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Full Length Research Paper

The effects of Niger State water treatment plant effluent on its receiving river (Kaduna)

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The effect of water treatment plant effluent on its receiving river (Kaduna) was examined. Samples were collected from the effluents discharge from Chanchaga water treatment plant into upstream and down stream of the receiving river monthly for six month. Samples were analyzed in the laboratory for microbial counts and identification, as well as physico-chemical properties. Laboratory analysis confirmed that the sludge recorded the highest number of pathogenic organisms like *Escherichia coli, Streptococcus faecalis, Aeromonas hydrophila*, *Shigella sonnei*, *Chromobacterium violaceum, Salmonella typhi*, *Aspergillus fumigatus*, *Aspergillus flavus* and *Aspergillus niger.* The result depicts seasonal changes in which higher numbers of microorganisms were recorded during the raining season. The values of total alkalinity, chloride, dissolve oxygen, sulphate, biochemical oxygen demand, organic matter and turbidity of sludges were all higher than the Federal Environmental Protection Agency (FEPA) limits for effluent discharge into surface water. The investigation revealed that the water treatment plant effluent may have adverse effects on its immediate environment.

Key words: Effluent, physicochemical, pathogenic microorganisms.

INTRODUCTION

Water related issues such as water treatment and distribution have become extremely important all over the world due to population growth, growing urbanization, health and environmental pollutions. Water supply are purified or treated to get rid of harmful substances or reduce them to the minimum permissible limit to make them safe and fit for human consumption or suitable for the intended general domestic uses. Wastes resulting from water treatment operations (sludge) are usually discharged into surface waters. This method of disposal often causes the build up of a sludge deposits in streams. The effects of sludge effluent has a characteristics such as dissolve oxygen (DO), nitrates and suspended solids on the environment have been established for sewage plant effluents. However, little work has been done on determining the levels of these waste parameters in water treatment plant effluents (Abdulazeez, 2003).

The production of portable water from surface or ground supplies usually results in a variety of waste streams, which may not be suitable for discharge to the environment (Terence, 1991). The coagulant sludge enmeshes particles and microbes along with some dissolve organic carbon (WHO, 1996). The flocks contain sufficient numbers of pathogens (Gale et al., 1997) and these organisms that are entrapped within the particles are shielded from the action of chemicals (WHO, 1996). The most important pathogenic bacteria are *Salmonella* sp*, Shigella* sp, *Vibrio cholerae, Yersinia enterocolitica, Yersinia pseudotuberculosis, Leptospira* sp*, Franscisella tularensis, Dyspepsia coli,* enterotoxin producing *Escherichia coli* and *Pseudomonas* (Stevik et al*.,* 2004).

The sludge effluent are characteristics of substances in the raw water (Joseph and Dee, 1992) these substances include; microorganisms such as bacteria algae, fungi, and protozoa (Annon, 1997); other substances in the sludge are chemicals added in water treatment. They contain suspended and settle solids, including organic and inorganic chemicals as well as trace metals, coagulant (usually aluminum hydroxide), polymers, clay, lime powdered activated carbon and other materials (Joseph and Dee, 1992).

Sludge's emanating from the drinking water purification

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Table 1. Total anaerobic heterotrophic bacterial colony counts.

Month	Bacteria counts (cfu/ml)			
	Sludge (N_2)	Upstream (N_1)	Downstream (N_3)	Row mean
March	3.0 x 10^2	2.5 x 10^2	2.6 x 10^2	270[a]
April	3.7 x 10^2	3.8 x 10^2	3.4 x 10^2	363.33[a]
May	6.0 x 10^3	1.5 x 10^3	2.2 x 10^3	3233.33[b]
June	1.5 x 10^3	2.0 x 10^3	2.0 x 10^2	1233.33[ab]
July	3.0 x 10^2	1.0 x 10^2	1.2 x 10^2	173.33[a]
August	6.0 x 10^3	3.0 x 10^3	3.5 x 10^3	4166.667[c]
Column mean	2411.667[a]	1205[a]	103.333[a]	

