A COMPARATIVE STUDY OF SOLID AND NON-SOLID POLLUTANTS IN DOMESTIC WATER SOURCES OF CALABAR METROPOLIS, CROSS RIVER STATE, NIGERIA.

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Abstract
This research work purposed to study solid and non-solid pollutants in domestic water sources in Calabar Metropolis of Cross River State, Nigeria. Samples of water from five (5) different sources within the two Local Government Areas that make up the metropolis were collected and subjected to various experimental separation techniques including filtration, sedimentation/ decantation, floatation and flocculation. This was to enable comparative analytical study of solids and non-solid pollutants in the water sources. Results of these analysis revealed that of the five water samples considered, solid pollutants were increasingly in the order of following: River Cross River were less than those in Calabar River, which were in turn less than those of the Great Qua River and greater than those of Municipal Water and Underground/Borehole water respectively. Based on the findings of this study, underground water obtained and stored in the best hygienic conditions is therefore recommended for users in the study area.

Key Words: Solid and non-solid pollutants, Filtration, Sedimentation/ decantation, Floatation and Flocculation.

Introduction and background

Profound speculations available indicate that there is significant deterioration in the ecological system mainly because of the activities of man. Such activities which are detrimental to the environment and cause adverse changes in the physical (abiotic) environment are what are coined into a single term called pollution. Environmental pollution covers land, air, noise and water pollutions. This research however intends to comparatively study solid and non-solid pollutants in water sources selected from five water bodies in Calabar metropolis of Cross River State.

Arimoro**,** Chukwuji, Iwegbue and Osiobe, (2008) observed that such pollutants have diverse effect on the chemistry of water, which include change in the colour of water, alteration in the amount of oxygen in water, an alteration of the chemical oxygen demand (C.O.D) etc. the various types of water pollutants are organic pollutants, pathogens, nutrients and agricultural runoff, suspended solids and sediments (organic and inorganic), inorganic pollutants (salts and metals), thermal pollutants, and radioactive pollutants. According to the authors, these have very critical effects on life processes, particularly those of aquatic organisms. Water pollution makes water unfit for drinking, fishes for example a valuable source of protein dies, water pollution may lead to food poisoning, human beings may contact diseases like cholera, typhoid, etc. During this study, the researcher should comparatively find out which of the sampled water bodies contained more solid and non-solid pollutants, and which water sample is preferred for domestic usage based on the parameters of the study.

The importance of water cannot be over stressed, water is the most important and essential chemical compound in human lives. Humans and other living things such as plants, lower animals and other organisms need water to survive. The author further agreed that water as a necessity for life is based on its characteristic nature of existing in more than two different states each necessary for a specific purpose. The importance of water can be summarized in five sub-headings; these headings are: water in synthesis, water in reproduction, water as a Coolant, water in transportation, and water as a Lubricant. Agbazue and Akpanisi (2012) stressed further that, water is a universal solvent, transparent medium, participant and catalyst in nearly all chemical reactions occurring in our environment.

Pollution in water is caused by indiscriminate dumping of refuse materials, sewage and industrial wastes such as pesticides, herbicides etc in water. The sources of water pollution are: Sewage and garbage: many towns and cities are built on the shores of rivers for easy waste disposal. These wastes contaminate the water and cause diseases such as cholera, dysentery etc. Imevbore (1980), Ogedemgbe (1981), saw that as in several other developing countries, and in Nigerian cities alike, sewage is carried in three major ways: through Septic tank and soak away system in which individual houses are treated separately, the manual collection by night soil men, and the pit latrine system.

Another source of water pollution is industrial waste: in which, most industries have caused a lot of environmental pollution in our society, by dumping pollutants such as cyanides, acids, alkalis, mercury compounds, salts, solvents among others. Industrial wastes are very harmful to harmful to human, aquatic organisms and other organisms that feed on them. Most industrial wastes are non-bio-degradable solid pollutants and are poisonous. Industries that pollute water include: power plants, mines, refineries, car factories etc.

Farm and agricultural wastes constitute another source of water pollutant. In an attempt to produce sufficient fund for the teaming population man pollute the environment with different types of organic and inorganic poisons. According to Imevbore (1981), along-side application of fertilizer on the soil is that of pesticides such as D.D.T. (Dichloronx Diphynyl Triochloro ethane), indosulphate and other chloninated hydrocarbons to control insects and agricultural pests. These eventually find their way into the aquatic ecosystem where they accumulate to poisonous or dangerous limits. In the words of Ringler (2016) the cause of less aesthetically pleasing and unwholesome value in water are mainly the invisible non-solid pollutants causing great harm to human health. James and Ebeling (2018) stated that “the suspended particles are more difficult to remove than those that possess relatively denser weight in water. And that water particles are less likely to have much suspended materials.

