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Research Article

EFFECT OF INDUSTRIAL EFFLUENT DISCHARGES OF RABAK CEMENT FACTORY ON THE MICROBIAL LOADS AND WATER CHARACTERISTICS OF THE WHITE NILE-SUDAN

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Abstract

This study was conducted to evaluate the effect of waste effluents of Rabak Cement Factory on the physiochemical and microbiological properties of the White Nile waters. The study was conducted during the period from April 2017 to April 2018. Samples were taken at different points before and after the point of discharging factory waste (500 meters before discharging and 500 1000, 1500 and 2000 meters after emptying). Standard physiochemical and microbiological analysis methods were used. The results showed high salinity, especially nitrates (5.07 mg / litre), ammonia (0.59 mg / litre), phosphates (0.68 mg / litre), carbonate (6.13 mg / litre) and bicarbonates (265.44 mg / litre). Microbiological analyses showed that the total living number of bacteria was higher in December 2017, as it reached 3,5 x 10^5 colony-forming units / mm, and 3,8 x 10^5 colony-forming units / ml, respectively. In addition, large numbers of coliform bacteria and faecal stools, along with *salmonella* and coliform bacteria, were recorded at the discharge points in numbers that are difficult to reconcile with the internationally and locally permitted standards for drinking water. The presence of these bacteria (coliform bacteria, faecal stools, and *salmonella*) in factory wastes and emptying points does not guarantee acceptable levels of sterilization for this water.

Keywords: Industrial effluents, Physio-chemical parameters, Microbial loads, White Nile- Effect.

INTRODUCTION

It is difficult to imagine a world without water. Water is vital for drinking, agriculture, sanitation, industry and countless other purposes. Life on earth began in water; fresh water brings life to thirsty cities and parched crops, and provides the habitat for a multitude of living entities. However, water can also mean death and destruction. Floods are the worst of natural disasters, killing more people and damaging more property than earth-quakes, volcanic eruptions or similar hazards. Polluted water brings disease and death to those who drink it and kills birds, fish and other forms of life that need it to survive (WMO, 1997). Accordingly, routine examination and monitoring of water systems is a necessity, particularly microbiological examination of water is necessary first and foremost to disclose the presence of micro-organisms that might constitute a health hazard. Although Sudan is one of the largest countries in Africa and lies mostly in the arid region where water is scarce, the country is considered to be rich in water resources (Ginawi, 1994). Over 70% of the population and the majority of livestock live around the river Nile. The recent drought, coupled with civil war, have led to exodus migration to urban centers resulting in overuse of the available and limited urban facilities, including water and sanitation systems. The economy of the country is largely agro-pastoral and hence provision of water for both human population and livestock herds imposes the major constraint for all developmental activities (Mukhtar, 1998). The available water resources comprise the Nile system, rainwater and ground water. The main Nile and its tributaries provide perennial fresh water of good chemical composition. Rainfall, though erratic and short-lived, is an important water resource, especially along the Savannah Belt. Groundwater represents – under the arid conditions – the main water resource especially in rural areas, and in most cases does not respond to short and medium term drought periods. Groundwater in sedimentary rocks tapped from the Nubian sandstone is of excellent chemical and bacteriological quality (Mukhtar, 1998). Water is an important component of all living beings, being the vehicle for the conduction of unique and indispensable activities in the biosphere. The growth and diversity of aquatic microflora in river system is influenced by several biological and physico-chemical parameters of the river. Many rivers, including the river Nile (Sabae *et al*., 2010) have been reported to be seriously affected by effluent pollution. Water pollution can be defined as the change of physical, chemical and biological properties of water, restricting or preventing its use in the various applications. Water is polluted artificially by human activities or naturally due to salt water intrusion and others without human intervention. In the new reclaimed lands, agricultural and industrial activities may create different sources of pollution. Globally, industrial waste water represents the main source of water pollution (Niewolak, 2000; Ekhaise and Anyasi, 2005; Akaninwor *et al*., 2007, Alam *et al*., 2007 and Gunkel *et al*., 2007).The river Nile, which represents more than 90% of the Nile basin's water resources, is the traditional receptor of waste and drainage waters generated by different activities (El-Gohary, 1994 and Abu-Shady *et al*., 1996). Different industries, such as Kenana Sugar Company, Assalaya sugar factory discharge their wastewater into the White Nile. Industrial waste waters are considered among the major sources of environmental pollution, endangering public health through direct use as well as feeding fish that live in the polluted streams. The sugarcane and starch industries are among the major producers of polluting agro-industrial effluents affecting the river Nile(Abu-Shady *et al*., 1996; Ezzat *et al*., 2002; Sabae, 2004 and Abdel-Satar, 2005).