Mean data carrying different superscript differ significantly from each other (P<0.05).

process is made up of coagulated suspended matter removed from untreated water prior to its disinfection. The removal of particulate matter is one of the most important goals of water treatment. These impurities may be mineral in nature, organic or humus particles or microorganisms. The wastes are simply characteristics of substances in the raw water and chemicals added in water treatment (Salvato and Dee, 1992), although most of the sludge volume consists of precipitates of the added chemicals rather than suspended solids (Turbidity removed) Annon, 1997).

The aims of this study include examination of the physicochemical characteristics of the water treatment plant effluent, examination of the effect of water treatment plant effluent on receiving river, isolation and characterization microbial population of the water treatment plant effluents, and assessment of the level of pollution done to the environment.

MATERIALS AND METHODS

Collection and analysis of sludge and water

The samples were collected from three designated points; upstream, sludge from point of discharge, and downstream, close to the point of discharge into the river. The samples were collected monthly for the period of March to August, 2006. The samples for the microbiological analysis were collected aseptically into sterile 300 ml glass bottles, while the sample for physio-chemical analysis were collected in a clean 3 litre plastic containers. Once collected, the samples were analysed within 6 h.

Characterization of microorganisms

Bacteria were isolated and characterized using cultural identification, morphological identification using gram staininig reaction and other biochemical tests which include catalase, methyl red, voges proskauer (MR-VP), nitrate reduction test, starch hydrolysis, gelatin liquefaction test, coagulase, indole, motility, oxidase, urease, triple sugar iron agar (TSI) and sugar fermentation as described by Ogbulie et al. (1998) and Cheesbrough (2003). While fungi were isolated using the growth rate, colonial morphological features and microscopic morphological features. The colour of aerial hyphae and substrate hyphae was observed and staining procedure was as described by Ellen and Sydney (1990).

Physico-chemical analysis

The physico-chemical analysis carried out include the pH, moisture content, temperature, chloride Ion, dissolved oxygen, organic matter and total suspended solids as described by Ademoroti (1996).

RESULTS AND DISCUSSION

The heterotrophic plate counts, total coliform counts and fungi counts of the treatment plant sampling point (Tables 1, 2, 3 and 4) shows that the raining months recorded the highest counts in the various sampling points and these could be due to the fact that heavy rains might have transported organisms into water bodies. Faecal contaminants from human excreta may also find their way to the water via this route. There was a significant difference (P <0.05) in the time of sampling, while no difference was observed between the sampling location. This result agrees with Solo et al. (2000) who demonstrated that soil and run-off after rains may have influence on the bacterial counts. This is because as the rain falls, soil macrobiota and micro organisms adhering to vegetation, municipal sewage, garbages, domestic and industrial waste are washed into these water bodies thereby polluting them. Rheinheimer (1991) reported that fungi usually colonized living and dead water plants, wood, sediments and stones. Fungi are heterotrophic organisms and therefore depend on the presence of organic materials. FEPA (1991) reported that heavy erosion significantly increases the presence of these substances in rivers. The statistical analysis of the samples from different point of collection reveals a significant difference (p< 0.05) of the fungi count at the month of sampling.

The bacterial identification tests showed an abundance of Gram-positive genera, particularly the genus *Bacillus* (Table 6) in all the samples. This agrees with the findings of Hassan and Banat (1995) who remarked that the abundance of *Bacillus* spp. is a reflection of the predominance of spore formers in the sands and water of these areas.

The numbers of isolates were higher in the sludge samples followed by that of the downstream, with the

Table 2. Total coliform bacterial colony counts.

