

Municipal Waste: Effect on the Physico-Chemical and Microbiological Parameters of Otamiri River in Owerri, Nigeria

Eze Chinwe Catherine^{1*}, Ekeke Evelyn Nkechi², Ezenwata Ifeoma Susan³, Frank-Ogu Ngozi¹, Okorie I. Ugochukwu¹, Anaebonam Emeka³, Nweze Kenneth Emeka³ & Onyemeka Regland Michael⁴

¹Department of Microbiology, Federal University of Technology, Owerri, Nigeria. ²Department of Medical Laboratory Sciences, Nnamdi Azikiwe University-Nnewi, Anambra, Nigeria. ³Department of Biological Sciences, Chukwuemeka Odumegwu Ojukwu University, Anambra, Nigeria. ⁴Department of Botany, Lagos State University, Lagos, Nigeria. Email: eze2chinwe@yahoo.com*

DOI: <http://doi.org/10.38177/AJBSR.2021.3310>



Copyright: © 2021 Eze Chinwe Catherine et al. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Article Received: 29 June 2021

Article Accepted: 30 August 2021

Article Published: 30 September 2021

ABSTRACT

Water pollution has deleterious effects as hazards to human health, living resources and hindrances to marine activities. Therefore this research aimed to ascertain the influence of municipal solid waste on physicochemical parameters and microbiological parameters of water samples obtained from Otamiri River. Stream samples were collected at five different points. The physicochemical and microbiological parameters of samples collected were analyzed. Most of the physicochemical parameters were high for some of the locations. The bacteriological analysis result shows a high bacteria count in the water which can be attributed to leachate from dumped human faeces in the river banks. At $P < 0.05$, acidity correlated negatively with THBC ($r = -0.903$), TCC ($r = -0.449$), FCC ($r = -0.594$). TSS correlated positively with *E. coli* ($r = 0.938$). PO_4 correlated positively with THBC ($r = 0.905$). At $P < 0.01$, Turbidity correlated positively with THBC ($r = 0.997$). Dissolved Oxygen correlated negatively with all the physicochemical parameters. BOD correlated negatively with TCC ($r = -0.877$), *E. coli* ($r = -0.929$), FCC ($r = -0.742$), TFC ($r = -0.117$). Total hardness correlated positively with FCC ($r = 0.975$), PO_4 correlated positively with *E. coli* ($r = 0.989$) and FCC ($r = 0.967$). NO_3 correlated positively with *E. coli* ($r = 0.976$). Summarily, the proximity of the waste dump to Otamiri River has certainly shown considerable physical, chemical, and most importantly, biological effects on its water quality. The presence of the organism shows that the river requires auxiliary treatment before usage as a source of drinking water.

Keywords: Physico-chemical, Microbiological, Waste disposal, Water pollution.

Introduction

Water is necessary to live on earth as all organisms contain it, some live in it and others drink it. Plants and animals require moderately pure water, and they cannot survive if their water is loaded with toxic chemicals or harmful microorganisms. If severe, water pollution can kill large numbers of fish, birds, and in some cases, killing all members of a species in an affected area. The level of its physical, chemical and biological impurities defines the quality of the water. Water quality is evaluated relative to its intended use. Extensive scrutiny of water used for diverse activities is necessary because numerous pathogens can live in them especially waters used as a source of drinking water like streams, lakes, ponds, and oceans [1].

The major water pollutants are chemical, biological, or physical materials that degrade water quality. Most developing countries are facing new constraints and pressure about solid waste management [2]. One common method of water disposal in Nigeria, which harms the surface water, is illegal (open) dumping. Population explosion, uncontrolled urbanization, and industrialization have caused a high rate of waste generation in Nigeria [3]; even as Ezeronye and Ubalua, [4] pointed out that aquatic pollution problems in Nigeria are on the increase.

Owerri is drained by two rivers, Nworie River and Otamiri Rivers, the later stretching its length to Etche in Rivers State from where it flows into the Atlantic Ocean. Industrial and commercial activities such as sand and gravel mining, landfills, a motor mechanic village among others are all located along the Otamiri watershed. Of paramount importance is the setting of refuse dump along the watercourse, Fakayode [5]. The initial effect of waste

is to degrade the physical quality of the water. Later, biological degradation becomes evident in terms of the number, variety, and organization of the living organisms in the water.