Some of the nutrients in these fertilizers particularly those of nitrogen in the form of nitrates and ammonium ions, phosphorous in the form of hydrogen phosphates, those of potassium etc are lost to the ground and hence contaminate ground water to surface water. The application of excess fertilizers brings about nutrient boom (enrichment in our water bodies). The excesses are washed by surface water into water bodies which become over enriched with nitrates thereby killing fish, and other aquatic organisms which decompose, resulting in the production of offensive odours and tastes (Udoh and Chukwu, 2014).

Oil and petroleum products constitute another source of water pollutant. Most petrochemical produce may be organic or inorganic, the former being more orderly used than the later. Petrochemicals may be used as insecticides, herbicides, nematocides, fungicides, rudencides and others are repellents, plant growing regulators and defoliants. Oil spillage resulting from wrecked oil tankers is very obvious in seas and oceans. When oil is in water, in floats and forms oil slicks. Oil can damage birds, fishes and other aquatic organisms in water. Oil also spoils beaches Udoh and Chukwu (2014).

Thermal pollution which increases water temperature results in a decrease in the amount of soluble oxygen (dissolved oxygen). Therefore, with an increase in temperature, the amounts of oxygen available for the aquatic organisms decrease. Further increase in temperature can cause a lot of changes in aquatic organisms responsible for the increase in temperature of water.

Solid wastes in water

Solid waste in water may be of no immediate health concern in themselves provided the water is continuously flowing and that the pollutant is of infinitesimal value when compared to the large volume of flowing water. Plastics, clay, organic materials, dead leaves, dead fruits, rotten seeds, constitute solid pollutants in water. When solid wastes are found in water, they are termed solid pollutants: These are the non-biodegradable pollutants or wastes e.g cans, tins, glass, plastics, clothing materials, metal scraps etc. These solid wastes are not easily broken down and hence difficult to treat in water. These pollutants are hazardous to health.

Turbid drinking water is particularly not appealing; this may lead consumers to select an alternate source of clear water. Solid wastes in water can be divided into three categories: those that float, those that sink and those that are suspended. Of this three categories, the suspended solids are the most difficult to remove (Cripps and Bergheim, 2000).

The nature of solid wastes in water depends on the locality from which refuse is collected. Cripps and Bergheim, (2000) upheld that, from the agricultural sector, the dumping of empty cans of insecticides, pesticides, vegetable leaves, sand/dust: and refuse from other segments which may include; paper and cardboards- constitute a major source of pollution. Textile/rags, glass and broken bottles, plastic, rubber, leather and bones in water are also considered as pollutants. Nelson, (2008) noted that solid particles in water which on analysis give positive result with sedimentation operation, will also give positive result with filtration operation, except that all may be caught on the filter paper may all not sediment.

Non-solid wastes in water

Non-solid waste is the term used for waste disposal in water or any other liquids, such wastes come from domestic sources, public buildings, recreation centres, hospitals and factories. It is the waste of this type which is referred to as sewage. It can be added here that many rural areas and even urban areas nearby bushes and streams are used for convenience particularly where a river flows through the town.

It is difficult to find clean, uncontaminated water for domestic and table use in Calabar metropolis of late. People resort to all available sources to meet their domestic needs. Whenever the municipal water supply comes on, it is either muddy, with a tang taste and smell, coloured like tea or with particles. Same thing goes for water obtained from the Calabar River, Qua River, or the River Cross River. Water from these open sources often comes with polythene plastic bags and plastic containers, plates, spoons, balls, nets etc.

Calabar Municipality has no waste treatment facilities. Human wastes and those from cottage industries are dumped in surface sites or into open drains. Torrential rains wash most of the wastes into the Calabar and Great Kwa Rivers (Akpan, Ofem, Nya, 2006). The quality of the water varies with the use with which it is to be put. As one of man’s natural resources, water is used for a multiplicity of purpose, including; water for domestic use, water for agriculture, water for industries, science, technological needs of man etc.

Arising from these various uses of water are some end products which are either organic or inorganic, solid or non-solid wastes etc. Our sewage is not completely treated nor properly disposed of; and much, if not all of our domestic wastes find their way into our different water bodies and thereby contaminating or polluting it, many industrial processes produce by-products that unavoidably end up in our rivers, lakes, the underground water or may evaporate to fall back as acid-rain etc.