Month	Bacteria counts (cfu/ml)			
	Sludge	Upstream	Downstream	Row mean
March	2.0×10^3	2.0×10^0	6.0×10^2	867.3[a]
April	1.1×10^3	5.0×10^1	1.0×10^0	383.7[a]
May	4.0×10^3	7.0×10^1	2.2×10^1	1364[ab]
June	1.0×10^4	2.0×10^3	6.0×10^2	4200[ab]
July	6.9×10^3	3.1×10^3	1.2×10^4	7333.3[b]
August	2.8×10^4	2.6×10^4	2.8×10^4	27333.3[c]
Column mean	8666.67[a]	5203.67[a]	6870.50[a]	

Mean data carrying different superscripts differ significantly from each other (P<0.05).

Table 3. Total aerobic heterotrophic bacteria colony counts.

Month	Bacteria counts (cfu/ml)			
	Sludge (N_2)	Upstream (N_1)	Downstream (N_3)	Row mean
March	3.6×10^3	2.0×10^3	2.5×10^3	2700[a]
April	4.0×10^3	2.4×10^3	2.4×10^3	2933.33[a]
May	1.8×10^4	4.0×10^3	7.2×10^3	9733.33[a]
June	3.0×10^4	1.5×10^4	1.8×10^4	21000.00[b]
July	2.6×10^4	1.2×10^4	1.4×10^4	17333.33[b]
August	3.9×10^4	2.1×10^4	2.5×10^4	28333.33[c]
Column mean	20100[a]	9400[a]	11516.666[a]	

Mean data carrying different superscripts differ significantly from each other (P<0.05).

Table 4. Total fungal colony counts.

Month	Fungi counts (cfu/ml)			
	Sludge (N_2)	Upstream (N_1)	Downstream (N_3)	Row mean
March	3.0×10^0	1.0×10^0	1.2×10^0	1.7333[a]
April	4.2×10^1	0	2.0×10^0	14.6667[ab]
May	7.5×10^1	6.0×10^1	7.8×10^1	71[b]
June	1.2×10^2	3.0×10^1	2.0×10^1	56.6667[ab]
July	9.1×10^1	8.0×10^1	1.1×10^1	60.6667[ab]
August	9.0×10^1	4.0×10^1	5.2×10^1	60.6667[ab]
Column mean	70.1667[a]	35.1667[a]	27.3667[a]	

Mean data carrying different superscripts differ significantly from each other (P< 0.05).

upstream having the least number of isolates. The sludge is rich in pathogens and this can lead to potential health hazard on re-suspension downstream (Gale et al., 1997; Moore et al., 2003). Pathogenic organisms like *E. coli*, *Streptococcus faecalis*, *Aeromonas hydrophila*, *Shigella sonnei*, *Salmonella typhi* and *Chromobacterium violaceum* were isolated from the samples. These bacteria have been reported as causative agents of various diseases (Dennis et al*.,* 2005). Such diseases include acute enteritis in infants and adult cause by *E. coli.* (Muoghalu and Omocho, 2000). *S. typhi* causes typhoid fever (Timothy, 1999), and *Shigella* spp. cause diarrhea world Wide (Samonis et al*.,* 1994). The bacterium *C. violaceum* was isolated from sludge of the treatment plant. On a worldwide scale, the bacterium is considered to be rarely occurring but is thought to be commonly found in tropical and subtropical waters and soil. Denis et al. (2005) isolated *C. violaceum* from Uganda springs water. Midani and Rathore (1998) reported that this bacterium is of public health concern given its high virulence with a reported mortality rate as high as 65 – 80%. *C. violaceum* infection symptoms mainly include sepsis and abscesses in multiple organs such as the liver, skin, lungs, lymph nodes and the brain (Perera et

Table 5. The frequency of fungi isolates from water treatment plant sludge and that of the receiving river/stream.