The nature of pathogens and their effects on humans is advanced – and continually advancing [6]. Aside from human health concerns, the input of waste into water bodies may not always hurt the aquatic environment because of the self-purification property of the water bodies but the indiscriminate dumping of wastes into natural water bodies can overtax this self-purifying capacity of the receiving water [7]. This will not only endanger the residents aquatic lives but may also impair other amenity purposes and non-consumption uses [8].

Nworie River, a first-order stream runs about a 5 km course across Owerri metropolis in Imo State, Nigeria before emptying into the Otamiri River. The Otamiri watershed is subject to intensive human and industrial activities resulting in the discharge of a wide range of pollutants. When the public water supply fails, the river further serves as a source of direct drinking water, especially for the poorer segment of the city. Microbial contamination of drinking water has a severe health impact on infants and young children in many developing regions of the world, where childhood diarrheal diseases from ingesting polluted water are the second most common cause of infant death. According to Cookey *et al.* [9], people who ingest polluted water can become ill, and, with prolonged exposure, may develop cancers or bear children with birth defects. The resultant effects of this on public health and the environment are usually great in magnitude.

However, the occurrence of these environmental problems depends on the presence of certain pathogenic microorganisms, which could be contributed by such anthropogenic establishments as municipal solid waste dumpsites, similar to the one located proximally to the Otamiri River in the Owerri Municipal council. This research is therefore an attempt to determine possible contributions of pathogenic microorganisms and other physiochemical imbalances in the Otamiri River by a solid waste dumpsite in its neighborhood. More specifically, this research aimed to ascertain the influence of municipal solid waste on physicochemical parameters and microbiological parameters of water samples obtained from Otamiri River.

Materials and Method

Area of Study

Owerri, the study area is the capital city of the Imo State, Nigeria. Owerri lies within latitude 05° 29' 06s and longitude 07° 02' 06s (Fig. 1). The area experiences a longer wet (which lasts from April to November) than the dry season (which lasts the rest of the year) (Victor *et al.* 2011). The Otamiri River is the major river that courses through the Ihiagwa Community in the Owerri West Local Government Area of Imo State, Nigeria. It runs from Egbu where it has its major base, through to Nekede, Ihiagwa, Eziobodo, Olakwu, Umuisi, Mgbirichi, Umuagwo and finally to Ozuzu in Etche town of Rivers State where it finally joins the Atlantic Ocean [3].

Research Design

A semi-experimental field research design was used for the study. A semi-experimental field research design allows a researcher to collect original data in a natural setting allowing experimentation without introducing confounding variables. The independent variable includes physicochemical.

Sample collection

Water samples from Otamiri River were obtained from locations (five communities) closest to landfill, mechanical workshop village and sand and gravel mine at the early hours of the day for four months: September, October, November, and December. Samples were taken once every month under aseptic conditions. Site location 1 was located 300m from the source of the stream at Egbu village near Owerri and served as the control. Site Location 2 was located at 300m from SL1, and about 31m from the dumpsite, while Site Location 3 was located downstream behind Emmanuel College premises, at about 300m from Site Location 2. Finally, the sample collected at Site Location 4 was a composite sample collected from the riverbanks around Nekede village; about 310m from Sample Location 3 and at 1m below the water surface. Sample Location 1 and Sample Location 5 represent the downstream and upstream samples respectively. Sample Location 2, 3, 4 were used to assess the contribution of municipal solid waste and other human activities from the municipality into the Otamiri River. Observations were equally made on the water current and human activities going on along the vicinity of the riverbanks.

Instrument for Sample Collection

The containers were unscrewed at a depth of 15-30cm below the surface of the water, facing the upstream direction and corked when filled while still underwater to prevent oxidation. A small air space of 2 to 3 cm above the sample was left in the container for proper mixing of the sample before analysis except for the water samples for biochemical oxidation demand (BOD) and dissolved oxygen (DO) determination. It was tightly closed and labelled. Bottles were rinsed with the river water before sampling. These were stored in the icebox to retard the biochemical activities and promptly transported to the laboratory. The media used in this study were Nutrient agar (Fluka Biochemica, Germany), MacConkey agar (Antec), Sabourand dextrose agar (Fluka Biochemica, Germany), Eosin Methylene Blue (EMB), MF-Endo agar medium, KF- streptococcus agar thiosulphate and citrate bile sucrose agar (TCBS). Nutrient agar medium was used for isolation of aerobic heterotrophic bacteria while total coliform isolates were obtained using MF-Endo agar medium. KF- streptococcus agar was used for faecal streptococci while thiosulphate citrate bile sucrose agar (TCBS) was used to isolate *Vibrio* species. The enumeration of *Salmonella* species was carried out using the bismuth sulphate agar method [10]. Media preparations were according to manufacturer's instructions and incubation generally, except for faecal coliform, was at 35 -37°C for 24 h. All glassware and media used were sterilized by autoclaving at 121°C for 15 min, 15 pounds pressure and air-drying in the hot air oven at 160°C (two hrs.). Of the samples collected, one was immediately analysed for the following parameters in the field: pH, Temperature, Electrical Conductivity Total Dissolved Solids (TDS) and Dissolved Oxygen) using Digital Meters. Serial dilution of the water samples was carried out using sterile distilled water. The samples were analysed as per standard methods mentioned in APHA [11]. All the different dilutions were properly labelled and used for total plate count. The standards reagents used in the analysis were prepared using double distilled water.