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One of the most important factors of water pollution is the microbial contamination; especially with pathogenic microorganisms. Enteric pathogens are typically responsible for waterborne sickness (Karaboze *et al*., 2003).Contamination of water is a serious environmental problem as it adversely affects the human health directly or indirectly. The catastrophic death of fish in the White Nile by Jebel Awlia in June 2010 is a witness to such effects. The use of indicator bacteria such as faecal coliforms (FC) and faecal streptococci (FS) for assessment of faecal pollution and possible water quality deterioration in fresh water sources is widely practiced (APHA, 1995). The name of the Nile originates from the Greek word "Nelios", meaning River Valley. The River Nile is the longest river in the world and it is a source of life to millions of people, flowing 6.825 km (4.238 miles) from south to north over 35 degrees of latitude through civilization of great antiquity, and the Nile basin embraces nearly 3.2 km^2 of equatorial and north east Africa. The Nile water is derived from rainfall generating the two rivers, namely the Blue Nile and the White Nile coming from two major areas: the Ethiopian Plateau and the mountainous hinterland of the Great Lakes in Uganda, respectively (plate.1.). The Blue Nile, which is known as Aabbay in Ethiopia, has its source at Lake Tana (3.100 km^2). The lake is located in north western Ethiopia lying nearly 1800 meters above sea level and 1500 kilometers upstream from Khartoum. The Blue Nile drops about 410 meters and picks up the flow of two seasonal tributaries, the Dinder and Rahad rivers (Collins1900 - 1988). During flooding, it also carries large quantities of silt from the highlands of Ethiopia (El-Khodari, 2003). The river Nile has an annual flow in normal years of 84 billion cubic meters at Aswan, in southern Egypt. Of this, 59% comes from the Blue Nile (NRD, 2006), and the other 41% from the White Nile and Atbara and other small tributaries. This means that the Blue Nile contributes more than half of all Nile water throughout the year. The Nile is of great importance for the population because it is the main source of drinking water for all those who live within these countries and it is a primary source of soil formation, which extends the hip and is transferred from the Ethiopian mountains during the flooding season, and benefited rights in agriculture. But factors like the rapidly growing population combined with the ecological consequences, and the increasing agricultural and industrial development, which demands more and more water, are problems facing the Nile water users (Waterbury, 1979).

Plate 1. River Nile

River Nile is the longest river in the world, shared by 11 countries that constitute the Nile Basin countries, namely Egypt, Sudan, South Sudan, Ethiopia, Uganda, Kenya, Tanzania, Rwanda, Burundi, the Democratic Republic of the Congo, and Eritrea. The river stretches a 6695 km length from its source (the Kagera Basin in Rwanda and Burundi) to the Nile Delta in Egypt that empties into the Mediterranean Sea. The Nile basin covers about 10% of the African continent and is relied upon by over 160 million people for their food, irrigation water, domestic water supply, hydroelectric power production, tourism, transportation, and fishing. Despite its significant importance, the river Nile is experiencing increasing deterioration in water quality. This is due increasing pollution loads arising from high population and economic growth in the region. The River has been exposed to nonpoint source pollution such as chemicals and sedimentations from agricultural practices and very highly toxic substances from mining activities. In addition, there is severe point source pollution from domestic and industrial discharge, especially in urban areas. The lack of adequate wastewater treatment facilities has seen extensive discharge of untreated effluent into the river from domestic, agricultural and industrial sources in riparian states.

Covering an area of about 39 701 km2, the White Nile State is located in central Sudan, bordering Khartoum State in the north, North Kordofan State in the west, South Kordofan State and the Upper Nile State in the southeast, and Al-Jazira and Sinnar States in the east. In the White Nile State region, the sugar industry is the main pollution source into the River Nile. Sugar cane processing factories are located in close proximity to the banks of the Blue Nile and White Nile where they discharge their effluent directly into the river. According to the Sudan post- conflict environmental assessment carried out by UNEP (2007) the wastewater contains an elevated BOD, which can reach 800−3000 ppm. A prior investigation carried out at Assalaya, one of the sugar cane processors in the region, had revealed that the factory's discharge into the river had BOD, COD, and TSS of 1200 mg/L, 2160 mg/L, and 2080 mg/L, respectively (Magid*et al.,* 1988). Furthermore, the runoff from irrigated sugar cane fields that contains high agrochemicals content such as insecticides, herbicides, and fertilizers also finds its way into the river. This all contaminates the water leaving the lives of people and their livestock that depend on the river's water at risk. The objective of the study is to investigate the effects of the various types of effluents entering the White Nile on the microbial load and physico-chemical characteristics of the water, both of which can adversely impact the life of the human using that water or its products. This will be achieved through monitoring the microbial load and physic-chemical attributes of the Nile water in areas directly subjected to these effluents.

MATERIALS AND METHODS

The study area

White Nile: White Nile state is characterized by its strategic location in central Sudan, it is bordered by Khartoum State in the north, North Kordofan State in the west, South Kordofan State and the Upper Nile State in the southeastern and Al-Jazira and Sinnar States in the east. The state area is 39,701 square kilometers and the climate of the state characterized by hot, humid rainy summers and warm dry in winter.

