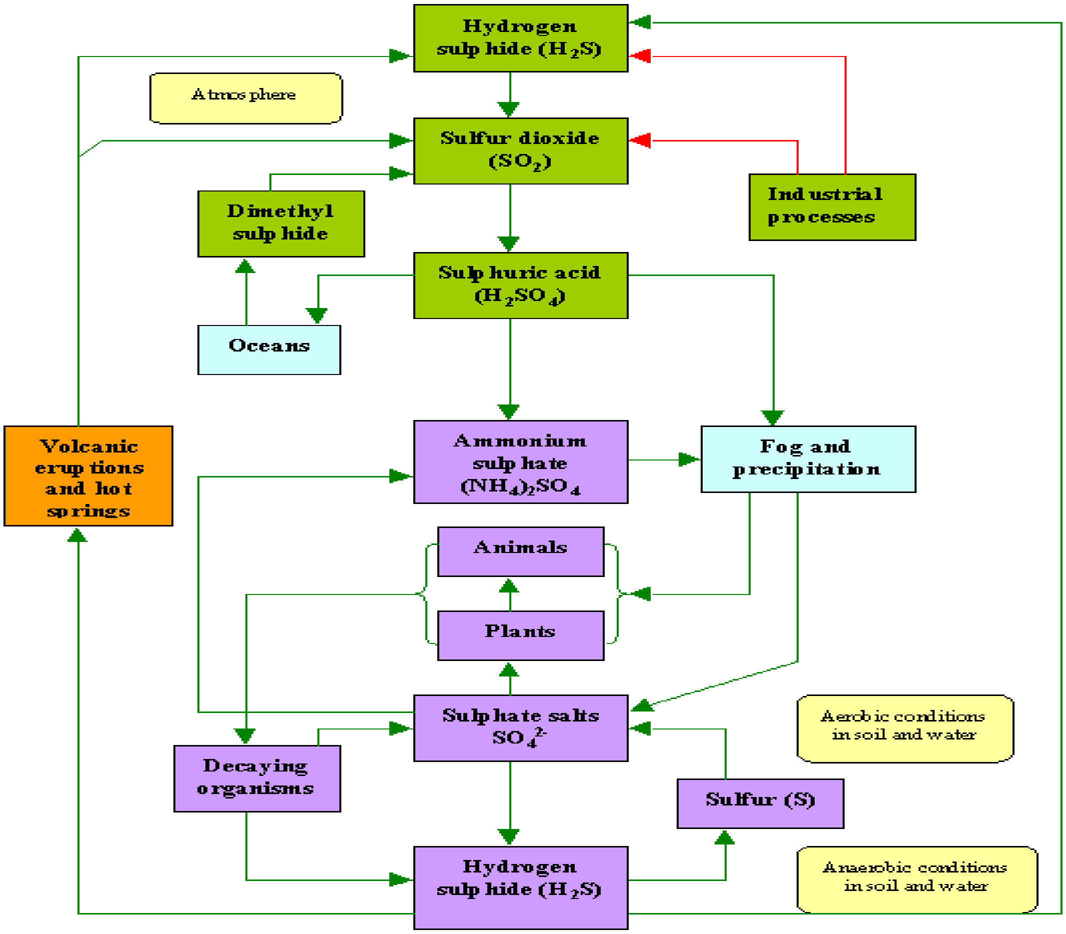


Fig1.5. The sulfur cycle

(Source: Lenntech)

2.10. Heavy metals

Heavy metals are needed in very small amount in living organisms in order to keep the body metabolism. Nevertheless when its level increases, heavy metals become toxic and may cause poisoning. Lead, Cadmium and Mercury are considered to be the most present in the environment (Lenntech, 2017). Rapid urbanization has direct impact on pollution and thus increases the amount of heavy metals in the aquatic environment (Afiza & Mohamed, 2012). Thus heavy metals from sea water penetrate into sediments **(**Wei Hsiang Tan et al.., 2016).

2.10.1. Cadmium

Cadmium is known as a carcinogen and an agent that causes defects in new born (Royal society of Chemistry, 2017). Cadmium is found in a relatively low amount in nature especially in the sea (Mart and Nürnberg, 1986). Cadmium is relatively motile in the sea (Jerry M Neff, 2002).

2.10.2. Chromium

Chromium is a water soluble metal which dissolves in water from the atmosphere. Chromium then deposits on sediments. This element also gets incorporated in the tissues of the fish. This element has an immune toxic impact on aquatic organisms (Oana, 2006).

2.10.3. Copper

Copper is present in the water, sediment and marine organisms due to natural and anthropogenic copper. Copper is an essential micronutrient to both plants and animals (Schmidt, 1978).

2.10.4. Manganese

Manganese is present in the sea as nodules and about 30% is found on the sea bed. It is found mostly in the first 5 m of the sea bed and thus decreases at greater depths (Patrick, 2010).

2.10.5. Nickel

Nickel gets into the sea through rivers. Phytoplanktons, in the sea contain nickel. Agricultural fertilizers and lands often contain traces of nickel (Laevastu et al, 2015).

3. Methodology

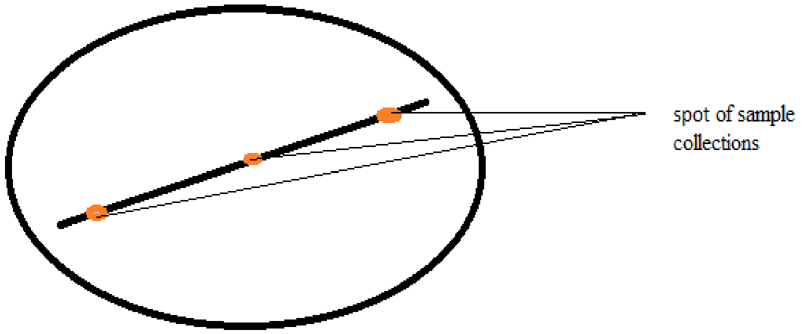
3.1. Site selection

Site selection is an exercise performed to obtain a representative piece of the environmental part of the remaining site to be analysed (Sampling and preparation for laboratory measurements, 2000). Before the analysis we need to have a review of the site that is been selected. For example previous analysis done at the site and projects those are ongoing there (Smodiš, Annareddy and Rossbach, 2003). For this particular analysis, a proposed site for barachois is selected situated in the south east coast of Mauritius known as residence La Chaux, Mahebourg. The location consists of 7 barachois and of which 4 sites is selected at random.

3.2. Sampling

3.2.1. Water sampling

In each barachois, three different spots were identified in a straight line. At each specific spot, 1L of water was collected in a de ionized bottle. Immediately after collection, the sample was put in an ice bag to preserve it and once in the lab the water sample is kept in the refrigerator at 4°C (Who.int, 2018).



3.2.2. Sediment collection

Sediments were taken at same site of water collection. The sample should be representative. The sediments were collected in polyethene bags using a corer. The upper 0-3 cm layer of sediments was taken for sampling. A mass of 500g of sediment was collected at each site for analysis (Smodiš, Annareddy and Rossbach, 2003).

3.2.3. Fish collection

Fish samples were collected by fishing or with nets in the barachois chosen for sampling of water and sediments. After the fish had been taken out of water, the samples were kept in crushed ice to prevent any chemical and biological damage (Fish collection and dissection for the purpose of chemical analysis of tissues, 2017).

3.3. Preparation of samples for testing

3.3.1. Water sample

Water samples were stored in the refrigerator at a temperature of 4 °C and the further analysis was done with the water sample (Sample Collection, Storage and Preservation, 2018).

3.3.2. Sediment

Trays were used to dry the sediments collected. Paper was first placed on the trays and then the sediments were spread on the trays. The sediments were left to air dry. From time to time the sediments were reversed to ensure complete dryness in the samples. After air drying for a few days, further processing of the samples was carried out. The samples were first crushed using a mortar and pestle and then passed through a sieve of 2mm to remove the big uncrushed particles and to obtain fine particles of the sediments. After processing the samples for analysis, the sediments were stored in jars (Weppi.gtk.fi, 2018).

3.3.3. Fish

The fish was descaled and the internal parts of the fish were removed (Nrm.se, n.d.). After descaling, the fish was cut into small pieces and was put in a freeze dryer to remove all the water content of the sample for long term storage. After freeze drying, the samples were kept in a refrigerator at 4°C (Unistelmedical.co.za, 2018).

3.4. Water tests

Temperature of water was measured in situ that is upon collection the temperature was measured using a thermometer (Marianydesigns.com, 2008).

3.4.1. pH of water

Water samples were removed from the refrigerator and let to stabilize to room temperature. A pH meter was used to calculate the pH. The pH meter was calibrated using pH buffer pH 7 and then pH 4. 10 of each water sample were measured in different test tubes. The probe of pH meter was dipped in each test tube and the pH of each water sample was recorded (pH of Salt Water, 2008).

3.4.2. Salinity of water

There are several ways to measure salinity. One way to measure salinity is by using electrical conductivity method. The electrical conductivity meter was calibrated with 0.01M of KCl. 10 ml of each water sample was measured in different test tubes. The probe was inserted in each test tube and the electrical conductivity was recorded. The probe was washed and wiped before inserting it in another test tube for analysis (Conductivity Theory and Practice, 2004).

3.4.3. Nitrates in water

An apparatus known as the Hanna meter was used to measure the amount of nitrates present in water. 6 ml of water sample was placed in the cuvette, closed and the cuvette was placed in the apparatus. The zero key was pressed and when the screen of the apparatus showed zero, the cuvette was removed and a packet of HI 93728-0 reagent was added to it. The cap was replaced and the cuvette was shook quickly for 10 seconds and then was shook gently for 50 seconds until all the reagents dissolved in the water. The cuvette was again placed in the apparatus and timer was pressed. After 4.3 minutes a value was displayed on the screen and it was noted.

3.4.4. Phosphate in water

Same as for nitrates, to calculate phosphate in water the same apparatus was used, the Hanna meter. Phosphate HR method was selected for the test. The cuvette was filled 10 ml of water and placed into the Hanna meter and zero was pressed. When the screen showed zero, the cuvette was taken out and the packet of HI 937178-0 Phosphate HR reagent B followed by 10 drops of HI 93717A Molybdate reagent was added and the timer button was pressed and after 5 minutes the value was recorded.

3.4.5. Heavy metals in water

Water samples were prepared by addition of Aquaregia (25% concentrated nitric acid and 75% concentrated hydrochloric acid). To 50 ml of water sample, 15 ml of Aquaregia solution was added. After this digestion water samples were stored in polyethylene bottles in refrigerator at 4 ℃ for seven days (Radulescu et al.., 2014).