Sample Analyses of Physico-Chemical Parameters

The BOD was evaluated by first diluting the sample and incubating it in the dark at 20°C for five days and measuring the amount of oxygen consumed. The DO sample was fixed with 2 ml each of Wrinkler I and II reagents

at the site, while BOD₅ sample bottles were corked and wrapped with aluminum foil and the BOD₅ sample was fixed with the Wrinkler method after five days of incubation at room temperature (25°C) in the dark place. Conductivities were measured at 25°C directly in $\mu\text{s}/\text{cm}$ using a digital conductivity meter (NorLab; LM8). Turbidities were measured with a digital turbidimeter (Hach Chemicals; 2100P). The total suspended and total dissolved solids were separated by filtering the water through a 0.45 μm filter paper and determined according to standard procedures [12]. Acidity and alkalinity were determined by titration methods. Dissolved oxygen was determined using a dissolved oxygen meter; In this case, the dissolved oxygen (DO) of the samples was determined using the Schott Gerate Dissolved Oxygen meter and then incubated for five (5) days at 200C. DO was again measured after five days and BOD in mg/l was determined from the following calculation and reported accordingly. BOD₅ was determined using BOD₅ Track; electrical conductivity was measured by electrical conductivity meter – DIST3 by HANNA limited. Ammonia – Nitrogen (NH₃-N) was determined by direct Nesslerization for natural effluent and Nitrate – Nitrogen (NO₃-N) was determined by the Brucine method [13]. Their absorbance values were read with UNICAM 8626 UV/VIS spectrophotometer at 470 nm for NO₃-N and PO₄ and 420 nm for SO₃ ions.

Test for the presence of nitrite

The test for the presence of nitrite was carried out using a modification of the method described by [14] which involves Greiss-Ilosvay reagent. Suspensions had to be prepared by dissolving some part of the isolated cultures from the selective medium in 1 ml of sterile deionised water.

Test for Temperature

This was determined at the point of sample collection by dipping the bulb of mercury-in-glass thermometer into the soil suspension and recording the readings. Reading was taken when there was a steady temperature from the calibration on the capillary tube.

Conductivity Test

This was measured using the suntex conductivity meter (DD 193). After it was calibrated, the electrode was inserted into the portion of the sample and the conductivity button was pressed. The valve was read.

Test for Phosphorus

This was determined using Vanado-molybdophosphoric acid colourimetric method using ammonium molybdate which formed molybdo-phosphoric acid under acidic conditions. The intensity of the yellow colour was measured using a spectrophotometer at 490 nm.

Result

Parameters of Samples

The Physico-chemical parameters of samples from the predetermined spots in Otamiri River, Imo State, Nigeria are presented in Table 1. After incubation, the colonies were enumerated macroscopically and the results of the microbial population from soil samples from the five site locations are shown in Table 2.