Rabak cement factory: Is located between latitude (13°10′8″ N) and longitude (32° 43′39″ E).Rabak is a city in southeastern Sudan and the capital of the Sudanese state of White Nile. It is one of the major cities of Sudan, an industrial city in which are located several factories, such as the Nile Cement Company factory, the Kenana sugar factory, and the Assalaya sugar factory. The city is located on the eastern bank of the White Nile, approximately 260 kilometers (160 mi) south of Khartoum and 340 kilometers (210 mi) west of the Ethiopian border. Rabak lies some 362 meters above sea level. It is linked to the north of Sudan via the Khartoum–Rabak road; and it is linked by road eastward to Sennar and westward to Al-Ubayyid. Rabak is one of major commercial cities in Sudan owing to its unique location in the country and its transportation links to the other major Sudanese states. In the city there is a cement processing company called the Nile Cement Company, which produced 50,200 tons in 2001 and 41,000 tons in 2002.

The sampling locations

Samples of Nile water were collected from different locations along the river Nile stream specifically from points where the river receives the polluting discharge and from points of increasing distance from discharge reception. Samples will also be taken from the wastewater effluent just before it mixes with the Nile water. Different industrial effluent discharges were collected from the following areas along the White Niles (Plate.2).

Collection of samples

A total of one hundred and forty samples of White Nile waters were collected from locations: Rabak cement factory (4 times during the period of April 2017 to April 2018).

Sampling strategy

Samples were collected at the following points:

- Point A: 500 meters before discharging
- Point B: The factory effluent
- Point C: The point of discharge into the river (Discharge point)
- Point D: 500 meters after discharging
- Point E: 1000 meters after discharging
- Point F: 1500 meters after discharging
- Point G: 2000 meters after discharging

Sterile screw-cap bottles (200 ml capacity), connected to and held by sterile threads, were dropped into the water at 20 cm to collect water samples from all sites. Then the samples were stored in ice containers and laboratory analysis began immediately after arrival. Time of collection was between eight O`clock (morning) to one O`clock in the afternoon. The samples were analyzed for the microbiological quality and physicochemical properties. During sample collection, water and air temperature, pH and electrical conductivity (EC) were measured in situ. Glass-stopped oxygen-sampling bottles (300 ml capacity), for dissolved oxygen (DO) and biochemical oxygen demand (BOD) determinations, were filled carefully with water samples; those of DO were fixed immediately by adding 2 ml $MnSO_4$ and 2 ml alkaline KI. In addition, one-liter plastic bottles were filled with water for undertaking the rest of the chemical analyses.

Glassware sterilization

Washed glassware were sterilized in a hot air at 160^{o}C for 3 hours (Harrigan, 1998). Other instruments such as loops and spatulae were sterilized by flame after being dipped into ethanol.

Plate 2. Map showing sampling sites

Physico-chemical parameters

The objective of sampling is to collect a portion of material small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material being sampled (APHA, 1992). Samples, however, have to be handled in such a way that no significant change in composition occurs before the tests are made. The water samples were collected and stored in 1 liter capacity clean plastic bottles. Before collection of samples, the bottles were properly washed. Prior to collecting the samples, the containers were rinsed by the water to be sampled.

Temperature

The water temperature at the different sampling sites was measured at the time of sampling with a mercury-filled Celsius (centigrade) thermometer (Bio-tech, India) by the methods described in the Standard Methods for the Examination of Water and Wastewater (A.P.H.A., 1965).

pH

Water pH was measured in the laboratory by the glass electrode method with an electrode – type pH 211 Microprocessor pH meter (HANNA Instruments, Romania).

Electric conductivity (EC)

The electric conductivity (in micromhos/cm, µs/cm) was measured directly at 25^{0}C using a HQ14d conductivity meter (Hach Instruments, U.S.A.).

Nitrate (NO_3^{-2})

The water nitrate content was determined using a DR/4000UV Spectrophotometer (HACH, USA) by the method described in the Hach Company Handbook by filling a sample cell with 10 mL of the water sample and the contents of one vial of the

NitraVar 5 Powder Pillow reagent was added, the light shield was closed and the result (in mg/L nitrate) was displayed.

Phosphate ($P_2O_5^{-2}$)

The phosphate content was measured using a DR/4000UV spectrophotometer (HACH, USA) by the method described in the Hach Company Handbook by filling a sample cell with 10 mL of the water sample and the contents of one vial of the PhosVer 3 Powder Pillow reagent was added, the light shield was closed and the result (in mg/L phosphate) was displayed.