The oil industry, poses a strong threat to our wild life, terrestrial and aquatic ecosystems. The chemical industry on the other hand cannot avoid being implicated in spilling solid and non-solid pollutants in water nor would we exonerate our agricultural and irrigational practices from this menace. Run-offs of non-solid pollutants from sewage etc or solid pollutants such as plastics, metals etc are the primary cause of water quality degradation. Disposal of untreated sewage cause deterioration of rivers and streams which changes from the sparkling colourless and odourless quality to a coloured and foul-smell water making such rivers and streams unfit for most human needs (Udoh and Chukwu, 2014).

Furthermore, sewage contains bacteria and viruses from both healthy and unhealthy people. The sewage in contact with fishes, domestic water supply, kitchen utensils, clothing etc can cause infection of healthy people with numerous water-borne diseases. This problem also affects the laundry services as some water samples hardly form foams hence difficult to wash materials. It is worthy to ask here generally, which water body or source in Calabar metropolis is fit for domestic consumption? Comparatively, which of them contains less solid and non-solid wastes? These water bodies are the Great Qua River, Calabar River, River Cross River, Municipal Water Supply (Water Board) and underground/Borehole water.

Objectives of the study

The main objective of this research study is to comparatively study solid and non-solid pollutants in the Great Qua River, Calabar River, River Cross River, Municipal Water Supply (Water Board) and underground/Borehole water.

Research questions

1. Is there any significant difference in terms of solid and non-solid pollutants in water samples obtained from 5 water sources in Calabar metropolis?
2. If the water samples are subjected to Filtration procedure, sedimentation/ decantation procedure, floatation procedure, flocculation and subsequent filtration, coagulation and subsequent filtration procedures, what will be the quantity of solid and non-solid pollutants in each of them?

Methodology

The experimental research design is adopted for this research study because the researchers comparatively used different chemical/scientific procedures to study pollutants in water samples and generalizations made to cover the entire length and breadth of the rivers. The sampling technique adopted is purposive sampling because all the five (5) major sources of water in Calabar metropolis were sampled for the study. The study area is Calabar Metropolis comprising of Calabar South and Calabar Municipal Councils of Cross River State. Calabar is the capital of Cross River State, and has often been described as the tourism capital of Nigeria. Administratively, the city is divided into Calabar Municipal and Calabar South Local Government Areas. It lies along the Calabar River, 5 miles (8 km) upstream from that river’s entrance into the Cross River estuary (www.britannica.com/place/calabar).

The river system formed by the Cross River, Calabar River, Great Qua River and other tributaries forms extensive flood plains and wetlands that empty into the Cross River estuary. The system has an estimated area of 54,000 square kilometres (21,000 square miles). The city of Calabar is bounded by the Calabar River to the west, Great Qua River to the east and the wetlands of the Cross River estuary to the south. The Calabar River houses the Calabar Port and the Calabar free trade Zone and recently Tinapa Resort.

The Metropolitan area has an area of 406 square kilometres (157 square miles) and with a population growth rate of +0.89% per year as was between 2006-2015, Calabar population in 2018 is projected to be *479 329 (NpoC, 2018 estimates).* Temperature in Calabar ranges from 21°C to 29°C. The Climate is of the "Am" type (tropical Monsoon Climate- following Koppens Classification system) and the metropolis highest Elevation is 32 m (105 ft). With a lengthy wet season spanning ten months and a short dry season covering the remaining two months. The harmattan, which significantly influences weather in West Africa, is noticeably less pronounced in the city. Calabar averages just less than 3,000 millimeters (120 inches) of precipitation annually. Calabar sits on a hill near the Calabar River and the Cross River Delta. Calabar is a beneficiary of foreign donors' water project which began in early 2004. Water intake that supplies the entire city is obtained from the Great Qua River.

Historically, the old town was called "Akwa Akpa, until the Spanish renamed it Calabar. The Efiks, the Quas, and the Efuts make up the indigenious communities of the area. Calabar is a large metropolis today, with several towns like Akim, Ikot Ansa, Ikot Ishie, Kasuk, Duke Town, Henshaw Town, Ikot Omin, Obutong, Bakassi, Biase, and Akamkpa. It presently houses indigenes from across the federation and several foreigners. Several government establishments and schools thrive in Calabar and several markets to service the population.