Table 1. Descriptive statistics of the physicochemical parameters

Parameters	Minimum	Maximum	Range	Mean	SE
pH	6.23	7.12	.89	6.5240	.17137
TSS	112.80	568.60	455.80	320.5400	90.42545
EC	60.13	154.30	94.17	87.6780	17.46188
Acidity	28.45	32.44	3.99	30.0820	.66453
TDS	49.00	67.00	18.00	55.4000	3.31059
Turbidity	10.60	110.24	99.64	72.7260	17.94098
DO	3.76	5.60	1.84	4.6760	.31752
BOD	2.50	3.53	1.03	2.9200	.21324
Cl	20.20	120.60	100.40	63.6000	20.14229
Alkalinity	30.24	37.33	7.09	32.6960	1.30086
T. Hardness	39.27	98.27	59.00	69.8240	11.63673
Ca	1.47	64.24	62.77	16.1780	12.04413
Mg	2.24	3.60	1.36	2.6820	.27240
K	2.54	2.73	.19	2.5980	.03455
Na	3.27	5.27	2.00	4.5540	.35413
PO ₄	.10	10.23	10.13	5.5120	1.96288
SO ₄	1.98	2.66	.68	2.3940	.12883
NO ₃	2.80	4.22	1.42	3.5840	.28335
NH ₃	.003	.100	.097	.03740	.018041
Temperature	25.00	29.00	4.00	27.1400	.76785
Fe	.14	1.04	.90	.4240	.16080

SE= standard error of mean, TSS=Total Suspended Solids, EC=Electrical Conductivity, TDS= Total Dissolved Solids, Do=Dissolved Oxygen, BOD= Biological Oxygen Demand, CL= Chlorides, T hardness= Total Hardness, Ca= Calcium, Mg= Magnesium, K= Pottasium, Na= Sodium, PO₄= Phosphates,SO₄= sulphates, NO₃= Nitrates, NH₃=Ammonium, Fe = Iron, THBC= Total Heterotrophic Bacterial Count, TCC= Total Coliform Count, TFC= Total Fecal Count, COD= Chemical Oxygen Demand.

Table 2. Descriptive statistics of the microbial groups of Otamiri River

Microbial groups	Minimum	Maximum	Mean	SEx10 ⁴
THBC (cfu/ml)	3.24x10 ⁵	6.7x10 ⁵	5.4x10 ⁶	6.1x10 ⁴
TCC (cfu/ml)	2.5x10 ⁴	3.74x10 ⁴	3.30x10 ⁴	2.20x10 ³
E.coli (MPN/100ml)	1.39	3.80	2.68	0.52
FCC (cfu/ml)	2.10x10 ²	3.80x10 ²	2.92x10 ²	3.2x10 ¹
TFC (cfu/ml)	2.49x10 ³	3.4x10 ³	3.02x10 ³	1.79x10 ²

SE= standard error of mean, THBC= Total Heterotrophic Bacterial Count, TCC= Total Coliform Count, FCC= Faecal Coliform Count, TFC= Total Faecal Count

Table 3 shows microscopic morphology and cultural characteristics of fungal isolates from soil samples. *Aspergillus spp*, *Fusarium spp*, *Penicillin spp*, and *Mucor*, *Candida spp*, *Rhizopus spp*, and *Norcadia spp* were the fungal isolates identified.

Table 4 shows biochemical tests of bacteria isolates from the soil samples. The bacterial genera isolated were *Pseudomonas*, *Serratia*, *Shigella*, *Bacillus*, *Staphylococcus*, *Escherichia*, *Proteus*, *Klebsiella*, *Streptococcus*, *Micrococcus*, and *Corynebacterium spp*.

Table 3. Microscopic morphology, cultural characteristics and % occurrence of fungal isolates from Otamiri River

Organism	Microscopic morphology	Cultural characteristics	Occurrence (%)				
			SL1	SL2	SL3	SL4	SL5
Aspergillus niger	Has septate hyphae with long and smooth conidiophores, large, round unbranched sporangiophores	Golden reverse side, creamy and brownish mycelium, powdery	20	21	17	24	18
Aspergillus flavus	Colourless, long, erect swollen conidiophores and septate hyphae	Colonies are Greenish yellow colour with creamy edge	19	18	24	19	21
Fusarium species	Dark pigmented conidiophores, spherical	Powderish and creamy colonies	20	17	22	23	18
Penicillin species	Fruity mycelium, branched conidiophores with white margin	Greenish and filamentous colonies	19	18	17	26	20
Mucor pusillus	Non septate hyphae with short sporangiophores	Creamy and irregular colonies	22	18	23	25	12

Table 4. Biochemical tests and percentage occurrence of bacteria isolates from Otamiri River