Bicarbonate (HCO_3^-) and carbonate (CO_3^{-2})

The bicarbonate and carbonate were both determined according to the Standard Methods for the Examination of water and Wastewater (A.P.H.A, 1998). Fifty mL of sample were taken into a 250-mL conical flask together with 2-3 drops of methyl orange and phenolphthalein indicator, titrated against 0.1 N H_2SO_4 until the reactants obtained red color and colorless, for bicarbonate and carbonate, respectively. The contents were calculated by the equation:

$$HCO^{-3} \text{ or } CO_3^{-2} \text{ (mg/L)} = \frac{Mw \times N \times V \times 1000}{\text{Sample volume (mL)}}$$

Where:
Mw= Molecular weight of (HCO^{-3} or CO_3^{-2})
N= Normality of H_2SO_4
V= Volume of H_2SO_4 (mL)

Dissolved oxygen demand (D.O.D)

The dissolved oxygen demand was determined in the laboratory using a DR/4000UV Spectrophotometer (HACH, USA) by the method described in the Hach Company Handbook (Ultra High Range Method) by inserting the AccuVacAmpul Adapter into the sample cell and filling a zeroing vial (the blank) with 10 mL of water sample. The ampul was shaken for 30 seconds and placed into the cell holder. The light shield was closed and the result (in mg/L dissolved oxygen) was displayed.

Total dissolved solids (T.D.S.)

The T.D.S were measured directly at 25^0C using a HQ14d Conductivity Meter (Hach Instrument, U.S.A.).

Microbiological examination

Sterilization of glassware: All glassware was washed thoroughly and left to dry, followed by sterilization in a hot air oven (Human Gmbh, Germany) at 160°C for at least 3 hours (Harrigan and MacCance, 1976). Instruments such as loops and spatulas were flame-sterilized after being dipped into ethanol.

Total viable counts of bacteria (TVC)

Total viable count (TVC) was assayed using the pour plate technique as described by Harrigan (1998). One mL of each 10-fold dilution of the water samples was aseptically transferred, in duplicate, into sterile Petri-dishes. Ten mL of molten Plate Count Agar (Labmate, UK) (45-46°C) were poured into each dish. The dishes were then thoroughly mixed to facilitate distribution of the sample throughout the medium. The medium was allowed to solidify and the plates were incubated aerobically in an incubator (Human Gmbh, Germany) at 37°C for 48 hours. A colony counter (Labtech digital colony counter, India) and a hand-tally were used to count the viable bacterial colonies. The count was expressed as colony-forming units (CFU) per mL.

Most probable number (MPN) technique: The 3-tube most probable number test was used for the enumeration of total coliforms (TC), faecal coliforms (FC) and faecal streptococci (FS). MacConkey Broth (s.d. fine-chem. Ltd., India) was used for the presumptive test for coliform bacteria and results were confirmed by culturing positive tubes into Brilliant Green Bile Broth (Himedia, India) tubes. Both media were incubated at 35ºC for 48 hours. EC Broth (Merck, Germany) was used for the enumeration of faecal coliforms after incubation in a water-bath at 44.5º C for 24 hours. Further confirmation of faecal coliforms was done by isolation on EMB agar (Difco, USA) and carrying out of the indole test. Azide Dextrose Broth (Himedia, India) was used for the enumeration of faecal streptococci. Here the tubes were incubated at 35ºC and checked for turbidity after 48 hours. For the confirmation of faecal streptococci, esculinAzide Agar (Himedia, India) was used (WHO, 1996).

Statistical Analysis

The date were analyzed by two- was analysis of variance (ANOVA). Mean separations were performed and difference at P≤ 0.05 were considered as significant (Statix Version 8.0 software Inc. 1986).

RESULTS AND DISCUSSION

Physico-chemical analyses

Table 1. Water electrical conductivity (µs/cm)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	286.33^{f}	317.67^{f}	322.67^{f}	287.33^{e}
Effluent	479.67^{a}	498.67^{a}	508.67^{a}	523.33^{a}
Discharge point	443.33^{b}	486.67^{b}	465.67^{b}	517.67^{a}
+500	377.00^{c}	426.00^{c}	411.33^{c}	466.67^{b}
+1000	354.33^{d}	366.33^{d}	385.33^{d}	422.00^{c}
+1500	294.67^{e}	322.67^{e}	346.33^{e}	347.33^{d}
+2000	277.33^{g}	288.33^{g}	312.00^{g}	274.67^{f}
SE±	1.07	0.62	0.54	3.34
CV	2.29	1.32	1.15	7.16

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).
- 500 = 500 m before the point of discharge; +500, +1000, +1500, +2000 = distance (m) after point of discharge

Table (1), water electrical conductivity (WEC) varied significantly ($p \leq 0.05$) among sampling points. Factory effluent recorded the highest EC values, the peak being in April 2013. The second highest EC value was reported at the discharge point which could be attributed to the effect of dilution. This dilution effect increased with increase of distance from the point of discharge; whereby by about 2000 m, the effect was negligible, non-existent, or the value was even lower than at 500 m before discharge.