3.5. Sediment analysis

3.5.1. Salinity analysis

To measure the salinity of the sediments electrical conductivity method was used. The sediment sample was prepared for the experiment. 5 g of each sample were measured in 100 ml conical flask. Then 25 ml of distilled water was added to each conical flask. A ratio 1:5 was used to add distilled water. After addition of distilled water, the conical flasks were placed on an orbital shaker for 30 mins. After the 30 mins, an electrical conductivity meter was used to measure the electrical conductivity and the values obtained were recorded (Conductivity Theory and Practice, 2004).

3.5.2. Determination of Total Nitrogen in sediments

3.5.2.1. Digestion

The digestion tube was taken and 0.5g of sediment was measured in each digestion tube followed by the addition of 1g of $CuSO_4$ and 15ml of concentrated H_2SO_4. The samples were next placed on the digestion rack at 380℃ for 1 hour. After 1 hour, the samples were let to cool. After cooling, distilled water was added to each digestion rack, and was topped up to 100 ml in a 100 ml volumetric flask.

3.5.2.2. Distillation-

Boric acid was prepared and 5 ml of the acid was transferred to 100 ml conical flask followed by two drops of indicator. Then 5 ml of the digested sample pipetted and added to the Markham distillation apparatus through the funnel. The digest was let slowly in the condenser and then 5 ml of NaOH was let slowly in the funnel. The 100 ml conical flask was put at the receiver. Approximately l0 ml of the extract was collected and a colour change occurred from pink to blue and the solution wash kept for titration (Taylor, 2001).

3.5.2.3. Titration

The retained solution was titrated against 0.01M HCL and the value obtained was recorded.

3.5.3. Determination of available phosphorus in sediments

3.5.3.1. Preparation of ammonium molybdate

12 g of powdered ammonium molybdate and 0.3 g of antimony potassium tartrate was dissolved in 600 ml distilled water in a 1000 ml volumetric flask. Then to this solution 148 ml of concentrated H_2SO_4 was added and the solution was made up to the mark of 1L with distilled water. This solution was further diluted by transferring 125 ml of the solution in another 1000 ml volumetric flask and was topped up with distilled water. This prepared solution was kept in a cool place.

3.5.3.2. Preparation of ascorbic acid

Powdered Ascorbic acid of mass 1.5 g was measured and a solution was made out of it by the addition of 100 ml distilled water in a 100 ml volumetric flask. Upon each use fresh solution was prepared.

3.5.3.3. Preparation of standard phosphate solution

Potassium Dihydrogen Orthophosphate was dried for one hour at a temperature of 105℃. The dry content was placed in a desiccator after drying. 1.099g of the powder was measured and put in a 250 ml volumetric flask and 1 ml of 36% m/m Hydrochloric acid was inserted to the volumetric flask. This followed a dilution by adding distilled water up to 250 ml. Five drops of toluene was added to the solution for storage. The standard phosphate solution was prepared. This was used to prepare other concentrations of phosphate solution. From the standard solution 10 ml was pipetted into a 100 ml volumetric flask and filled up to the mark with water. Then 10 ml of this solution was transferred into a 100 ml volumetric flask and topped up with distilled water and was labeled A. Then different volumes of 0, 5, 10, 15, 20, 30 ml from A were transferred to 6 different 100 ml volumetric flask. To each volumetric flask, 8 ml of Ammonium molybdate and 8 ml of Ascorbic acid was added and the solutions were made up to the mark of 100 ml with distilled water.

3.5.3.4. Extraction of phosphorus from sediments

Extraction of phosphate was done for this test. 5g of each sediment sample was measured in different 100 ml conical flask and 50 ml of 0.01M of H_2SO_4 was added to the sediments. The conical flasks were placed on the orbital shaker for 30 minutes. Then each conical flask was filtered and 5 ml of each extract were transferred to different 100 ml volumetric flask. 8 ml of Ascorbic acid and 8 ml of Ammonium molybdate were added to each extract and were made up to the mark with distilled water.

Both the standard phosphate solution and the extracts were passed through the spectrometer at 880 nm and the values obtained were noted.

3.5.4. Determination of organic carbon

3.5.4.1. Preparation of standard

15 g of sucrose was oven dried at 105℃ for 2 hours and let to cool in the desiccator. Then 11.886 g of sucrose were used to make a solution. 0, 5, 10, 15, 20 and 25 ml of this prepared solution were added to 100 ml volumetric flask and made up to the mark. Then 2 ml of each solution were transferred to different beakers and let dried at 105 ℃ in an oven. This standard contained 0, 5, 10, 15, 20 and 25 mg of carbon. Then 10 ml of potassium dichromate was added to each and were dissolved in it. Concentrated sulfuric acid of 10 M was added to each in a fume hood and was allowed to cool. After cooling, 50 ml of Barium chloride was inserted to the solutions, it was swirled and let to deposit overnight and passed through spectrometer at 600 nm.

3.5.4.2. Sample preparation and analysis

For the sample preparation, 1 g of each sample was added to different 100 ml conical flask and 10 ml of potassium dichromate was added to it followed by the addition of 20 ml of sulfuric acid. The solution was left to cool down and then 50 ml of barium chloride was added and swirled. The suspension was let to settle overnight and the passed through spectrometer at 600 nm.

3.5.4.3. Heavy metals in sediments

Aquaregia is firstly prepared. Then 2.5g of sediment sample was measured in a conical flask and 15 ml of Aquaregia was added. The Aquaregia was added slowly to the sediments as it dissipates a lot of heat (Okoro et al.., 2012). The samples were left to digest overnight. The samples were then filtered and topped with distilled water in 50 ml volumetric flask and stored in polyethylene bottles. The samples were passed through AAS (Atomic Absorption Analysis).

3.6. Fish test

3.6.1. Heavy metals in fish

3.6.1.1. Ashing of fish

Fish samples were prepared before heavy metal analysis. The fish samples that were freeze dried were used. 10 g of the small fish samples were measured in different crucibles. The crucibles were then placed into muffle furnace at 450℃ for 8 hours. After this period of time, ashes of fish samples were obtained.

3.6.1.2. Digestion of ashes of fish

After ashing, 15 ml of Aquaregia were added to each sample and were let to digest overnight (Okoro et al.., 2012). After digestion, the samples were filtered in 50 ml volumetric flask and made up to the mark. The samples were stored in poly ethylene bottles and analysed in the AAS (Atomic Absorption Analysis).

4. Results

4.1. Water sample

4.1.1. pH of water samples

Table 1: pH of water

	Sample 1	Sample 2	Sample 3	mean	Standard deviation
Site 1	8.192	8.252	8.242	8.229	0.032
Site 2	8.216	8.478	8.616	8.437	0.203
Site 3	9.172	9.054	9.196	9.141	0.076
Site 4	8.16	7.722	9.062	8.315	0.683

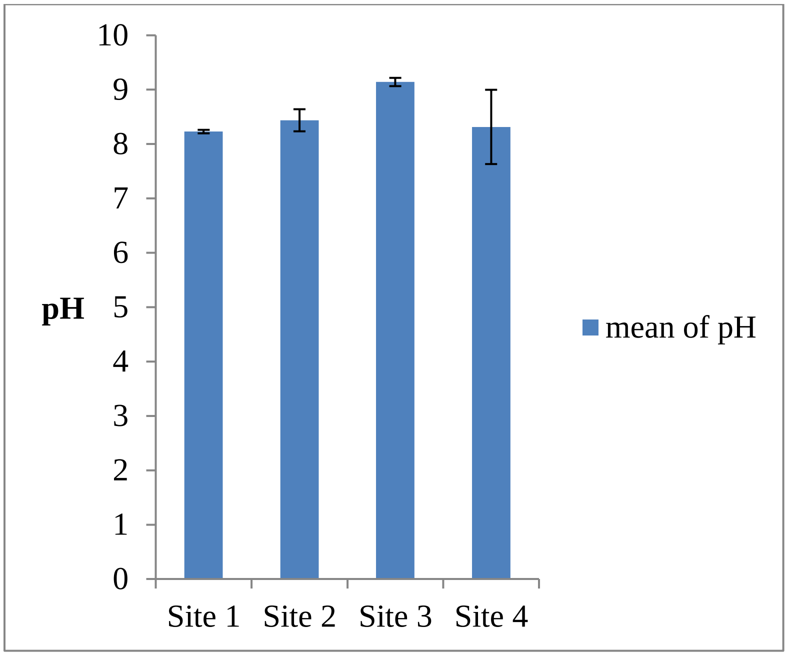


Figure 1: pH of water

P value: 0.051

H_o (Null Hypothesis) - There is significance difference between pH of water of different sites.

H_1 (Alternative Hypothesis) – There is no significance difference between pH of water of different sites.

As the p-value is greater than 0.05, H_o is rejected and we accept H_1 and conclude that there is no significance difference between the values of pH of water between different sites.

4.1.2. Salinity in water

Table 2: Salinity in water

	Sample 1 (ppt)	Sample 2 (ppt)	Sample 3 (ppt)	Mean (ppt)	Standard deviation
Site 1	28.98	28.64	28.72	28.78	0.0316
Site 2	31.14	31.2	32.4	31.58	0.7072
Site 3	33.32	35.32	31.24	33.29	2.04
Site 4	35.3	34.64	33.42	34.45	0.9538

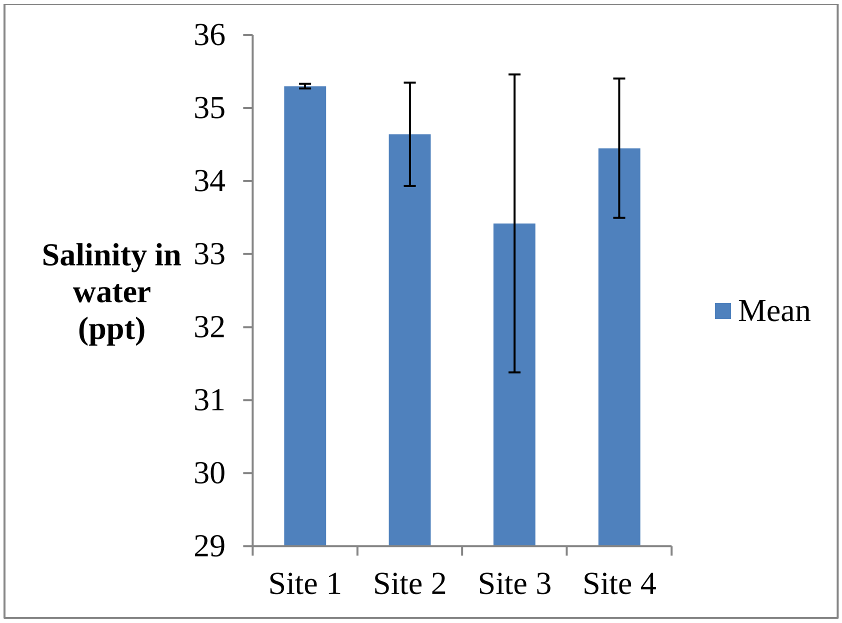


Figure 2: Salinity in water

P value: 0.002

H_o (Null hypothesis) - significance difference in the salinity of water of different sites.