Organism	Gram Reaction	Cultural Characteristics	Motility	Oxidase	Catalase	Citrate	Congula se	Vp	Mr	Urease	Indole	Occurrence (%)				
												SL1	SL2	SL3	SL4	SL5
<i>Pseudomonas sp</i>	Negative rods	Blue green colonies on NA	+	+	+	+	-	-	+	-	-	8	10	28	35	19
<i>Shigella</i>	negative rods	Pink colonies on DCA	+	-	-	-	-	-	+	-	-	10	15	24	28	23
<i>Serratia sp</i>	Negative rod	Red, circular entire margin colonies	+	+	+	+	-	+	-	-	-	10	ns	ns	43	47
<i>Bacillus sp</i>	Positive rod	Milky white colonies	+	+	+	+	-	+	-	-/+	-	15	17	38	20	10
<i>Staphylococcus sp</i>	Positive cocci	Round, golden-yellow colonies, often with hemolysis, on blood agar plates	-	-	+	-	+	+	-	-	-	14	15	25	30	16
<i>Corynebacterium sp</i>	Positive rod		-	-	+	+	-			-	+	12	15	25	26	22
<i>E.coli</i>	Negative rods	Small white colonies	+	+	+	-	-	-	+	-	+	5	11	28	23	17
<i>Proteus Spp</i>	Positive rods	Large milky white	+	-	+	+	-	+	-	+	-	8	11	31	27	23
<i>Kleb Spp</i>	-rods	Slightly gummy colonies, circular, convex, entire margin	+	-	-	+	-	+	-	+	-	10	15	25	22	28
<i>Streptococcus Sp</i>	+ cocci		-	-	-	-				-	-	5	10	30	33	22
<i>Micrococcus Sp</i>	Positive cocci	Yellow punctiform colonies	-		+							3	ns	36	39	22

(+ =positive; - negative reactions) ns= not seen

Table 5. Correlations (r) matrix (MPN/100ml) between the physicochemical parameter and microbial groups

	Cfu/ml	pH	TSS	EC	Acidity	TDS	Turbidity	DO	BOD	Cl-	Alkalinity	T-Hardnes	Ca	Mg	K	Na	PO43-	SO42-	NO3	NH3	Temp	Fe
TFC	0.679	0.781	0.914	0.867	-0.594	0.693	0.850	-0.775	-0.742	0.946	0.774	0.975**	0.723	0.817	0.356	0.843	0.967**	0.888*	0.943	0.833	0.188	-0.0805
FCC	0.636	0.735	0.669	0.470	0.750	0.750	0.910	-0.851	-0.929	0.879	0.772	0.868	0.595	0.690	0.392	0.735	0.989*	0.949*	0.976*	0.768	0.163	-0.796
E.coli	0.403	0.657	0.669	0.470	-0.449	0.510	0.563	-0.514	-0.877	0.528	0.474	0.428	0.423	0.342	0.139	0.152	0.689	0.597	0.661	0.416	0.358	0.289
THBC	0.403	0.735	0.669	0.470	-0.903*	0.542	0.997**	-0.770	0.745	0.684	0.540	0.763	0.586	0.437	0.223	0.843	0.905*	0.918*	0.863	0.546	-0.316	0.925
TCC	0.255	0.657	0.669	0.470	-0.449	0.510	0.563	-0.514	-0.877	0.528	0.474	0.428	0.423	0.342	0.139	0.152	0.689	0.597	0.661	0.416	0.358	0.289

* = significant at p < 0.05, ** = significant at p < 0.01.

The Pearson correlations between the physiochemical parameters and the microbial groups are shown in Table 5. At $P < 0.05$, acidity correlated negatively with THBC ($r = -0.903$), TCC ($r = -0.449$), FCC ($r = -0.594$). TSS correlated positively with E.coli ($r = 0.938$). PO_4 correlated positively with THBC ($r = 0.905$). At $P < 0.01$, Turbidity correlated positively with THBC ($r = 0.997$). Dissolved Oxygen correlated negatively with all the physiochemical parameters. BOD correlated negatively with TCC ($r = -0.877$), E.coli ($r = -0.929$), FCC ($r = -0.742$), TFC ($r = -0.117$). Total hardness correlated positively with FCC ($r = 0.975$), PO_4 correlated positively with E. coli ($r = 0.989$) and FCC ($r = 0.967$). NO_3 correlated positively with E. coli ($r = 0.976$). The test of homogeneity in mean variance of levels of the physicochemical parameters across the sampling locations revealed significant difference.

Discussion

Physiochemical analysis

From the analysis of available data, the major findings of this research are as follows: Variations in the pH, colour, turbidity, temperature, hardness and conductivity of the Otamiri River are shown in Table 1.