Table (2) shows the total dissolved solids in mg/L. Again the highest concentrations were observed in the factory discharged effluent, which suggests that the factory waste might be

responsible for increase in this parameter as in the previous parameter. However, TDS was consistently diluted by increase in the distance from the discharge point. After 1000 meters from the discharge point, the TDS values were equivalent to those determined 500 meters before the discharge point (April 2012).

Table 1.Water total dissolved solids (mg/L)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	160.47^{d}	162.44^{f}	153.57^{f}	158.50^{f}
Effluent	265.33^{a}	287.67^{a}	272.00^{a}	271.67^{a}
Discharge point	261.43^{b}	275.67^{b}	252.33^{b}	263.67^{b}
+500	241.37^{c}	247.00^{c}	237.67^{c}	251.67^{c}
+1000	159.53^{d}	213.40^{d}	211.40^{d}	222.33^{d}
+1500	153.33^{e}	175.53^{e}	182.13^{e}	163.37^{e}
+2000	151.30^{f}	159.13^{g}	151.83^{g}	152.03^{g}
SE±	0.81	1.00	0.51	0.59
CV	1.73	2.15	1.10	1.27

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).

Table 2. Water pH

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	8.37^{a}	8.47^{a}	8.23^{b}	8.37^{a}
Effluent	7.50^{c}	7.17^{d}	7.47^{c}	7.50^{c}
Discharge point	7.43^{c}	7.27^{d}	7.43^{c}	7.43^{c}
+500	7.83^{b}	7.67^{c}	7.87^{c}	7.77^{b}
+1000	7.77^{b}	8.23^{b}	7.73^{d}	7.67^{b}
+1500	8.43^{a}	8.23^{b}	8.13^{b}	8.43^{a}
+2000	8.47^{a}	8.53^{a}	8.47^{a}	8.33^{a}
SE±	0.05	0.06	0.06	0.05
CV	0.11	0.14	0.12	0.12

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5)

From Table (3) it might be concluded that the water of the White Nile is somewhat alkaline. The factory effluent tends to cause a drop in the pH of samples indicating the slightly acidic nature of the effluent. However, after 1500 meters of the discharge point, the samples pH values were maintained to the levels observed at 500 meters' distance before the factory waste drained into the river.

Table 3. Ammonia content (mg/mL)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	0.32^{e}	0.37^{d}	0.36^{d}	0.43^{d}
Effluent	0.46^{a}	0.47^{a}	0.47^{a}	0.46^{a}
Discharge point	0.46^{b}	0.46^{b}	0.46^{b}	0.45^{b}
+500	0.41^{c}	0.42^{c}	0.43^{c}	0.44^{c}
+1000	0.34^{d}	0.31^{e}	0.35^{e}	0.42^{e}
+1500	0.28^{f}	0.24^{f}	0.32^{f}	0.40^{f}
+2000	0.23^{g}	0.22^{g}	0.30^{g}	0.3763^{g}
SE±	0.73	0.12	0.43	0.47
CV	0.15	0.24	0.93	0.10

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).

Ammonia (NH_3) concentrations as expressed in Table (4) support the data shown in Table (3). The highest values were obtained in the effluent itself, followed by those of the discharge point. Ammonia concentrations consistently dropped, thereafter. After one kilometer of the discharge point, ammonia values dropped to values comparable to those at 500 meters before the discharge point.

Water nitrate content is shown in Table (5). The factory waste might be responsible, as in many investigated parameters, for the higher nitrate content at the discharge and discharge point. The river itself reported the third highest nitrate concentration. Water nitrate, however, decreased consistently and significantly after 500 meters from the discharge point to levels lower than that of 500 meters before waste disposal poi

Table 4.Water nitrate content (mg/L)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	1.07^{b}	0.87^{d}	0.77^{c}	1.17^{b}
Effluent	1.47^{a}	1.63^{a}	1.73^{a}	1.47^{a}
Discharge point	1.43^{a}	1.43^{b}	1.63^{a}	1.57^{a}
+500	1.00^{bc}	1.17^{c}	1.23^{b}	1.30^{b}
+1000	0.83^{cd}	0.67^{e}	0.90^{c}	0.97^{c}
+1500	0.70^{de}	0.53^{f}	0.83^{c}	0.83^{cd}
+2000	0.60^{e}	0.30^{g}	0.50^{d}	0.73^{d}
SE±	0.09	0.04	0.09	0.07
CV	0.20	0.09	0.18	0.15

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).

Table 5.Water bicarbonate content (mg/L)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	129.32^{e}	133.17^{e}	146.93^{f}	133.78^{f}
Effluent	239.28^{a}	246.99^{a}	265.44^{a}	241.19^{a}
Discharge point	234.22^{b}	239.80^{b}	250.84^{b}	239.44^{b}
+500	136.59^{c}	173.55^{c}	213.11^{c}	172.29^{c}
+1000	131.77^{d}	143.06^{d}	178.56^{d}	152.13^{d}
+1500	126.87^{f}	123.82^{f}	154.88^{e}	144.33^{e}
+2000	126.06^{g}	113.89^{g}	144.53^{g}	132.14^{g}
SE±	0.11	0.31	1.03	0.23
CV	0.23	0.67	2.22	0.48

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).