H_1 (Alternative hypothesis) – there is no significance difference in the salinity of water of different sites.

According to the p-value obtained which is less than 0.05, there is a significance difference in the salinity of water between different sites. Hence we accept the null hypothesis.

4.1.3. Nitrates in water

Table 3: Concentration of nitrates in water

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard Deviation
Site 1	8.2	7.9	16.46	10.85	4.858
Site2	15.14	14.46	16.36	15.32	0.963
Site 3	14.7	14.46	14.6	14.59	0.121
Site 4	14.94	16.22	15.66	15.61	0.642

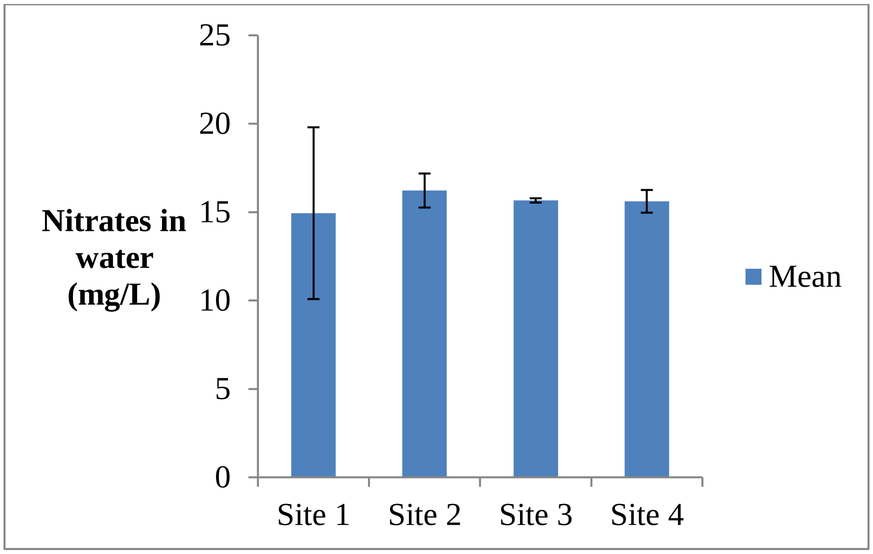


Figure 3: Concentration of nitrates in water

P value: 1.51

H_o (Null hypothesis) – There is a significance difference in nitrates in water between different sites.

H_1 (Alternative Hypothesis) – There is no significance difference in nitrates in water between different sites.

After Anova analysis, the p-value is 1.51 which is greater than 0.05 and therefore H_o is rejected and H_1 is accepted. This shows that there is no significance between nitrates in water of different sites.

4.1.4. Phosphates in water

Table 4: Concentration of phosphate in water

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard Deviation
Site 1	11.2	5.32	4.34	6.95	3.71
Site2	12.94	11.56	13.28	12.59	0.911
Site 3	13.94	12.98	14.16	13.69	0.627
Site 4	4.98	6.04	5.28	5.43	0.546

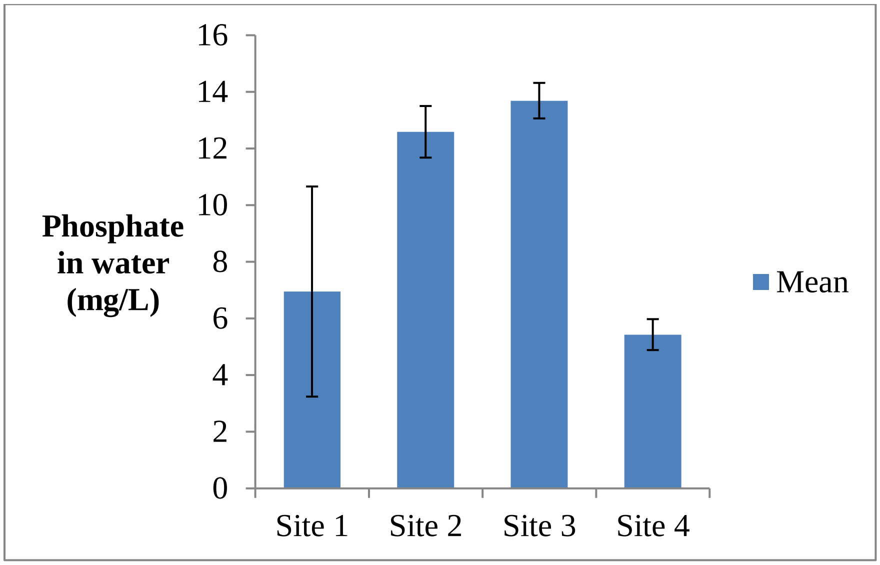


Figure 4: Concentration of phosphate in water

P value: 0.002

H_o (Null hypothesis) – There is a significance difference in the concentration of phosphates in water between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of phosphates in water between different sites.

As per p-value which is 0.002, H_o is accepted and H_1 is rejected and thus showing that the concentration of phosphates in water is significant.

4.1.5. Heavy metals in water

4.1.5.1. Cadmium

Table 5: Concentration of cadmium in water

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Sample 4 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0	0	0	0	0	0
Site 2	0	0	0	0	0	0
Site 3	0	0	0	0	0	0
Site 4	0	0	0	0	0	0

Cadmium was not obtained in the water samples as it is found in very little amount in the ecosystem.

4.1.5.2. Chromium

Table 6: Concentration of chromium in water

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Sample 4 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.02	0.012	0.029	0.014	0.0188	0.0085
Site 2	0.394	0.412	0.342	0.365	0.379	0.0364
Site 3	0.268	0.29	0.314	0.216	0.272	0.0230
Site 4	1.774	1.214	1.369	1.524	1.47	0.2892

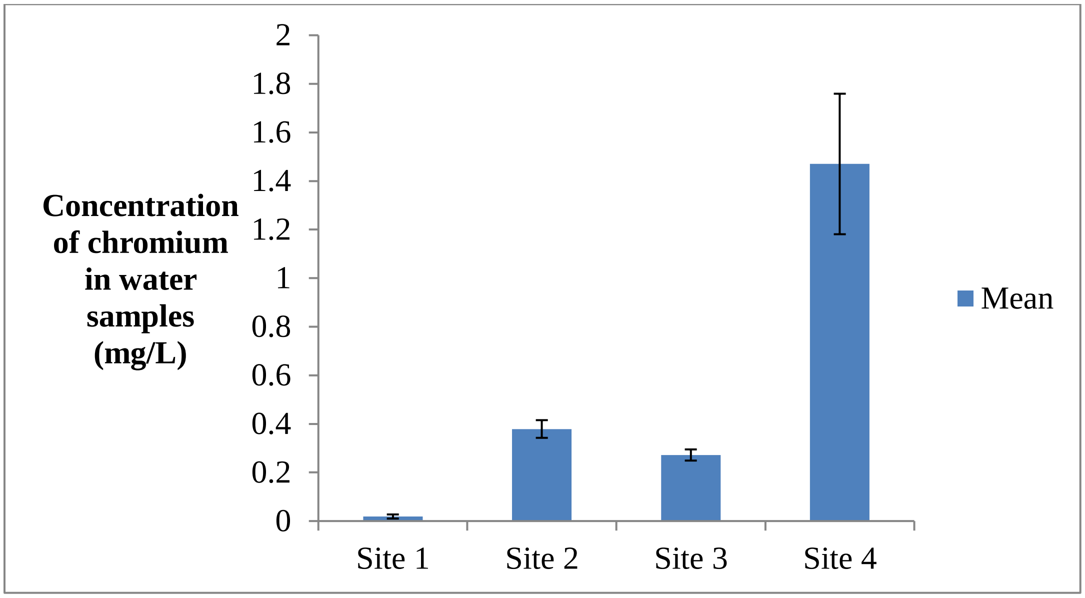


Figure 5: Concentration of chromium in water

P value: 0

H_o (Null hypothesis) – There is a significance difference in the concentration of Chromium in water between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Chromium in water between different sites.

As per p-value which is 0, H_o is accepted and H_1 is rejected and thus showing that the concentration of Chromium in water is significant.

4.1.5.3. Copper

Table 7: Concentration of copper in water

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.057	0.061	0.054	0.05733	0.00351
Site 2	0.69	0.61	0.58	0.627	0.0569
Site 3	0.328	0.412	0.365	0.368	0.0421
Site 4	0.137	0.124	0.182	0.148	0.0304

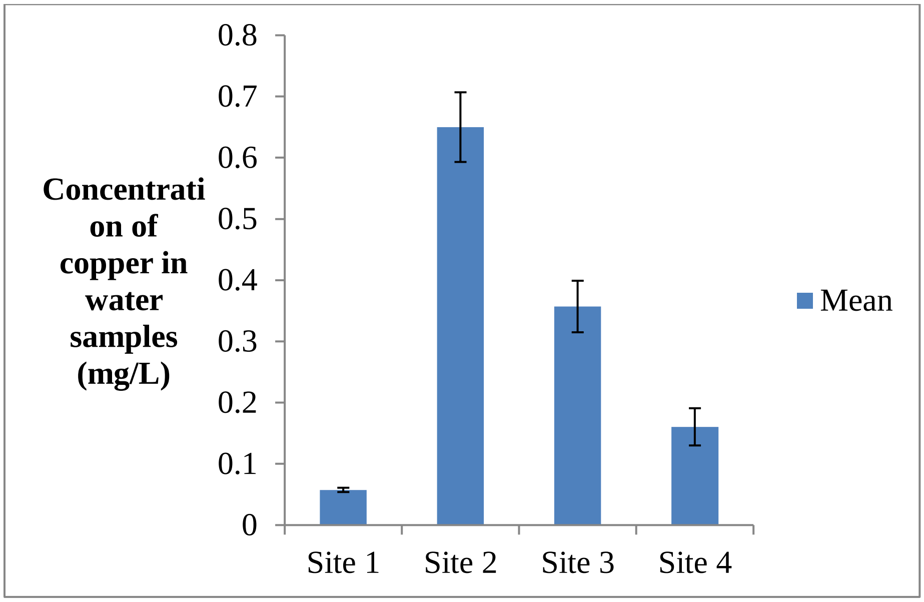


Figure 6: Concentration of copper in water

P value: 0

H_o (Null hypothesis) – There is a significance difference in the concentration of Copper in water between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Copper in water between different sites.

As per p-value which is 0, H_o is accepted and H_1 is rejected and thus showing that the concentration of Copper in water is significant.