Experiments

Materials and reagents

The experiments require the following materials: fine mesh screen filters; one (1) 10 liters Plastic bucket; a funnel and four (4) water bottles. These items were acquired locally. The flocculants, coagulants and nutrients reagents used for this investigation were of laboratory standard and were purchased from chemical shops in Calabar (Cross River State).

Sourcing for test water samples

Five (5) water samples were obtained from different sources and designated as SWA, SWB, SWC, SWD and SWE (Where SWA means sample water A, sample water B,C, D and E.

Preparation of the samples

Ten (10) liters each of the water samples were collected from where the people also fetch for their daily use and stored for the study. Test samples were extracted from the 10 liter volume for each experiment. Coagulants such as aluminum sulphate, sodium aluminate, ferrous sulphate etc and the flocculants; Aluminum hydroxide were purchased in excess of the test requirements.

Experimental techniques

A number of experimental techniques were employed for the realization of the stated objectives. These include; Filtration procedure, sedimentation/ decantation procedure, floatation procedure, flocculation and subsequent filtration, coagulation and subsequent filtration, to ascertain the quantity and weights of solid and non-solid pollutants in these water bodies, records were kept of all the results.

Sedimentation/Decantation Procedures

200ml of each water sample was removed after proper agitation. The removed quantity was allowed to stand and settle within 60 minutes. At the end of the 60th minute the test sample was carefully decanted. The sediments so obtained were weighed dry in each case and recorded.

Filtration Procedure

200ml was measured out of each water sample after proper agitation and gradually passed through a funnel carrying a fine mesh screen filter. The weight of the filter was taken before and after the operation. The difference in weight was calculated in parts per million (P.P.M).

Floatation Procedure

Five (5) mls of each water sample were poured into a basin and allowed to stand for 30 minutes. Thereafter, the floated particles were skimmed off dried and weighed, and the weights were recorded.

Flocculation procedure

Equal weight (2g) of the flocculants: Aluminum hydroxide [$Al(OH)_2$] was added to 20ml each of the filtered sample of water. This system was left undisturbed for a period of three hours. Thereafter, the test water was filtered and the filter paper weighed dry before and after the operation. The difference was calculated in PPM, and recorded.

Coagulation Procedure

Equal weights (2g) of the coagulant Aluminum [$Al_2 (So_4)_3$] was added to 20ml of each water sample from the 5 different sources. The multi-charged cation ($A1^{3+}$) produced, neutralized the negative charges on the suspended particles. The neutralized particles which settled at the bottom were obtained by filtration and the weights compared by calculations in PPM.

Results and discussions

Results of the experiments carried out and the subsequent calculations are recorded in the tables below; each table carry different information on different event test.

Note that SWA stands for sample water from “River CROSS RIVER”; SWB for sample water from “CALABAR RIVER”, Sample Water (SWC) from ‘GREAT QUA RIVER’, SWD sample water from Municipal water supply (Water Board), and SWE for sample water from Borehole.

The results of sedimentation/decantation, filtration, floatation, flocculation and coagulation procedures are shown on tables 1,2,3,4 and 5.

Table 1: Sedimentation/decantation results

Water sources	Volume of water	Time (minutes)	Weight of sedimentation
SWA	200ml	60m	0.00176mg
SWB	200ml	60m	0.00147mg
SWC	200ml	60m	0.00152mg
SWD	200ml	60m	0.00158mg
SWE	200ml	60m	0.00156mg

Table 2: Filtration results

Water sources	Volume of water used	Weight of Residue/PPM
SWA	200ml	0.152
SWB	200ml	0.172
SWC	200ml	0.183
SWD	200ml	0.132
SWE	200ml	0.121

Table 3: Floatation results

Water sources	Volume of water Used	Time of settling	Weight of Float particle
SWA	5 Litres	30 minutes	Tiny plastic
SWB	5 Litres	30 minutes	NIL
SWC	5 Litres	30 minutes	Leaf particle
SWD	5 Litres	30 minutes	NIL
SWE	5 Litres	30 minutes	NIL

Table 4: Flocculation results

Water sources	Water Volume Used	Weight of Flocculants	Weight of sludge (PPM)
SWA	200ml	0.5mg	0.25
SWB	200ml	0.5mg	0.20
SWC	200ml	0.5mg	0.21
SWD	200ml	0.5mg	0.70

SWE	200ml	0.5mg	0.18

Table 5: Coagulation results

Water sources	Volume of water Used	Weight of coagulant	Weight of residue
SWA	200ml	0.5mg	0.25
SWB	200ml	0.5mg	0.19
SWC	200ml	0.5mg	0.21
SWD	200ml	0.5mg	0.65
SWE	200ml	0.5mg	0.18

Discussion of Findings/Result

The result of the analysis obtained when filtration was carried on the water samples showed that the visible solid particles in River Cross River were greater than those in Calabar River which were in turn less than those of the Great Qua River and greater than those of Municipal Water and Borehole water respectively.