Turbidity of the water increased greatly from 10.6 NTU at SL1 to 110 NTU at SL4 showing an increase in the concentration of suspended matters in the water sample and soil particles transported by runoff to the river but highest at the point SL4 after input of wastes from the municipal waste dump. Reduction to 88 NTU at the point of leaving is indicative of self-purification by the river.

Significant increases in conductivity may be an indicator that polluting discharges have entered the water. The result of the analysis shows that the pH varied between pH 6.27 and 7.12, the highest pH was recorded at point SL5 with a mean temperature range of 24.3 to 25.8 °C. The total hardness of the water was recorded to be highest at SL5. Calcium and Magnesium hardness range from 1.47mg/l to 6.24mg/l and from 2.24 to 3.6 mg/l respectively.

Nitrate levels across the sampling locations were progressively high, the highest located at SL 5. This may explain the rich growth of water weeds and plankton around the study area. Farming and dumping of animal waste along the river course might be responsible for these high readings. A recent study of the Nworie and Otamiri rivers in Nigeria showed a strong relationship between nitrate concentration and urbanization. As urbanization increased, so did the nitrate concentration of the rivers [15]. Phosphate levels varied along with the sampling locations, the highest recorded at SL4 (10.23mg/l). These findings agree with the findings of [16]. Crowther *et al.* [16] opine that increased nutrients especially nitrate and phosphates imply increasing plant bloom, a situation which may lead to eutrophication in future.

The mean concentrations of dissolved oxygen (DO) of Otamiri vary from 3.76 to 5.6 mg/l with a mean value of 4.6mg/l. Organic wastes and other nutrient inputs from sewage and industrial discharges, septic tanks and agricultural and urban runoff can result in decreased oxygen levels. Nutrient inputs often lead to excessive algal growth. When the algae die, bacteria decompose the organic matter. Bacterial decomposition consumes a great deal of oxygen. Dissolved oxygen is depleted by the decaying process. The lower level of DO noted at site SL3 may be attributed to increased growth of aerobic bacteria in the presence of large organic matter, due to anaerobiosis.

The BOD values from SL 3-5 were higher than those of other locations. The oxygen demand is directly proportional to the amount of oxygen waste materials that are to be broken down [18]. This accounts for the oxygen required in the decomposition of organic matter. The concentration of BOD from the water analysis varies from 3.33-5.54 mg L⁻¹. The huge waste rich in organic matter and nutrients along the course of the river and probably as a result of the increased microbial activity (respiration) occurring during the degradation of the organic matter may be responsible for the high BOD value in the water.

This trend indicates a significant increase in organic input into the river. In their study, Desai and Tank [19] corroborate that high levels of pollutants in river water systems causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), and faecal coliform and hence make such water unsuitable for drinking, irrigation and aquatic life.

The temperature ranged between 26- 29°C. The mean temperature values of the water samples are not statistically different from each other ($p < 0.05$). Hence, the temperature of the water from Otamiri River could not be implicated as influencing the observed variations in the bacterial population as well as in other physicochemical parameters. However, the observed range of the temperature allows for an optimum proliferation of most of the bacteria isolated from the water samples.

The high TSS and TDS content values of the water show significant direct relationships to the high bacterial population obtained from the water samples. Total Suspended solids increased from 112.8mg/l at SL2 to 568.6mg/l at SL5 but recorded 120.3mg/l at SL 1.

Microbiological analysis

The bacteriological analysis result shows a high bacteria count in the water which can be attributed to leachate from dumped human faeces in the river banks. The presence of total coliform in water is an indication of faecal contamination and is responsible for most water-borne diseases such as meningitis, cholera and diarrhoea as well as morbidity and mortality among children [20].

On average about 70% of the total coliforms are of faecal origin. Faecal indicators (*Enterococci* or coliphage) are microbes whose presence indicates that the water may be contaminated with human or animal wastes. Results of bacteriological analyses including total heterotrophic count, total coliform and thermotolerant coliform counts revealed a high level of faecal pollution of the river. This range is higher than WHO standards. Some genera could be of soil origin while others are of intestinal and hence faecal origin. Bacteria and other pathogens are the greatest threat to the quality of water for domestic consumption [21]. Bacteria originating from human faeces are a leading cause of child mortality, and water is a common transmission route [20].