4.1.5.4. Manganese

Table 8: Concentration of manganese in water

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.048	0.056	0.051	0.0468	0.00404
Site 2	0.52	0.34	0.51	0.455	0.1011
Site 3	0.36	0.42	0.38	0.393	0.0306
Site 4	0.23	0.28	0.19	0.23	0.0451

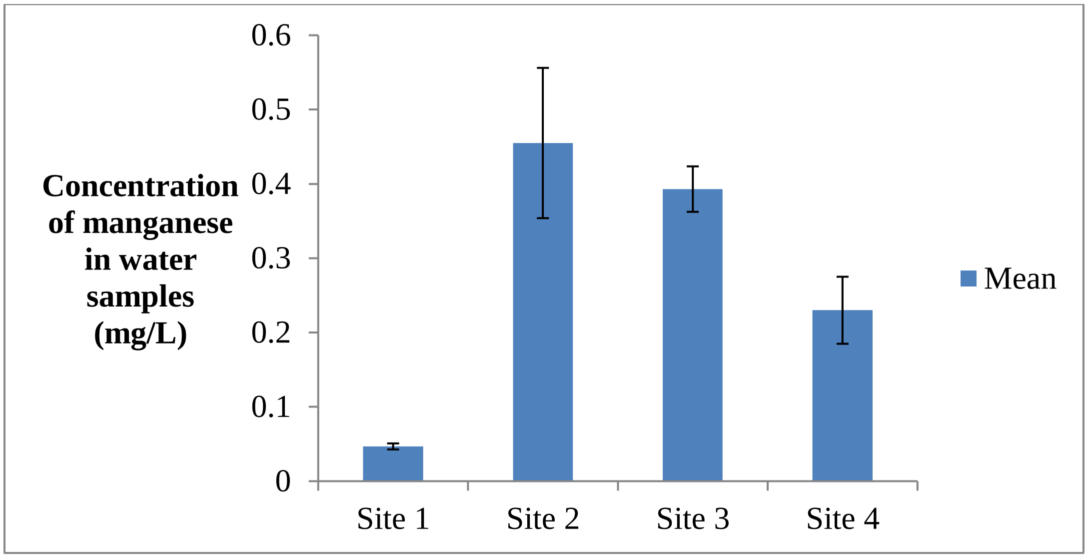


Figure 7: Concentration of manganese in water

P value: 0

H_o (Null hypothesis) – There is a significance difference in the concentration of Manganese in water between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Manganese in water between different sites.

As per p-value which is 0, H_o is accepted and H_1 is rejected and thus showing that the concentration of Manganese in water is significant.

4.1.5.5. Nickel

Table 9: Concentration of nickel in water

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.018	0.008	0.009	0.0125	0.00551
Site 2	0.043	0.053	0.048	0.0488	0.00500
Site 3	0.013	0.016	0.025	0.0183	0.0624
Site 4	0.314	0.36	0.41	0.366	0.04801

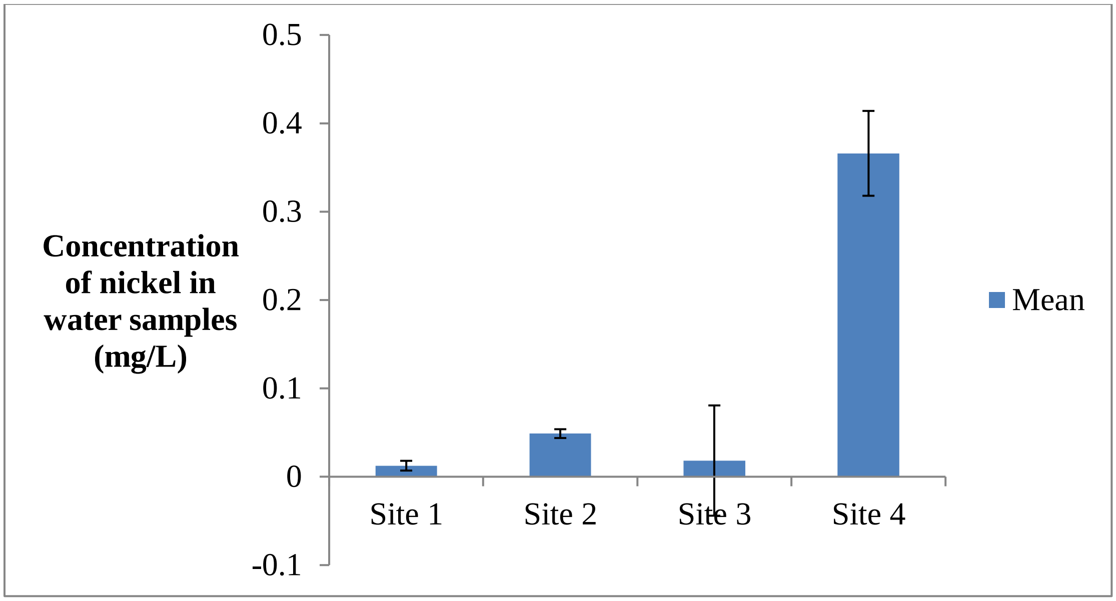


Figure 8: Concentration of nickel in water

P value: 0

H_o (Null hypothesis) – There is a significance difference in the concentration of Nickel in water sample between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Nickel in water sample between different sites.

As per p-value which is 0, H_o is accepted and H_1 is rejected and thus showing that the concentration of Nickel in water sample is significant.

4.2. Sediments

4.2.1. Sediment pH

Table 10: pH of sediments

	Sample 1	Sample 2	Sample 3	mean	Standard deviation
Site 1	8.036	7.69	7.87	7.865	0.173
Site 2	7.72	7.682	7.756	7.719	0.037
Site 3	8.12	8.094	8.216	8.143	0.0643
Site 4	8.03	7.83	8.014	7.958	0.1111

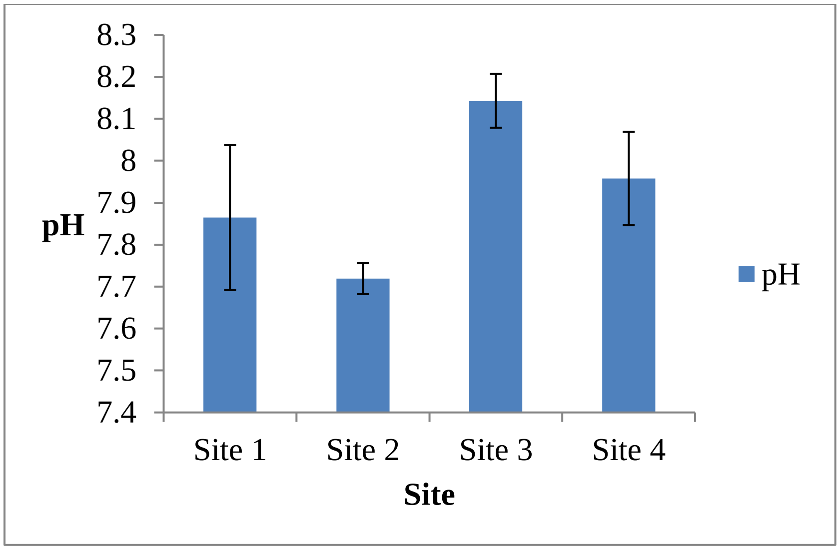


Figure 9: pH of sediments

P value: 0.009

H_o (Null hypothesis) – There is a significance difference in the concentration of pH of sediments between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of pH of sediments between different sites.

As per p-value which is 0.009 which is less than 0.05, H_o is accepted and H_1 is rejected and thus showing that the concentration of pH of sediments is significant.

4.2.2. Salinity of sediments

Table 11: Salinity of sediments

	Sample 1 (ppt)	**Sample 2 (ppt)**	**Sample 3 (ppt)**	**Mean (ppt)**	**Standard deviation**
Site 1	22.28	24.02	24.62	23.64	1.215
Site 2	34.4	33.52	30.22	32.71	2.204
Site 3	6.34	7.86	5.94	6.71	1.013
Site 4	14.32	21.56	13.9	16.59	4.306

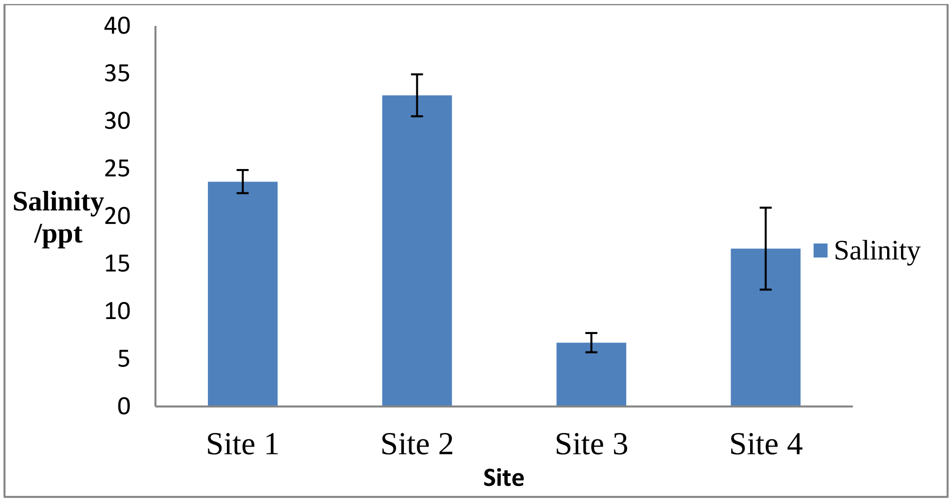


Figure 10: Salinity of sediments

P value: 0

H_o (Null hypothesis) – There is a significance difference in the concentration of Salinity of sediments between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Salinity of sediments between different sites.

As per p-value which is 0, H_o is accepted and H_1 is rejected and thus showing that the concentration of Salinity of sediments is significant.

4.2.3. Available phosphorus in sediments

Table 12: Concentration of available phosphorus in sediments

	Sample 1 (mg/g)	Sample 2 (mg/g)	Sample 3 (mg/g)	Mean (mg/g)	Standard deviation
Site 1	0.55	0.889	0.49	0.6433	0.2151
Site 2	0.587	0.1744	0.426	0.3958	0.2080
Site 3	0.532	1.177	0.438	0.716	0.4023
Site 4	0.178	0.438	0.3032	0.306	0.1300

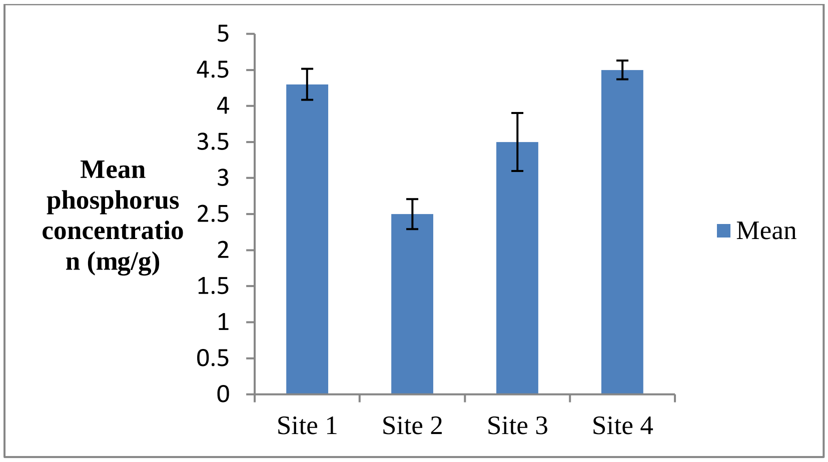


Figure 11: Concentration of available phosphorus in water

P value: 0.243

H_o (Null hypothesis) – There is a significance difference in the concentration of available phosphorus in sediments between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of available phosphorus in sediments between different sites.