Factory waste effluent appeared to be the source of the high bicarbonate content presented in Table (6). Bicarbonate content decreased from the discharge point consistently.

Table 6.Water phosphorus oxide content (mg/L)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	0.38^{c}	0.42^{c}	0.44^{c}	0.43^{b}
Effluent	0.40^{a}	0.46^{a}	0.46^{a}	0.45^{a}
Discharge point	0.39^{b}	0.45^{b}	0.45^{b}	0.42^{c}
+500	0.37^{d}	0.42^{c}	0.43^{d}	0.42^{d}
+1000	0.36^{e}	0.40^{d}	0.40^{e}	0.39^{e}
+1500	0.32^{f}	0.38^{e}	0.38^{f}	0.37^{f}
+2000	0.26^{g}	0.36^{f}	0.36^{g}	0.36^{g}
SE±	0.66	0.97	0.39	0.97
CV	0.14	0.20	0.85	0.20

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).

As seen in Table (7), the pattern of non- metal oxides, as represented by the phosphorus oxide, followed the pattern shown by the other measured parameters. However, the reported values differed slightly, but differences were significant.

Table 7.Water carbonate content (mg/L)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	3.47^{e}	3.83^{d}	3.70^{e}	4.90^{b}
Effluent	5.93^{a}	5.77^{a}	5.27^{a}	6.13^{a}
Discharge point	5.33^{b}	5.77^{a}	5.00^{b}	6.03^{a}
+500	4.83^{c}	5.13^{b}	4.47^{c}	4.67^{c}
+1000	4.20^{d}	4.70^{c}	4.10^{d}	4.13^{d}
+1500	3.57^{e}	3.97^{d}	3.33^{f}	3.53^{e}
+2000	3.10^{f}	3.20^{e}	3.10^{g}	2.73^{f}
SE±	0.05	0.07	0.06	0.06
CV	0.11	0.14	0.13	0.13

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).

The same previous pattern of increase in non-metal oxides in the factory effluent is also evident in Table (8) expressed as carbonate. It is conceivable that the second highest carbonate concentration is present at the discharge point, then the carbonate value steadily and significantly decreased whereby at 1500 meters from the discharge point in April 2012 it reaching the levels obtained at 500 meters before the effluent point.

Table 8.Water phosphate content (mg/L)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	0.55^{c}	0.55^{b}	0.54^{d}	0.56^{c}
Effluent	0.58^{a}	0.68^{a}	0.59^{a}	0.57^{a}
Discharge point	0.57^{b}	0.58^{ab}	0.57^{b}	0.57^{b}
+500	0.56^{c}	0.56^{b}	0.56^{c}	0.52^{d}
+1000	0.47^{d}	0.55^{b}	0.52^{e}	0.49^{e}
+1500	0.43^{e}	0.42^{c}	0.42^{f}	0.44^{f}
+2000	0.39^{f}	0.39^{c}	0.39^{g}	0.39^{g}
SE±	0.12	0.05	0.92	0.71
CV	0.27	0.01	0.19	0.15

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5)

Water phosphate content is shown in Table (9). The factory waste might be responsible, as in many investigated parameters, for the higher phosphate content at the discharge point. However, the phosphate content decreased consistently and significantly after 500 meters from the discharge point to levels lower than that at 500 meters before waste disposal point.

Table 9. Biological Oxygen Demand

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	3.23^{e}	2.67^{g}	2.87^{e}	2.47^{f}
Effluent	5.33^{b}	4.37^{b}	4.27^{a}	4.87^{c}
Discharge point	5.97^{a}	4.77^{a}	4.33^{a}	5.67^{a}
+500	5.27^{b}	4.03^{c}	4.00^{b}	5.13^{b}
+1000	4.37^{c}	3.57^{d}	3.63^{c}	4.77^{c}
+1500	3.67^{d}	3.13^{e}	3.13^{d}	4.23^{d}
+2000	2.93^{f}	2.83^{f}	2.40^{f}	3.63^{e}
SE±	0.08	0.06	0.08	0.06
CV	0.18	0.12	0.17	0.12

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).

Table (10) displays the values of Biological Oxygen Demand. The highest value was recorded at the discharge point of the factory waste to a value even higher than that of the effluent. The situation suggests that the increase in the (BOD) at the discharge point might be related to a mixing effect. That effect persisted even after 2000 meters from the discharge point irrespective of the fact that it decreased gradually. However, the mixing –related effect on BOD was sustained throughout the seasonal sampling intervals.