Total counts of heterotrophic bacteria were highest at SL3 (close to the municipal solid waste) with fairly steady increases in counts of the microorganisms. The profile showed that bacterial populations increased reaching a peak at SL3. Partially eutrophicated sites seem to have higher isolates of these organisms. Run-offs into this river from a government-owned abattoir located about 100 meters on a slope off the bank of the river and emptying into the river may have greatly contributed to its load of coliforms. This situation is in accordance with other reports of

Keraita *et al.* [22] who attributed increased bacterial presence notably *S. aureus* populations to the presence of the refuse dump. Activities such as swimming, washing of vehicles and domestic wares take place daily at SL5, unlike site SL1. WHO [23] reveals that any water intended for drinking should contain faecal and Total coliform count of 0 respectively in any 100ml. It was posited that the total number of heterotrophic bacteria reflects the contamination extent by the easily decomposable organic matters, while the faecal coliform bacteria number gives an idea of the contamination size by faecal substance

Results show that bacterial populations increase downstream with a peak at SL5. *Escherichia coli*, *Klebsiella species*, *Proteus species*, *Shigella species* and *Salmonella species* belong to the family Enterobacteriaceae (Kistemann *et al.*, 2002). Their presence in water indicates faecal contamination of the water. For instance, *Shigella species* have been implicated in bacterial dysentery. *Proteus species* thrives in urinary tract infection in humans. *Staphylococcus epidermitis* and *Bacillus species* are pathogenic and non-pathogenic bacteria respectively. *Staphylococcus epidermitis* implicated with mucous of man and other warm-blooded animals.

Their presence in water signifies waste material contamination of the water body from humans and other warm-blooded animals whereas; *Bacillus species* are harmless but are saprophytic in nature indicating the presence of decomposing organic materials in a water body. High counts of bacterial load reflect the level of water pollution as it indicates the amount of organic matter present. A major natural source of pollutants is runoff, which carries debris, sand, silt and nutrients into the river that affects colour and turbidity. These activities include the indiscriminate dumping of refuse into the river, channelling of raw sewage, open defecation, discharge of untreated effluents and dumping of industrial waste into the Otamiri River. *Enterobacteriaceae* are mesophiles most of which grows optimally at a temperature range of 20 °C and 32 °C. In *E. coli* counts were recorded higher counts in order in SL4 (3.8), SL5 (3.5) and SL 3(3.22). These values corresponded with the high level of BOD recorded in all the samples, which indicated the presence of microorganisms in them. The river showed a high bacterial count as is characteristic of water bodies receiving organic pollutants. The presence of *E.coli* is a definite indication of faecal contamination [23].

Conclusion

Summarily, the proximity of the waste dump to Otamiri River has certainly shown considerable physical, chemical, and most importantly, biological effects on its water quality. The presence of the organism shows that the river cannot be used directly as a source of drinking water; it ranks among water that requires auxiliary treatment. In addition, some of the organisms encountered in the water are potential pathogens contrary to the WHO (2004) recommendation that drinking water should be free of pathogens.

All these observations pose serious public health hazards, as they constitute potential sources of food-borne gastroenteritis, diarrhoea, salmonellosis, dysentery etc. Increases in nutrient levels, river flow, and aeration enhance aerobic decomposition of organic matter and therefore bacterial counts, leading to the deterioration of the aesthetic value of the river. The presence of some of the organisms suggests that materials were being added to the water from other sources likely to be the refuse dumps. The dumps are exposed and hence can be washed into the river during rains or material be carried from it to the water during heavy winds. Based on the major findings in this

research, it has become imperative to put up some recommendations that are necessary to improve the environmental and health conditions of the people.

Government intervention is needed in providing infrastructure for waste collection and appropriate management, waste disposal management through adequate funding, giving preference to recycling wherever possible while existing laws and regulations guiding environmental sanitation and health should be reviewed and enforced with stiffer actions to make them more effective. Solid waste handling, controlling and monitoring techniques in Owerri metropolis must be geared towards achieving quality environmental conditions for man to live in and to protect natural resources such as water that are degraded by these solid wastes.

Declarations

Source of Funding

This research did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare no competing financial, professional and personal interests.

Consent for publication

Authors declare that they consented for the publication of this research work.

Availability of data and material

Authors are willing to share data and material according to the relevant needs.