As per p-value which is 0.243 which is greater than 0.05, H_1 is accepted and H_o is rejected and thus showing that the concentration of available phosphorus in sediments is significant.

4.2.4. Total nitrogen

Table 13: Concentration of total nitrogen in sediments

	Sample 1 (mg/g)	Sample 2 (mg/g)	Sample 3 (mg/g)	Mean (mg/g)	Standard Deviation
Site 1	1.1984	1.2768	0.9856	1.1536	0.1507
Site 2	6.216	6.5027	5.891	6.203	0.3060
Site 3	3.452	4.5024	4.2448	4.0664	0.5475
Site 4	5.768	6.093	5.704	5.855	0.2086

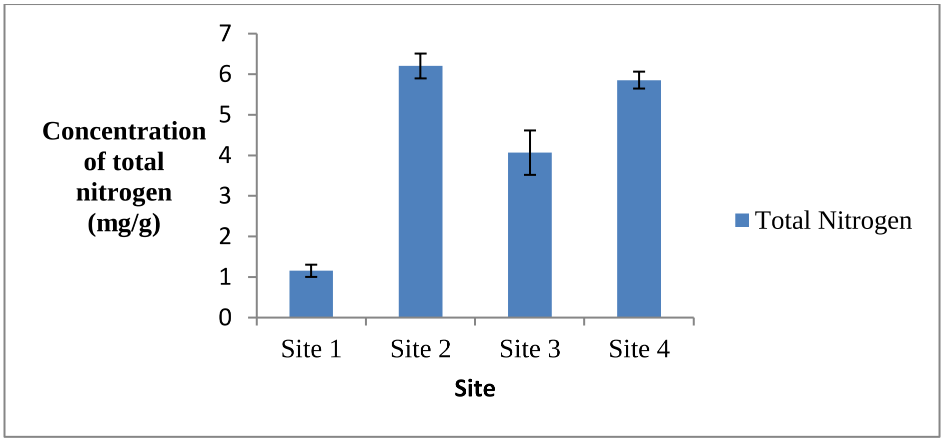


Figure 12: Concentration of total nitrogen in sediments

P value: 0

H_o (Null hypothesis) – There is a significance difference in the concentration of Total nitrogen in sediment between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Total nitrogen in sediment between different sites.

As per p-value which is 0, H_o is accepted and H_1 is rejected and thus showing that the concentration of Total nitrogen in sediment is significant.

4.2.5. Organic Carbon in sediments

Table 14: Concentration of organic carbon in sediments

	Sample 1 (mg/g)	Sample 2 (mg/g)	Sample 3 (mg/g)	Mean (mg/g)	Standard deviation
Site 1	0.0007424	0.0001531	0.0002459	0.000380	0.000317
Site 2	0.0123	0.0143	0.0108	0.0125	0.00176
Site 3	0.00107	0.000877	0.000464	0.000804	0.000310
Site 4	0.00186	0.00397	0.00402	0.00328	0.00123

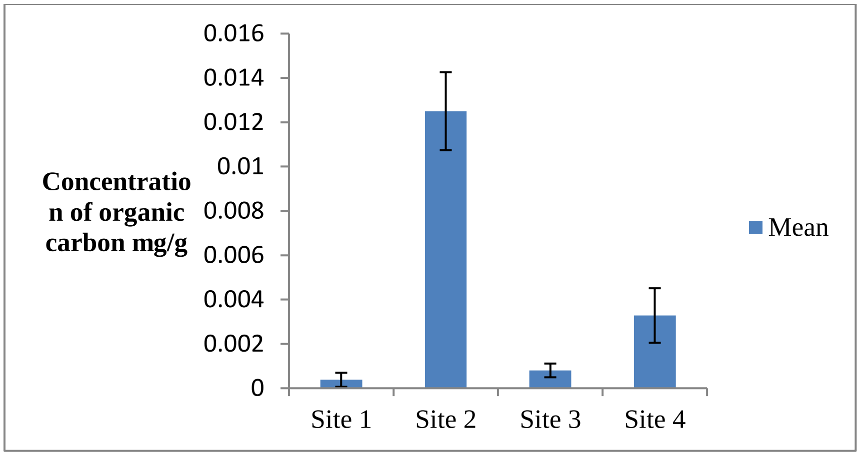


Figure 13: Concentration of organic carbon in sediments

P value: 0

H_o (Null hypothesis) – There is a significance difference in the concentration of organic carbon in sediment between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of organic carbon in sediment between different sites.

As per p-value which is 0, H_o is accepted and H_1 is rejected and thus showing that the concentration of organic carbon in sediment is significant.

4.2.6. Heavy metals in sediment sample

4.2.6.1.Cadmium

Table 15: Concentration of cadmium in sediments

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.014	0.001	0.002	0.00567	0.00723
Site 2	0	0	0	0	0
Site 3	0	0	0	0	0
Site 4	0	0	0	0	0

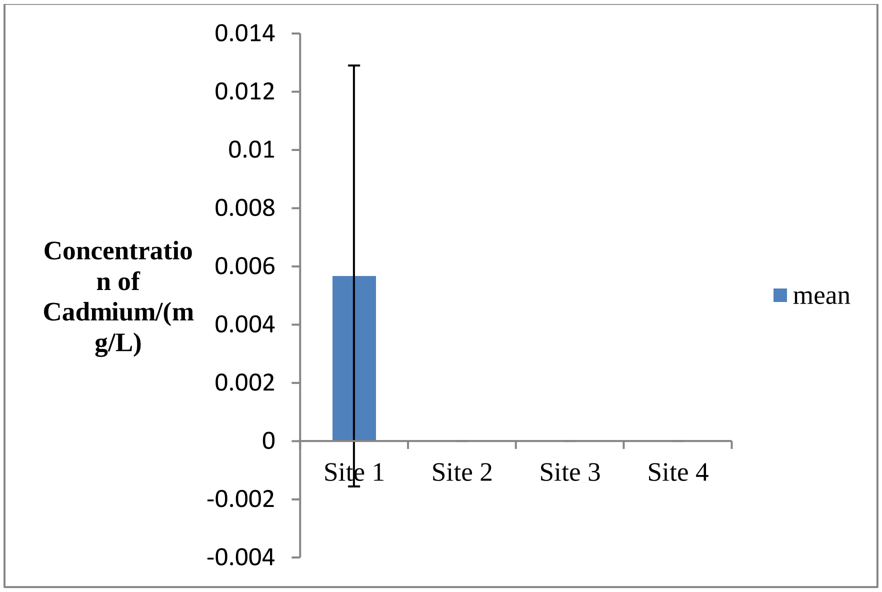


Figure 14: Concentration of Cadmium in sediments

P value: 0.218

H_o (Null hypothesis) – There is a significance difference in the concentration of Cadmium in sediments between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Cadmium in sediments between different sites.

As per p-value which is 0.218 which is greater than 0.05, H_o is rejected and H_1 is accept and thus showing that the concentration of Cadmium in sediments is significant.

4.2.6.2.Chromium

Table 16: Concentration of Chromium in sediments

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	1.327	1.678	0.425	1.1433	0.6464
Site 2	1.241	0.709	0.954	0.968	0.2663
Site 3	1.328	0.886	0.424	0.87933	0.4520
Site 4	1.557	2.446	3.021	2.341	0.7376

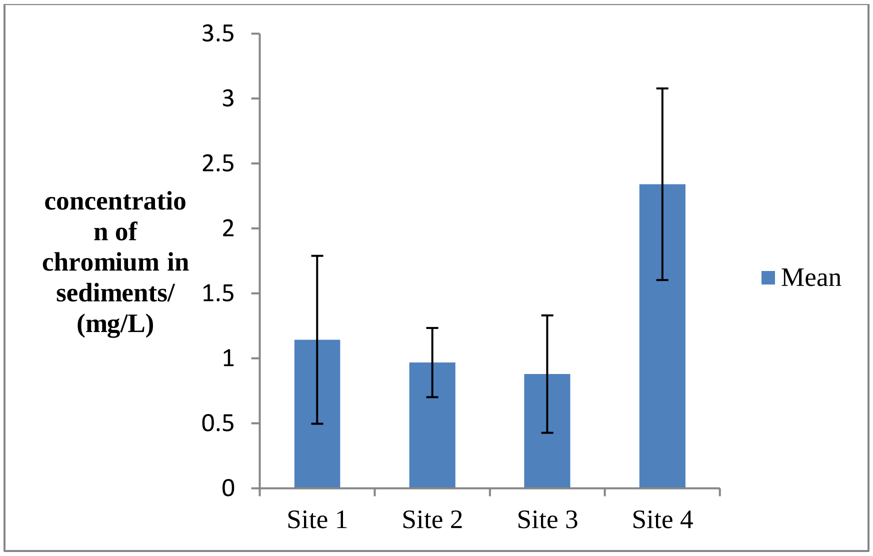


Figure 15: Concentration of Chromium in sediments

P value: 0.039

H_o (Null hypothesis) – There is a significance difference in the concentration of Chromium in sediment between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Chromium in sediment between different sites.

As per p-value which is 0.039 which is less than 0.05, H_o is accepted and H_1 is rejected and thus showing that the concentration of Chromium in sediment is significant.