Isolate	Sludge (N_2)		Upstream (N_1)		Downstream (N_3)	
	Total No. of Isolates	Percentage (%)	Total No. of Isolates	Percentage (%)	Total No. of Isolates	Percentage (%)
Aspergillus niger	6	26.09	5	41.67	6	31.58
Rhizopus nigricans	6	26.09	5	41.67	5	26.32
Asperrgillus flavus	5	21.73	2	16.67	6	31.58
Aspergillus versicolor	4	17.39	-	-	1	5.26
Unidentified yeast	2	8.70	-	-	1	5.26

Table 6. The frequency of bacteria isolates from water treatment plant sludge and that of the receiving River Kaduna.

Isolate	Sludge (N_2)		Upstream (N_1)		Downstream (N_3)	
	Total No. of Isolates	Percentage (%)	Total No. of Isolates	Percentage (%)	Total No. of Isolates	Percentage (%)
Pseudomonas aeroginosa	4	13.33	2	10	2	9.09
Bacillus sp	6	20	4	20	5	22.73
Escherichia coli	5	16.67	3	15	4	18.18
Enterobacter aerogenes	4	13.33	3	15	3	13.64
Staphylococcus epidermides	-	-	-	-	1	4.55
Streptococcus faecalis	2	6.67	1	5	3	13.64
Aeromonas hydrophilla	1	3.33	-	-	-	-
Bacillus cereus	-	-	2	10	1	4.55
Shigella sonnei	2	6.67	1	5	-	-
Salmonella typhi	3	10	-	-	2	9.09
Proteus vulgaris	-	-	1	5	1	4.55
Micrococcus roseus	1	3.33	2	10	-	-
Klebsiella aerogenes	1	3.33	1	5	-	-
Chromobacterium violaceum	1	3.33	-	-	-	-

al*.,* 2003). Fatal animal cases have also been reported (Dyer et al*.,* 2000).

The other species of bacteria isolates: *Pseudomonas* spp*, Aeromonas* spp. and *Staphylococcus* spp.*,* are non faecal indicators of water quality. Kuch et al*.* (1995) revealed that there is a significant relationships between *Aeromonas* levels and gastrointestinal illness.

The fungi that were more frequently isolated from these studies were *Rhizopus nigricans* and *A. niger*. Except for *A fumigatus, A. flavus* and *A. niger*, the fungi isolated from water usually are not considered to be medically important (USEPA, 1989). Fungal infections may be significant for individuals with compromised immune systems. Most of the fungi are common soil saprophyte (Table 5).

The reduce water volume during the dry season exacerbates algae growth and eutrophication (FEPA, 1991). This could have been the reason behind the greenish appearance of the downstream of River Kaduna. Pollution during dry season causes more severe problems because with less water the absorptive capacity for pollutants and threshold levels of water bodies are much lower (Oluwande et al*.,* 1983).

WHO (1996) pointed out that natural organic matter in water has been associated with several undesirable properties like impacting colour, taste and odour. This may be the reason behind the odour perceived in the industrial effluent. Water treatment plant sludges are rich in organic matter (Annon, 1997).

The pH of the sludge falls within the FEPA limits of no risk. The pH value of the effluent contributed to the lowering of the pH of the downstream of the river and stream. The temperature ranged between 27 to 31°C which is below FEPA limit. Thus, the effluent will not constitute a thermal pollution hazard. The total suspended solids (TSS) of the effluent was high. Muoghalu and Omocho (2000) reported that high TSS values have tendency to absorb heat from the sun and transfer this heat to stream thereby raising the temperature. These results agree with that of Nwaedozie (2000) in which all the values of TSS were all above the FEPA limit of effluent discharge. High TSS can also cause clogging problem in the operation of a drip irrigation system (Oyebode and Abubakar, 2001) as the river is used for irrigation downstream. Fajemisin (1991) indicated that TSS increases the turbidity of water; it disperses light

Table 7. The mean values of the physico-chemical properties of water treatment plant sludge and that of the receiving River Kaduna.