References

1. Zwane, T.M. (2003) 'Industrial Growth and Water Pollution: Implications and Challenges in Swaziland' [online] (accessed: 14 September, 2008). Available from: <http://users.ictp.it/~eee/workshops/smr1597/Zwane.doc>.
2. Nnorom, I.C and Osibanjo, O. (2006). Determination of Lead and Cadmium Contents of Dry Cell Batteries Available in Nigeria. J. Appl. Sci. Environ. Mgt., 10(3), 37- 41.
3. Egereonu, U.U, Ukiwe I.N, Edet J.A and Ogukwe C. E. (2012) Investigation of some pollution index of Oramiruikwa, Nworie and Otamiri Rivers, Imo state Nigeria. J. Chem. Soc, Nig. 37(1), 25-29.
4. Ezeronye, O.U. and Ubalua, A.O. (2005). Studies in the effect of abattoir and industrial effluents on the heavy metals and microbial quality of Aba River in Nigeria. Afr. J. Biotechnology. 4(3): 266-272.
5. Fakayode, S.O. (2005). Impact Assessment of Industrial Effluent on Water Quality of the receiving Alaro River in Ibadan, Nigeria. African Journal of Environmental Assessment. Vol.10.
6. Jaiswal, P.C. (2003). Soil, Plant and Water Analysis. Kalyani Pub. New Delhi.
7. Olanrewaju, A.O. (2002). Dangers of indiscriminate refuse dumps in metropolis countries. Environment opinions. 35: 567-571.

8. Onyido, A.E., et al., (2009). A survey of vectors of public health diseases in un-disposed refuse dumps in Akwa town, Anambra state, south eastern Nigeria. *Research Journal of Parasitology*, 4:22-27.
9. Cookey, P., Kokpan, B.A., Aguo, M.R., Wenes, W. and John, P.C. (2008). Assessment of Water Supply and Sanitation of some Coastal Communities of the Niger Delta. 33rd WEDC International Conference, Accra, Ghana.
10. Nwanebu, F.C (2003). Studies on physico-chemical indicators of pollution in Urashi and Iyiechi Rivers, Imo State, Nigeria. *Int. J. Environ. Health Human. Dev*, 4(2): 22-28.
11. APHA. (1995). *Standard Methods for the Examination of Water and Waste Water*. 19th Edition, APHA-AWWA-WPCF. Washington DC. Pp 2.8-4.45.
12. Prescott, I.M, Harley J.P, Klein D.A. (2002). *Microbiology*. 5th ed. Mc Graw-Hill Inc., NY 10020, 648-688.
13. Ademoroti, C.M.A. (1996), *Standard methods for water and effluent analysis*, Ibadan Poludex Press, 15–55.
14. Rocchini, R and L. Swain. (2001). ‘The British Colombia water quality index Civil and Environmental Research www.iiste.org ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online) Vol.7, No.4, 2015 53.
15. Osibanjo, O., Daso A.P. and Gbadebo A.M. (2011) The impact of industries on surface water quality of River Ona and River Alaro in Oluyole Industrial Estate, Ibadan, Nigeria *Afr. J. Biotechno.* 10(4): 696-702.
16. Oboh, I.P. and Edema, C.U. (2007). Levels of heavy metals in water and fishes from the river Niger, *J. Chem. Soc. Nig*, 32(2) 29-34.
17. Crowther, J., Kay, D., Wyer, M.D. (2001). Relationships between Microbial Water Quality and Environmental Conditions in Coastal Recreational Waters: the Fylde Coast, UK. *Water Res.* 35:4029 – 4038.
18. Pereira, E, J.A. Baptista-Neto, B.J. Smithand J.J. Mcallister. (2007). The contribution of heavy metal pollution derived from highway runoff to Guanabara Bay sediments--Rio de Janeiro/Brazil. *Annals Brazilian Acad. Sci*, 79: 739-750.
19. Desai, J. and Tank S.K. (2010). Deterioration of water quality due to immersion of Ganesh idols in the river Tapti at Surat, India, *J. Environ. Res. Develop*, 4(4), 999-1007.
20. WHO. (2006). *Guidelines for drinking water quality*, First addendum to the 3rdEd. 1: 491-493.
21. EPTA, 2001, the effect of heavy metals on the environment and on health. <http://www.eptanetwork.org/EPTA/projects.php>.
22. Keraita, B, Drechsel, P, Amoah, P. (2003). “Influence of Urban Wastewater on Stream Water Quality and Agriculture in and around Kumasi, Ghana”, *Environment and Urbanization*, 15: 2, 171-178.
23. World Health Organization. (2004). *World Health Organization guidelines for drinking water quality (3rd Edition)*. Geneva, Switzerland.