4.2.6.3.Copper

Table 17: Concentration of copper in sediments

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.026	0.033	0.014	0.0243	0.00961
Site 2	0.001	0.012	0.039	0.0173	0.01790
Site 3	0.004	0.015	0.018	0.0123	0.00737
Site 4	0.006	0.083	0.071	0.0533	0.04143

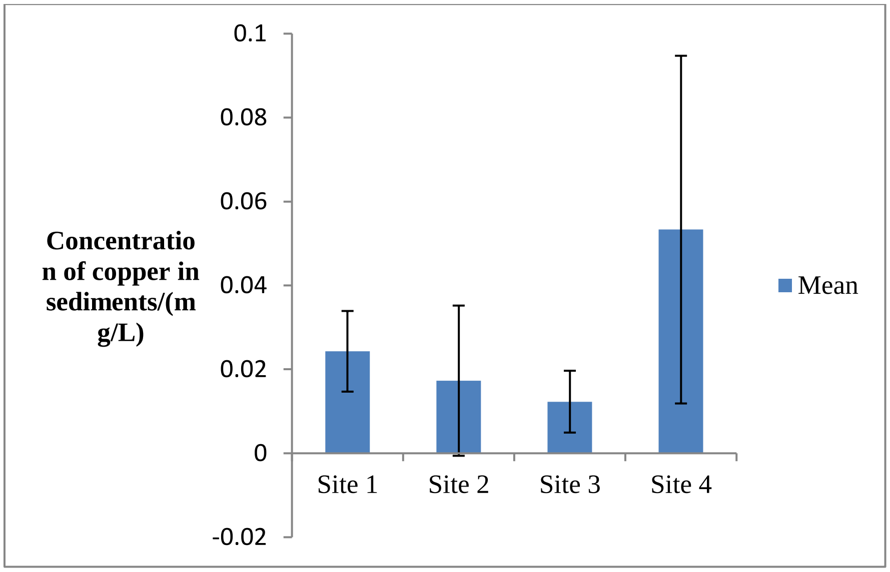


Figure 16: Concentration of copper in sediments

P value: 0.211

H_o (Null hypothesis) – There is a significance difference in the concentration of Copper in sediment between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Copper in sediment between different sites.

As per p-value which is 0.211 which is greater than 0.05, H_o is rejected and H_1 is accepted and thus showing that the concentration of Copper in sediment is significant.

4.2.6.4.Manganese

Table 18: Concentration of manganese in sediments

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.664	0.852	0.892	0.80	0.1217
Site 2	1.016	1.217	1.797	1.3433	0.4055
Site 3	0.258	0.241	0.27	0.256	0.0146
Site 4	0.001	0.004	0.002	0.00233	0.0015

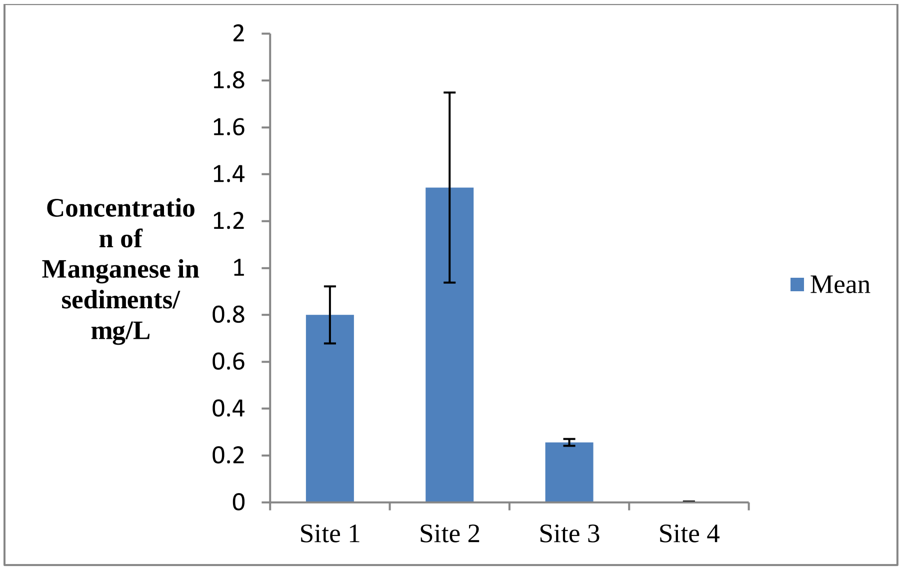


Figure 17: Concentration of manganese in sediments

P value: 0

H_o (Null hypothesis) – There is a significance difference in the concentration of Manganese in sediment between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Manganese in sediment between different sites.

As per p-value which is 0, H_o is accepted and H_1 is rejected and thus showing that the concentration of Manganese in sediment is significant.

4.2.6.5.Nickel

Table 19: Concentration of nickel in sediments

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.145	0.154	0.111	0.1367	0.0227
Site 2	0.248	0	0.287	0.17833	0.1557
Site 3	0.251	0.256	0.656	0.388	0.2324
Site 4	0.674	0.895	1.855	1.141	0.2336

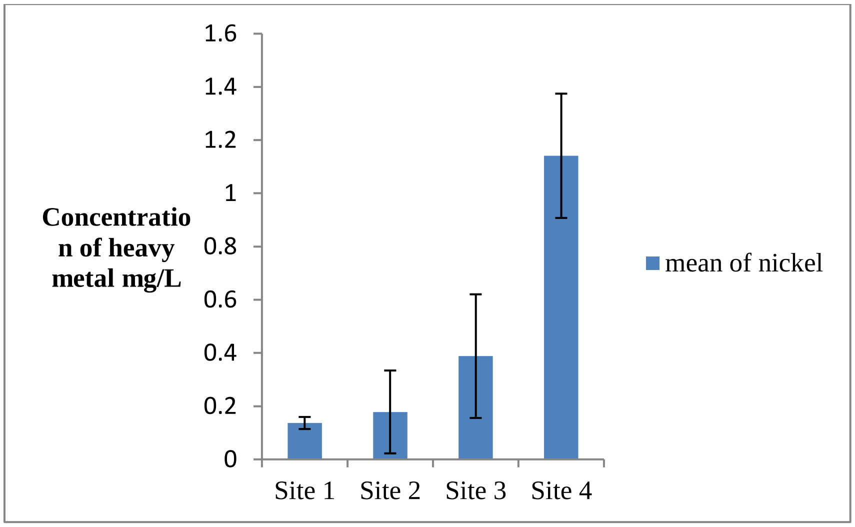


Figure 18: Concentration of nickel in sediments

P value: 0.003

H_o (Null hypothesis) – There is a significance difference in the concentration of Nickel in sediment between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Nickel in sediment between different sites.

As per p-value which is 0.003 less than 0.05, H_o is accepted and H_1 is rejected and thus showing that the concentration of Nickel in sediment is significant.

4.3. Fish samples

4.3.1. Cadmium

Table 20: Concentration of cadmium in fish

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0	0	0	0	0
Site 2	0	0	0	0	0
Site 3	0	0	0	0	0
Site 4	0	0	0	0	0

P value: 0

Cadmium is found in very trace amount and thus it was not found in the samples.

4.3.2. Chromium

Table 21: Concentration of Chromium in fish

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.459	0.365	0.421	0.415	0.0473
Site 2	0.313	0.356	0.475	0.381	0.0839
Site 3	0.038	0.045	0.026	0.0363	0.00961
Site 4	0.595	0.495	0.369	0.4863	0.11325

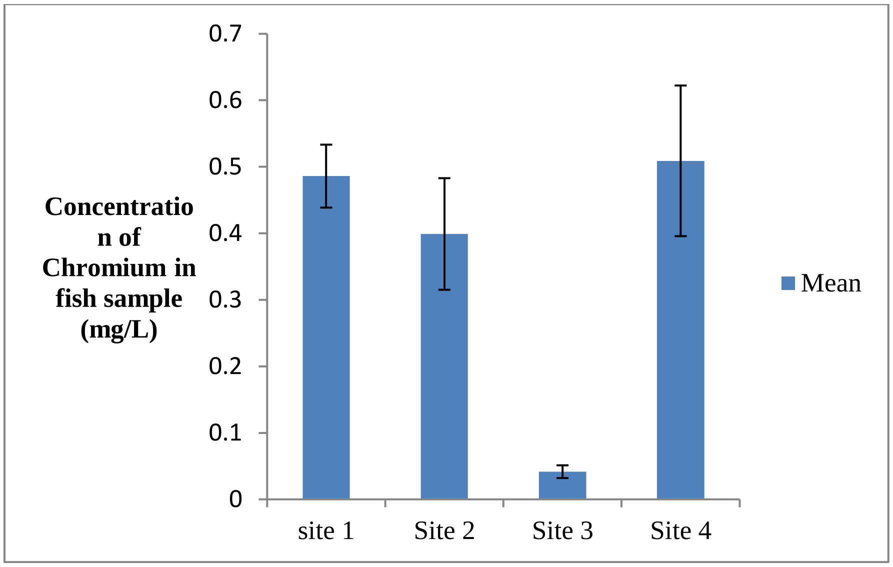


Figure 19: Concentration of Chromium in fish

P value: 0

H_o (Null hypothesis) – There is a significance difference in the concentration of Chromium in fish between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Chromium in fish between different sites.

As per p-value which is 0, H_o is accepted and H_1 is rejected and thus showing that the concentration of Chromium in fish is significant.

4.3.3. Copper

Table 22: Concentration of copper in fish

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.3	0.345	0.456	0.367	0.08029
Site 2	0.093	0.068	0.058	0.073	0.01803
Site 3	0.058	0.067	0.05	0.0583	0.00850
Site 4	0.074	0.068	0.057	0.06633	0.00862

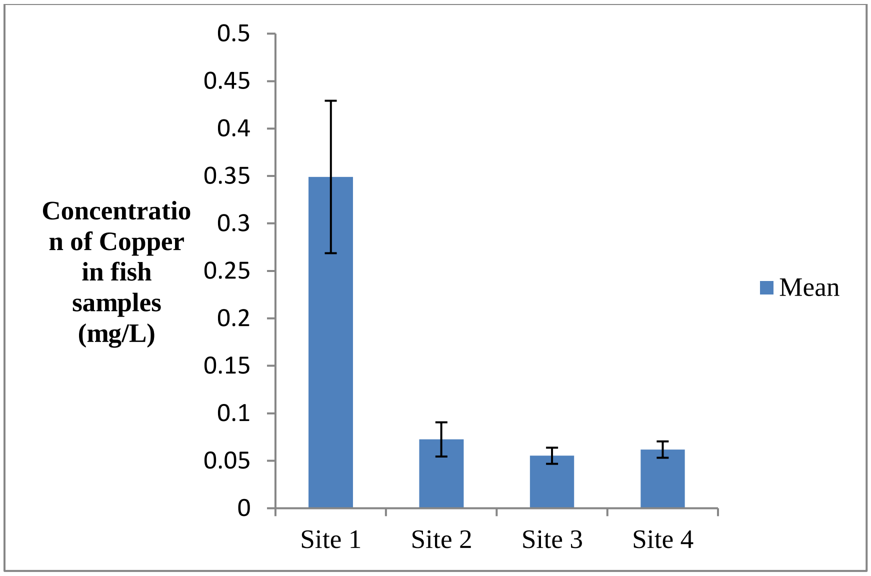


Figure 20: Concentration of copper in fish

P value: 0

H_o (Null hypothesis) – There is a significance difference in the concentration of Copper in Fish between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Copper in Fish between different sites.