Parameter	Sludge (N_2)	Upstream (N_1)	DowNDtream (N_3)	FEPA limit
pH	7.4	7.8	7.4	6-9
Temperature (^oC)	30.83	30.50	30.33	<40
Suspended solids (mg/l)	70	18.83	27	30
Total hardness (mg/l)	146.67	42.33	50.67	ND
Total alkalinity (mg/l)	160	64.67	79.33	ND
Iron (mg/l)	3.30	0.120	7.26	20
Manganese (mg/l)	2.5	0.23	0.45	5
Nitrate (mg/l)	2.88	0.46	1.12	20
Sulphate (mg/l)	417.83	15	162.50	500
Phosphate (mg/l)	1.13	0.58	0.73	5
Chloride (mg/l)	668.82	25.56	63.90	600
Dissolved oxygen (mg/l)	3.87	7.01	4.67	Not < 2
Biochemical oxygen demand (mg/l)	105.37	11.12	40.45	30
Organic matter (mg/l)	4.78	0.38	1.4	ND
Turbidity FAU	2117.83	12.82	18	ND

FEPA = Federal Environmental Protection Agency (1991); NS = Not determined.

hence limits its penetration into a body of water which in turn affects the feeding habits of fish. Finally, Ongley et al. (1988) observed that TSS is an important vector for the transport of contaminants in river systems.

Hardness causes water not to foam with soap (Annon, 1997). Although the value of the effluent discharge by the water treatment plant falls within water that is moderately hard (101 – 200) (Annon, 1997) but downstream it has little effect as the value falls within that soft water range (0 – 55). The values for iron, manganese and nitrate all falls within the FEPA limit of effluent discharge to surface water.

The relatively higher sulphate levels found in the effluents (Table 7) as compared to the upstream samples may be due to coagulant (aluminum sulphate) that is used in water treatment. F_2 values were all above the FEPA limit of effluent discharge to surface water; this is because in Chanchaga water treatment plant this coagulant is occasionally used. Odoemelan (1999) reported the presence of high sulphate from discharges of four industries located along Aba River. The high sulphate concentration can cause intestinal irritation. The phosphate level falls within the normal FEPA limit of effluent discharge. The chloride ion exceeded the FEPA limit of discharge to surface waters for Chanchaga water treatment plant sample from March to June. Excess chloride in water, according to Anon (1997B), can impact bad taste to water.

The dissolve oxygen (DO) of the two industrial effluents was very low. Downstream, the DO value of the river was affected as the values falls below 5 mg/l, which is not satisfactory for aquatic life (USEPA, 1989A). Thus the DO of the downstream water was not within the acceptable limits. According to UNEP, (1991), low DO arise as a result of the breaking down in water of organic matter by aerobic microbes. The oxygen required for this process is taken from the surrounding water thus diminishing its total oxygen content. It may also be partly due to the displacement of dissolved oxygen by dissolved solids within the effluents as reported by Odokuma and Okpokwasili (1993). Nevondo and Cloete (1999) opined that DO provides an indication of pollution of natural water and it decreases when water is polluted (Nevondo and Cloete, 1999). This therefore indicates that the downstream section of the river Kaduna is highly polluted.

The BOD (biological oxygen demand) level was extremely high in the sludge water treatment plant thus, affecting the oxygen demand of the downstream water. Muoghalu and Omocho (2000) observed that when wastes are heavily laden with pollutants and dissolved solids gain access into stream or water bodies, they need large doses of oxygen for decomposition, particularly if their BOD_5 content is high. In this way, the oxygen needed by aquatic organisms is used up.

Okonkwo and Oboatu (1999) indicated that organic contents of most industrial and chemical waste deplete the oxygen content of receiving water as dissolved oxygen is utilized during the process of decay and this can result in the water having undesirable properties like colour, taste and odour (Exall and Vanloon, 2003). The high concentration of organic matter in the sludge in this study will therefore have an effect on the water downstream.

The high turbidity value of the sludge which is above the WHO limit of 5 NTU will have an effect on the aquatic ecosystem. This will result in a decrease in the photosynthesis process, since turbidity precludes deep penetration of light in water (Muoghalu and Omocho, 2000).

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