This implies that "River Cross River" in the study Area carried along more solid particles than the other four water samples considered.

The same trend was observed when decantation/sedimentation results were analyzed. This is very much expected because solid particles which cannot easily pass through a fine mesh screen filter in the semi-permeable holes is capable of possessing sufficient densities that will cause it to sediment in less troubled water.

This observation is in consonance with the reports of Nelson, (2008) who noted that solid particles in water which on analysis give positive result with sedimentation operation, will also give positive result with filtration operation, except that all may be caught on the filter paper may all not sediment.

Nelson, (2008) stated that primarily speaking, water treatment involves sedimentation/ filtration and that solids respond on analysis in similar manner. The sedimentation analysis report carried out on the five water sources in Calabar metropolis revealed that the Underground/Borehole water is fairly the purest of the five sources in terms of solid pollutants, followed by the Municipal Water supply. The Great Qua River is next to the River Cross River and the Calabar River is last in terms of sediments found.

The result of the non-solid pollutants analysis as presented in tables 4 and 5 appear to follow a certain order. Flocculation report shows that the non-solid particles matter as obtained from analysis decreases in the order: Borehole water< Calabar River< municipal water supply (Water Board) < Great Kwa River and<River Cross River. This

implies that with respect to non-solid pollutants in water, Borehole water is purer than the others.
This observation is in agreement with James and Ebeling (2018), who stated that "the suspended particles are more difficult to remove than those that possess relatively denser weight in water. And that underground water is less likely to have much suspended materials.

Comparatively, we can say that borehole water contains less solid particles. Suspended in it are many non-solid particles. It has also been confirmed that this water source apparent purity with regards to solid matter is still impure considering that lots of non-solid chemical substances may be suspended or dissolved in it. Chlorination may be needed to kill germs and remove impurities before such water can be used domestically. According to Ringler (2016) what cause less aesthetically pleasing and wholesome value in water are mainly the invisible non-solid pollutants which causes great harm to human health.

It is therefore dangerous to have non-solid impurities in drinking water than the solid as it is easier to handle the solid than the non-solid pollutants. Furthermore, the non-solid pollutants which may be loose particles with negative charged ions may be uneconomical for washing.

Ringler (2016) noted that particles that have negative charges on their surfaces repel each other hence are not capable of setting to the bottom of the stream /pond or the gravity basin. And that to get these out of water, chemicals known as coagulants are added. According to him, examples of coagulants include Aluminum sulphate, sodium aluminate, ferrous sulphate and ferric chloride. These compounds, according to him ionize in water to produce large multi-changed surfaces and cause them to coagulate (come together), acquire denser nature and sink to the bottom of the water source. These invisible enemies are more dangerous to health than others the author concluded.

Conclusion

Comparative analysis of solid and non-solid pollutants in water samples in Calabar Metropolis has been carried out. It is discovered that each Water source of the five considered has some level of impurities ranging from solid to non-solids. Of these, Borehole water appears cleanest at the Molecular level followed by Calabar River, municipal Water supply (Water Board), The River Cross River and lastly the Great Kwa River. The Purity from the unaided eye consideration is not the goal of this research project. The study did not treat cleanliness of water generally but dwelled on solid and non-solid pollutants point of view. It is hoped that other research about Calabar Municipal water bodies should be mounted in future, which will examine the total water purity of water in the study area.

Recommendations

Based on the findings and conclusion of this study, it is recommended among others that:

1. The choice of domestic and industrial use of water for Calabar Metropolis should be based on our results after careful study to avoid contacting water borne disease.
2. It is also recommended that Borehole water which contains the least of non-solid pollutants should be used for both industrial and domestic purposes. After careful analysis to check for non-solid contaminants and subsequent treatment which should involve: sedimentation, filtration, disinfection, chlorination, and boiling.
3. Finally, it is recommended that based on this level of impurities, waters from the metropolis its environs should be treated before use with chlorine to kill germs after other procedures have been carried out.

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