As per p-value which is 0, H_o is accepted and H_1 is rejected and thus showing that the concentration of Copper in Fish is significant.

4.3.4. Manganese

Table 23: Concentration of manganese in fish

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.024	0.034	0.045	0.03433	0.0105
Site 2	0.039	0.068	0.054	0.05367	0.0145
Site 3	0.019	0.054	0.048	0.04033	0.0187
Site 4	0.019	0.013	0.008	0.01333	0.00551

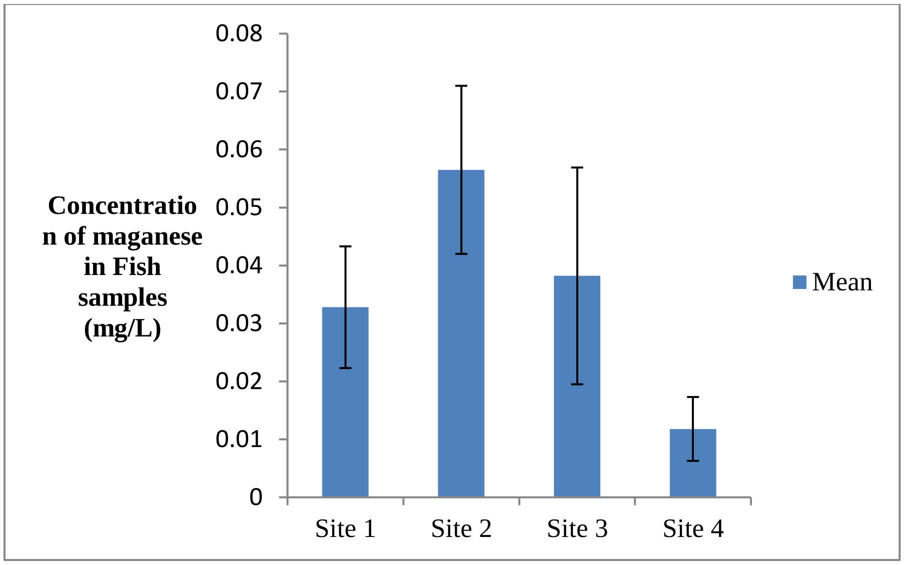


Figure 21: Concentration of manganese in fish

P value: 0.033

H_o (Null hypothesis) – There is a significance difference in the concentration of Manganese in fish between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Manganese in fish between different sites.

As per p-value which is 0.033 less than 0.05, H_o is accepted and H_1 is rejected and thus showing that the concentration of Manganese in fish is significant.

4.3.5. Nickel

Table 24: Concentration of nickel in fish

	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Mean (mg/L)	Standard deviation
Site 1	0.013	0.026	0.016	0.0183	0.006807
Site 2	0.013	0.023	0.038	0.0246	0.012583
Site 3	0	0	0	0	0
Site 4	0	0	0	0	0

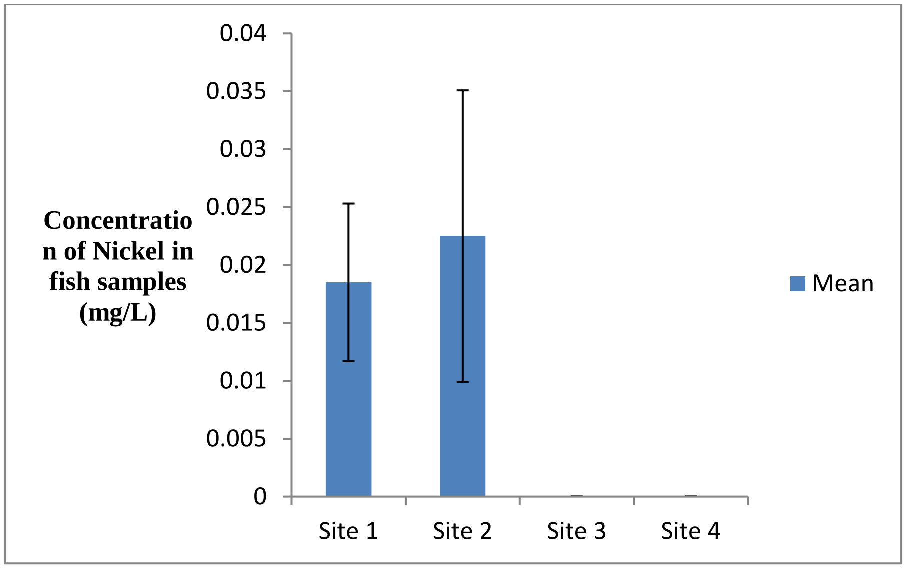


Figure 22: Concentration of nickel in fish

P value: 0.005

H_o (Null hypothesis) – There is a significance difference in the concentration of Nickel in Fish between different sites.

H_1 (Alternative hypothesis) – There is no significance difference in the concentration of Nickel in Fish between different sites.

As per p-value which is 0.005 less than 0.05, H_o is accepted and H_1 is rejected and thus showing that the concentration of Nickel in Fish is significant.

5. Discussion

5.1. Water

5.1.1. Analysis of pH of seawater between different sites

The pH of sea water is supposed to be alkaline in the range of 8.1 (Morgan, 2018). Due to the absorption of carbonates and bicarbonates in sea water, the pH of water may change and become alkaline, that is a pH of 8.6. The survival of certain marine species may become difficult if the pH falls to less than 5.0 or climbs to more than 9.0 (Ohrel and Register,2006). An increase in the pH can be observed as rocks and minerals also dissolve in sea water (Renforth, 2017). Carbon dioxide from the atmosphere dissolves in sea water and thus makes the pH of water to become acidic. This process of ocean acidification is increasing very fast. This process of acidification affects the aquatic life such as urchins and molluscs whereas some species are able to adapt to the change in pH. Corals are also affected by the decrease in pH as their growth is limited due to this phenomenon (Bennett, 2017). According to the results obtained, the pH of water in the different sites is in the range of 8.1 to 8.6 and it gives an indication that the pH is in line with the range as discussed above. Except for Site 3, the pH of water sample was 9.141, which is relatively high value as compared to the other sites. Hence this may affect some species found in that site. In reference to the results obtained, there was no sign of acidification of sea water.

5.1.2. Analysis of salinity of seawater between different sites

The range of salinity of sea water can be said to be in the range of 34 to 36 ppt. There are places where there is less rainfall and thus due to warm winds there is evaporation of water leaving the salt. This process causes the water to become more saline and the salinity may rise up to 38 ppt. in places where there is frequent rainfall, water is diluted and therefore salinity decreases up to 30ppt (Ocean Salinity, 2010). The sites that were chosen for sampling were near a river mouth. The presence of the river mouth could be a reason for the low salinity among the sites (Subramaniam, 2017). However, salinity in site 3 was high because the site is found in the middle and only when the sea rises that water gets in. So the water remains stagnant and it evaporates causing the salinity to be high that is 34.45 ppt (Sutton, 2010).

5.1.3. Analysis of Nitrates and Phosphates in seawater between different sites

According to Harvey (2009), the normal nitrates and phosphate content in sea water is supposed to be 10 mg/L. From the result in table 3.1.3, they range of Nitrates obtain in this study was 10.85 mg/l to 15.61 mg/L which is higher from the range provided above. Site 3 has a value of 14.59 mg/L which is high because of the presence of a river mouth near the site. Agricultural runoffs that occur on upper lands get into the river and finally end up in the sea. This causes an increase in the Nitrates concentration in site 3. The high ratio of Nitrates in site 3 affects the Nitrates concentration in site 1. Site 1 has a concentration of Nitrates of about 10.85 mg/L. Site 1 and Site 3 are separated by a barrier of rocks with small openings in between and nitrates form site 3 gets into site 1. As a result, there is an increase in the Nitrates concentration in site 1. However as compared to site 3, site 1 has a relatively low Nitrates concentration. This is due to the site location. Site 1 is located in a position where there is tidal action (Fatema et al, 2015). Thus the Nitrates are distributed between the sea and the site. Site 2 and Site 4 have a high Nitrates concentration. This can be explained as the sites are situated at places where there is habitation. The sites are been polluted by the habitants. For the concentration of Phosphates, Site 3 has the highest concentration of Phosphates giving the evidence that a river mouth is nearby. Same activity as nitrates occurs for Phosphate between Site 1 and Site 3. Phosphates from Site 3 get into Site 1 increasing the level of Phosphate in Site 1 that is 6.95 mg/L. The value of Phosphate for Site 2 is 12.59 mg/L and hence giving a sign that the area is polluted due to the presence of habitat. However, Site 4 has a normal Phosphate level and thus this site shows that it has a normal Phosphate level (Adesuy et al, 2015).

5.1.4. Analysis of heavy metals in sea water between different Sites

5.1.4.1. Cadmium

Cadmium is found in very little amount in seawater (Mullin and Riley, 1954). The range of cadmium present in seawater is 0.0002 mg/L that shows that it is present in trace amount (Talbot, 1984). The results show that there is no trace of cadmium in the water samples taken at each site. This shows that Cadmium is found in very little amount in seawater.

5.1.4.2. Chromium

Chromium occurs in sea water in the concentration range of 0.00024 mg/L to 0.00064 mg/L. Chromium gets into the sea water stream through mineral weathering activities, river line and also through atmospheric activities (Geisler and Schmidt, 1991).According to the results, the values obtained is too high as compared to the range provided above. This increase can be explained by the following activities such as pollution of the atmospheric pollution of the industrial outlet and also through runoff from the upper lands (Oana, 2006). All the sites have a high concentration for chromium.

5.1.4.3. Copper

Copper enters the marine environment through many natural and anthropogenic processes. The entrance of copper ions in the marine environment can be due to human activities as man uses copper a lot in their daily life. Weather actions and other biological reactions can contribute to the increase in copper concentrations. The approximate concentration of cooper in seawater should be 2.5x10-4 mg/L (Blossom, 1987). Copper has a positive effect on biological activities and also enhance antioxidant defenses in organisms (Lewis et al.., 2016). The results give an indication that there is a high concentration of copper in the identified sites. The high level of copper is good for the sites.

5.1.4.4. Manganese

Manganese is essential in both humans and animals in little amount. However, greater concentrations can be harmful to health. Manganese is present in high concentrations in the ocean (University of Gothenburg, 2009). The range of value for manganese in seawater is 0.003mg/L to 0.008mg/L. As per the result obtained, the values are relatively high. Site 2, 3 and 4 has a high value of range 0.23 mg/L to 0.455 mg/L. It can be harmful to aquatic animals and ultimately affecting humans.