Table 10. Air temperature (^{o}C)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	37.00^{bc}	33.33^{a}	34.33^{a}	37.33^{ab}
Effluent	37.33^{ab}	33.00^{ab}	34.00^{ab}	37.67^{a}
Discharge point	37.67^{a}	33.33^{a}	34.33^{a}	37.00^{ab}
+500	36.67^{c}	32.67^{ab}	33.33^{bc}	36.67^{bc}
+1000	36.00^{d}	32.33^{b}	33.00^{cd}	36.00^{cd}
+1500	36.00^{d}	32.67^{ab}	32.33^{d}	35.67^{d}
+2000	35.00^{e}	32.33^{b}	33.00^{cd}	35.33^{d}
SE±	0.31	0.44	0.36	0.40
CV	0.66	0.94	0.76	0.86

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).

As in Table (10), the mixing effect is also evident in table (11) where the air temperature was highest at the discharge point. The air temperature decreased afterwards to values even lower than those recorded 500 meters before the discharge point of the factory waste. The air temperature was generally maintained throughout the seasonal sampling intervals. In Table (12) the water temperature was highest on the factory effluent and at the discharge point. The water temperature decreased afterwards to levels even lower than those recorded 2000 meters after the discharge point of the factory waste. The water temperature was generally maintained throughout the seasonal sampling intervals.

Table 11.Water temperature (0C)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	34.67^{ab}	33.67^{cd}	32.00^{b}	34.33^{ab}
Effluent	35.00^{a}	35.00^{a}	34.00^{a}	35.00^{a}
Discharge point	34.67^{ab}	34.33^{b}	33.00^{ab}	34.00^{bc}
+500	34.00^{bc}	34.00^{bc}	33.00^{ab}	34.00^{bc}
+1000	33.67^{cd}	33.33^{de}	32.67^{b}	33.33^{cd}
+1500	33.00^{de}	33.00^{e}	33.00^{ab}	32.67^{de}
+2000	32.33^{e}	33.00^{e}	32.67^{b}	32.33^{e}
SE±	0.36	0.31	0.50	0.36
CV	0.76	0.66	1.08	0.76

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).

Microbiological Analysis

Total viable bacterial count (CFU/mL)

Table 12. Total viable bacterial count (CFU/mL)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	18.60^{d}	17.27^{e}	17.83^{e}	16.77^{e}
Effluent	32.23^{a}	33.67^{a}	34.57^{a}	31.73^{a}
Discharge point	29.20^{b}	26.87^{b}	26.90^{b}	28.67^{b}
+500	23.37^{c}	24.13^{c}	22.53^{c}	24.63^{c}
+1000	17.27^{e}	19.40^{d}	18.53^{d}	21.33^{d}
+1500	12.40^{f}	13.43^{f}	12.47^{f}	16.13^{e}
+2000	9.20^{g}	9.833^{g}	8.80^{g}	11.17^{f}
SE±	0.39	0.37	0.32	0.48
CV	0.83	0.78	0.69	1.03

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).

Total viable bacterial count as presented in table (13) was maximum at the factory effluent. The second maximum was recorded at the discharge point. Total viable bacterial count then decreased consistently and after 1000 meters it re-treated values even lower than at 500 meters before the factory discharge location. The effect was maintained throughout the seasonal sampling intervals.

The most probable number (MPN) of total coliforms (CFU/mL)

Table 13. The most probable number (MPN) of total coliforms (CFU/mL)

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	70.00^{cd}	80.00^{bc}	26.00^{c}	17.00^{c}
Effluent	136.67^{ab}	226.67^{a}	195.33^{a}	205.67^{ab}
Discharge point	150.00^{a}	246.67^{a}	240.00^{a}	286.67^{a}
+500	100.00^{bc}	166.67^{ab}	186.67^{ab}	206.67^{ab}
+1000	60.00^{cd}	106.67^{bc}	150.00^{abc}	130.00^{bc}
+1500	39.33^{d}	63.33^{c}	80.00^{bc}	59.33^{c}
+2000	33.33^{d}	38.67^{c}	39.33^{c}	22.67^{c}
SE±	0.05	0.05	0.05	0.05
CV	2.16	2.16	2.16	2.16

Means within each column followed by the same letters are not significantly different according to DMRT (p≥ 0.5).

Table (14) shows the most probable number (MPN) of total coliforms (CFU/mL). The highest readings were reported at the discharge point. The second highest reading was observed with the factory effluent, and it suggests a dilution effect of the river water to minimize a growth inhibiting factor in the effluent fraction. River effluent, perse, did not contribute to the elevated reading at the discharge point. However, the dilution effect was restricted to the discharge point only as the (MPN) fell drastically and steadily afterwards. The observation was maintained throughout the sampling intervals with highly significant value at December 2012 after 1000 meters from the discharge point. Fecal streptococci were present in the river water 500 meters before and after the discharge point and at 1000 meters after the discharge point. However, fecal streptococci fell down consistently afterwards (Table 15).