5.1.4.5. Nickel

According to a research conducted in the black sea, the range for which nickel was present in water was between 2.0x10^{-6} to 1.31x10^{-4} mg/L (Laevastu and Thompson, 1991). According to Lenntech, the range for nickel is sea water was identified to be 0.2-8 mg/L. As compared to the results for Laevastu and Thompson, the values obtained for nickel concentration in water is high. This difference can be due to location of area and due to pollution of the area. But according to Lenntech, the values are between the range.

5.2. Sediments

5.2.1. Analysis of pH of sediments between different sites

Carbon dioxide gas dissolves in sediment pores that cause the pH to increase (Taylor et al, 2014). Due to buffering organisms that result in acidification of the ocean, the pH of the sediments decreases (Herlihy and Mills, 1986). There has been a chronic toxicity growth in the marine environment due to the use of pharmaceuticals and personal care products. According to the study by Singare and others, the range of pH obtained was 5.1 to 7.2 (Singare et al, 2011). Based on the results obtained, the pH of the sediments was higher of range 7.7 to 8.2. The high pH indicates that there is less carbon dioxide that dissolves in the sites. The increase in salinity may be due to the dissolved rocks and minerals that has deposited at the bottom in the sediments (Renforth, 2017).

5.2.2. Analysis of salinity of sediments between different sites

The major parameters for climate change are ocean salinity and heat content. Fresh water fluxes and melting of ice has great effect on salinity content (Ivchenko, 2010). The salinity range of sediments for a normal site could be in the range of 30 ppt to 33 ppt. For places where the river outlets meet the ocean the salinity for sediments can be in the range of 6 – 12 ppt (Priya et al, 2016). For the values obtained for site 2, it is in range with normal site salinity that is 32.71 ppt. For site 3, the value obtained is in range with the salinity of the river outlet that is 6.71 ppt. Site 1 has a low value for salinity that is 23.64 as it is situated next to site 3 and hence site 3 has an influence on site 1 there is exchange of water between these two sites. Another reason for the low salinity in sediments in site 1 is due to ocean currents. Ocean currents wash away the sediments of the site which ultimately leads to a low salinity (Deep Ocean Currents, 2018). Site 2 and 4 has a low salinity because it is found in an enclosed area and due to rainfall. Rainfall makes the water to become dilute and therefore salts from the sediments diffuse into the water resulting in a decrease in the salinity factor of the sediments. This process is known as precipitation (Katsaros and Buitner, 1968).

5.2.3. Analysis of Available Phosphorus, Total nitrogen and Organic carbon in sediments between different sites

According to a study carried out, the recommendable concentration of Available Phosphorus, Total nitrogen and Organic carbon are 0.00373mg/g, 0.09914 mg/g and 0.00442 mg/g. Aquatic plants requires micronutrients such as nitrogen and phosphate for growth (Valdes and Real, 2004). As the coastal biodiversity provides a big space for the exchange of inland and aquatic origins, the aquatic environment is very fluctuate and the nutrient content also fluctuates (Gascón, et al, 2006). Excess micronutrients may cause eutrophication. Nutrients are introduced in the sea through sources of sewage, Agricultural waste water as well as agricultural runoff. With the action of time, the nutrients accumulate in the sediments and could be reused under different environmental different. Sediments providing an internal source of nutrients can be important as it may provide nutrients from sediments to water and results in algal growth in summer periods when the amount of dissolved dissolved oxygen is low (Hou et al, 2013). As per the results obtained, values for Available phosphorus, Total nitrogen and Organic carbon are higher than the range provided above. It shows that the amount of Micronutrients has increased in the Aquatic environment. And hence the facts produced above are explained.

5.2.4. Analysis of heavy metals in Sediments between different Sites

5.2.4.1. Cadmium

According to Förstner research, the value obtained for cadmium was 0.25 mg/L – 0.30 mg/L. Sediments are known as a pollutant and potential source of contaminants in the marine environment. Metals are not always fixed by sediments and are recycled through biological and chemical agents (Förstner, 1986). Heavy metals pollution in the Aquatic environment is a world problem and the situation is becoming worst as it is entering the food chain (Mwashote, 2003). Cadmium is a metal which can travel for long distances from its emission source and gets into many organisms easily such as molluscs (WHO, 2010). For the results obtained, cadmium was found only in site 1. According to the range obtained, the concentration of cadmium obtained is very low and can be concluded that cadmium is found in trace amount in the site.

5.2.4.2. Chromium

Chromium that is classified as heavy metal is used industrially around the world. And chromium enters the ecosystem as a byproduct in water, sediments and air through sewage and industrial discharge (Rifkin et al, 2004). The range of Chromium in the Nyanza gulf sediments is 0.0221 – 0.0339 mg/L (Mwamburi, 2016). The transport and availability of chromium can have an impact on Cr (VI) reduction (Wang et al, 2013). As per results, the concentration of Chromium is high. This is due to the presence of river outlet which brings sewage and hence causes a high amount of chromium.

5.2.4.3. Copper

Low copper concentrations encourage high sulfide concentrations which help in controlling and maintaining the amount of dissolved copper in sediments. The amount of copper recommended in sediments is 0.012 – 0.10 mg/L (Teasdale et al, 1996). Most input of copper in the marine environment is through river outlets. Marine organisms are able to deal with only a certain amount of copper. The results that were gained are of range 0.0123-0.0533. Therefore the results are between the limits and it can be assumed that the amount of copper is good for the sites (Blossom 1987).

5.2.4.4. Manganese

The amount of manganese found in the sediments is about 0.05mg/L (Abesser and Robinson, 2010).Manganese is presence has become a global concern as it is entering the environment in greater concentrations especially the marine environment. Manganese gets in water and accumulates in the sediments (Li P et al, 2014). Manganese is essential in sediments and may be found in abundance in the flora and it is also difficult to identify its abundance (Montalvo et al, 2014). The concentration of manganese is different in each site. Site 1, 2 and 3 have the highest concentration for manganese that is 0.256 – 1.4 mg/L. This provides the evidence that manganese is found in abundance in the nature especially in sediments. Where as in site 4, the concentration is relatively low because the site is found in an enclosed area and it gets less access to the sea.

5.2.4.5. Nickel

The nickel concentration in sediments can be in the range of 0.0156-0.0831 mg/L. Nickel can get into the marine ecosystem through different sources like pollution through fossil fuels, geological weathering and by industrial bodies through water sources (Gwiazda, 2011). The concentrations obtained in the sediments are too high and it gives the evidence that the sites are polluted. The river outlet present near the sites may be a source which brings a lot of nickel downwards and thus cause an increase in the concentration of Nickel.

5.3. Analysis of heavy metals in Fish samples between different Sites

5.3.1. Cadmium in fish

According to FAO, the permissible concentration of cadmium in fish is 2 – 20 mg/L (Fao.org, 2018). The results obtained indicate that there was no cadmium present in the samples. However, the AAS (Atomic Absorption Spectrum) is not too sensitive to detect if cadmium is present in smaller amount.

5.3.2. Chromium in Fish

Chromium exists in two states: Chromium (III) and Chromium (VI). Chromium (III) is not to below the level of 7.5 mg/L and Chromium (IV) is not toxic below the level of 75 mg/L. (Fao.org, 2018). Through human activities such as mining, improper waste management and fossil fuel usage, the environment especially the marine society is affected (Aslam and Yousafzai, 2017). The results obtained are lower in all the sites than the limits mentioned above. This shows that the area is less polluted by chromium.

5.3.3. Copper in Fish

The amount of cooper that is required to be in a fish is 0.005 – 0.02 mg/L (Solomon, 2009). Copper occurs naturally in the marine environment. Copper is required in trace amount for metabolism in living organisms. Copper can be toxic just above its limits to Aquatic organisms and may cause reversible reactions (Woody and O’Neal, 2012). Minerals found in soils and weathered rocks causes an increase in copper concentration (Blossom, 1987). The concentration of copper obtained in the samples is relatively high and it can be concluded that due to climatic change there is an increase in weathering actions causing the breakdown of rocks and increasing the concentration of copper in the marine environment.

5.3.4. Manganese in Fish

Manganese occurs naturally in sediments and water. Manganese exists in two forms in the marine society: Mn (II) and Mn (IV). Manganese is an important content for animals and plants. There are many anthropogenic sources of manganese namely: sewage discharge, combustion of fossil fuels and also through the use of pesticides in agricultural land. It gets into the sea through rivers and through water and sediments in aquatic organisms (Howe et al, 2005). Manganese may be present in the concentration of 0.2-8.4 mg/L in fish samples (Rajkowska and Protasowicki, 2012). The results shows that manganese is in very little amount in the fish samples. This shows that the organisms get only the required amount of manganese.

5.3.5. Nickel in Fish

Nickel is a transition metal that is essential for aquatic organisms. Pollution such as heavy metals has increased a lot and is accumulating in water, sediments and marine organisms. Heavy metals are not degradable. The normal range of nickel that should be present in fish is below 0.2 mg/L (Todorova, 2015). With respect to the results obtained, the concentration of nickel is in line with the range. Thus it shows that there is not much pollution in fish species regarding nickel. The concentration of nickel is a bit high in site 2 and hence it can be concluded that this high value is due to pollution.

6. Conclusion

From the analysis conducted above, it can be concluded that pH, salinity of water and sediments were almost better for the place that the sites are situated. However, there was an anomaly in site 3 and to identify the reasons for this anomaly further research for the pH of water should be carried out on the site. pH of sediments was almost constant in every site. The salinity of water was also almost constant in every site. Salinity of Sediments was different for every site because it depends on the location of the site selected and the factors that are influencing change in the salinity content.

The phosphate, nitrate and nitrogen content were high in both water and sediments. There are several factors such as agricultural runoff, presence of the river mouth and habitats around the coastal region responsible for this high content. It has both positive and negative impact of having high content for these variables. Due to the high presence of this content, processes like eutrophication may occur and hence may cause other variables like oxygen; light and carbon dioxide become a limiting factor. Organic carbon concentration was a bit low for the sites in the sediments. One plausible reason for this low content may be that the sites have not been developed and there is no culture of marine species and decaying matters in the sites.

Heavy metals were present in water, sediments and fish samples. Cadmium was not found in some samples. Chromium concentration was a bit high in the samples. Copper, manganese and nickel were found in little amount in the sites. A more sensitive Atomic Absorption Spectrum (AAS) should be used for the analysis of heavy metal.

According to the study conducted, all the sites are suitable places where Aquaculture systems can be set up. However further detailed analysis should be conducted so as to understand the ecosystem in the barachois.

7. Recommendation

- A test should be conducted on the biodiversity content on the different sites. This will enable the investor to understand the ecology and the availability of foods for the aqua cultured species.
- A test on zooplankton and Phytoplankton should be carried out in the sites. This is important as it is an essential part of the food web.
- A study should be conducted to monitor the growth of corals in the barachois and especially the study should be conducted on zooxanthellae in order to explore the biodiversity of the sites.

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