Table 15. Fecal Streptococci

Distance (m)	April 2017	August 2017	December 2017	April 2018
-500	10.33^{ab}	4.67^{c}	5.00^{de}	7.67^{c}
Effluent	13.33^{a}	14.33^{a}	12.00^{ab}	13.33^{a}
Discharge point	12.67^{a}	10.33^{ab}	13.33^{a}	10.33^{b}
+500	11.33^{ab}	10.33^{ab}	9.00^{bc}	8.33^{bc}
+1000	7.67^{bc}	10.00^{b}	7.67^{cd}	9.00^{bc}
+1500	6.00^{c}	7.00^{bc}	4.00^{e}	7.67^{c}
+2000	4.67^{c}	3.33^{c}	3.33^{e}	4.00^{d}
SE±	1.72	1.87	1.54	1.14
CV	3.69	4.01	3.31	2.45

Means within each column followed by the same letters are not significantly different according to DMRT ($p \geq 0.5$).

The Total Viable Count (TVC) of bacteria in the effluent discharge of Rabak cement factory ranged between 34.667 and 8.80 Colony Forming Units (CFU)/mL in December 2012.It seems that the Nile waters in Sudan are similar in microbial load to many other rivers of the world and greater than others, for example, in South Africa, Obi *et al.* (2002) found the plate count of the Levubu and Mudaswali rivers to range from 1.8 $x10^2$ to 1.3 $x10^6 cfumL^{-1}$. In Nigeria, Akaninwor *et al.* (2007) found the viable count in Calabar River to range between 4.5 $x10^3$ and 2.6 **x** $10^4 cfumL^{-1}$. In Brazil, Di Bari *et al.* (2007) found that most of bacterial counts were higher than 1.0 $x10^3 cfumL^{-1}$ in drinking water sources. The present results indicate that the viable counts agree with the findings obtained by Mahgoub and Dirar (1986) who found that the count of Blue Nile ranged from 7.5 $x10^2$ to 3.6 $x10^5 cfuml^{-1}$, while that of the White Nile ranged from 7.3 $x10^2$ to 2.4 $x10^3 cfumL^{-1}$, and the Main Nile total viable count ranged from 1.2 $x10^3$ to 3.8 $x10^4 cfumL^{-1}$. The increase of microbial load of these rivers shown by our data could be attributed to urbanization, industrial activities and agricultural practices which increased in recent years. This situation increased the waste discharged into water bodies. Moreover, the wastes of buildings take their way into the Nile waters during the flood season. It has been observed that most factories located in Khartoum discharge their waste directly into Nile rivers without any treatment, (Al-Sahafa newspaper 31 Marsh 2011; Alwannewspaper 22 March 2011; Al-Tayarnewspaper 2011). Payment and Riley (2002) and Okafor *et al*. (2003) reported that the major sources of contamination of surface water are urban and farm runoffs, discharges from sewage treatment facilities, failing septic systems, wildlife, farm animals and direct faecal contamination by human and animals. It could be said that if the levels of microbial contamination continue to rise, the Nile water quality would affect drinking water and other domestic purposes and may pose a potential health hazard. Therefore, a routine investigation is highly recommended to maintain a safe and rational acceptable level of the microbial pollution in the Nile and its tributaries in the future. The Most Probable Number (MPN) technique was used to estimate numbers of coliforms in the sampling points. The highest value of total coliforms by MPN was reported at the discharge point of Rabak cement factory effluent. According to quality guidelines for drinking water (WHO, 1997), the maximum limit for no risk of faecal coliforms is 0 $cfu100mL^{-1}$and 10/100mL for total coliform count. Contamination of river water and watersheds poses a serious problem throughout the globe. Studies carried out between 1994 and 2008 on selected rivers of Cameroon (Djuikom *et al*., 2006), Canada (Cameron 1996), China (Wang *et al*., 2008; Zheng *et al*., 2008,) Germany (Kistemann*et al*., 2002), Ghana (Yidana *et al*., 2008), Korea (Chang 2008), Nepal (Kannel *et al*. 2007), Nigeria (Kakulu and Osibanjo 1992;Ayotamuno 1994; Ajibade 2004), Adamiec and Helios-Rybicka 2002, Turkey (Parlak *et al*., 2006), and USA (Pennington *et al*. 2001) suggest that virtually one or more indicators of pollutions were higher than the permissible limits (WHO 2006). In India, the physicochemical parameters of the rivers Gola (Chandra *et al*., 2006), (Sundaray *et al.,* 2006), and Narmada (Sharma *et al.,* 2008) at selected sites exhibited considerable amount of contamination in terms of metals, organic pollutants, and coliform counts. However, according to the European Economic community (E.E.C) and WHO standard and guidelines faecal coliform MPN limits for surface water used as raw water to be treated for drinking is 200/100 mL and is less than 1000/100 mL for irrigation water for food crops consumed raw (Tebbut, 1990; WHO, 1996). In this work we found that during most of the month's faecal coliform bacteria count was less than 200/100.

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