Journal of Toxicology and Environmental Health Sciences Vol. 1 (2) pp. 034-037, July 2009
Available online at http://www.academicjournals.org/JTEHS

Full Length Research Paper

Studies on the pollution potential of wastewater from textile processing factories in Kaduna, Nigeria

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Accepted 25 May, 2009

Samples of effluents from 3 textile processing factories F(1), F(2) and F(3), were characterized for their pollution potential. The concentrations of solids were found to be 1020, 790 and 1,380 mg/l total solids for the factories 1, 2 and 3, respectively. The BOD's and COD's were 342.8 and 542.4 mg/l for F(1), 123.2 and 224.6mg/l for F(2) and 456 and 738.4mg/l for F(3). The pH for the effluents were 9.36, 8.98 and 9.44 for F(1), F(2) and F(3), respectively. This implies that the effluents were alkaline. The nitrogen and phosphorus concentrations were 56 and 2.13 mg/l for F(1), 51 and 1.14 mg/l for F(2) and 43 and 0.73 mg/l for F(3), respectively. The levels of copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), lead (Pb) and chromium (Cr) were higher than the Federal environmental protection agency (FEPA) standards for effluent discharge. This shows that the textile effluents have severe pollution potentials since the parameters measured have values above the tolerable limits compared to the FEPA standards. The results also showed that the ratio of COD: BOD were 1.58, 1.82 and 1.62 for F(1), F(2) and F(3), respectively, indicating that the effluents may not be able to undergo up to 50% substrate biodegradation, thus biological processes may not be feasible for the treatment of these effluents. The high values obtained for the parameters assessed, especially those of the concentrations of the solid and of the oxygen demands, call for a pretreatment of the effluent before its discharge into water body. Also, the high conductivity observed shows that sufficient ions are present in the effluents, thus suggesting that the chemical method of coagulation and flocculation may be an ideal treatment method.

Keywords: Textile wastewater, factory, pollution, substrate, biodegradation, coagulation, flocculation.

INTRODUCTION

The degradation of the environment due to the discharge of polluting wastewater from industrial sources is a real problem in several countries. This situation is even worse in developing countries like Nigeria where little or no treatment is carried out before the discharge. In spite of the many steps taken to maintain and improve the quality of surface waters, the quantities of wastewaters generated by these industries continue to increase, and municipalities and industries are confronted with an urgent need to develop safe and feasible alternative practices for wastewater management.

Some industrial wastewaters contain high concentration of nitrogen which may exist in the forms of ammonia, nitrate (v), nitrate (iii) and organic nitrogen (Priestly, 1991). It is widely acknowledged that nitrogen in wastewater has become one of the major pollutants for our water resources. Environmental legislation requires the removal of nitrogen from wastewater before being discharged (Zhiguo et al., 2000). Nitrogen can pose serious public health threat when present in drinking water above certain concentrations. Nitrogen is commonly found in oxic water as trioxonitrate (V), that is NO_3^- The nitrate (v) ion, is not dangerous as such. It is reduced to the highly toxic dioxonitrate (iii), that is, NO_2^- by certain bacteria at suboxic conditions commonly found in the intestinal tract. Nitrate (Iii) causes the disease known as methemoglo binemia in infants (Ademoroti, 1996a). Furthermore, ni-

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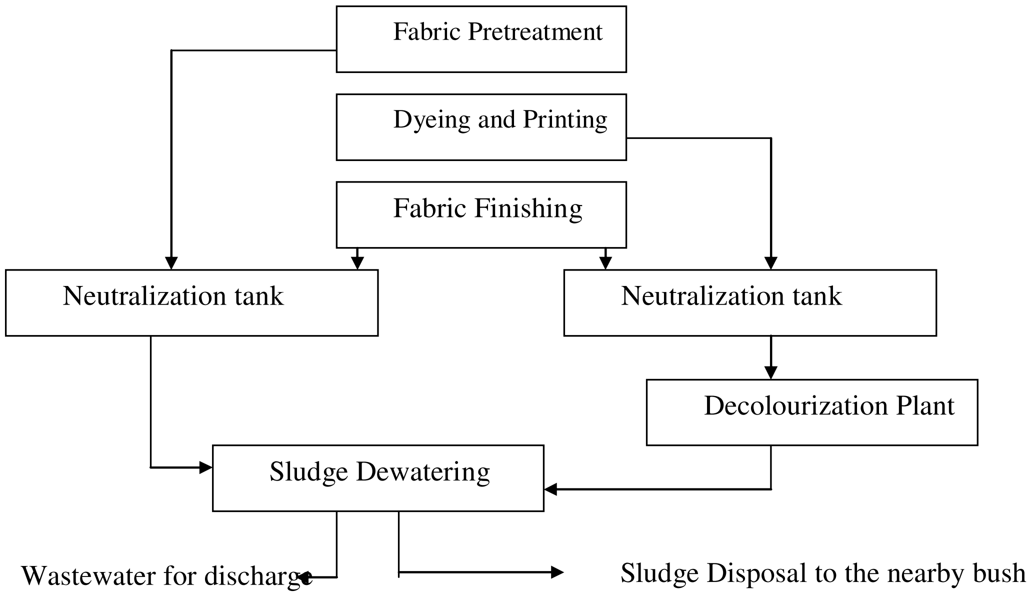

Figure 1. Wastewater flowchart of textile processing factory.

trates and phosphates, derived from wastewaters, are main nutrients, which promote growth of plants and algae. The amounts necessary to trigger algae blooms in water bodies are not well established but concentrations as low as 0.01 mg/l for phosphorus and 0.1 mg/l for nitrate may be sufficient for eutrophication when other elements are optimal (Henry and Heinke, 1989). In addition to having a detrimental aesthetic effect on lakes (odour and appearance), some algae are toxic to cattle, spoil the taste of the water, plug filtration units and increase the requirements for chemicals in the water treatment (Metcalf and Eddy, 1991)

The textile industry uses large volumes of waters in their operations and therefore discharges large volumes of wastewater into the environment, most of which is untreated. The wastewaters contain a variety of chemicals from the various stages of process operations which include desizing, scouring, bleaching and dyeing.

The textile industry is distinguished by the raw material used and this determines the volume of the water required for production as well as the wastewater generated. The production covers raw cotton, raw wool and synthetic materials. The industries studied in the present report are raw cotton based. In this type of production, slashing, bleaching, mercerizing and dyeing are the major sources of the wastewater generated. The main products of the factories are superprint, guarantee-superprint and minibrocade.

The factories consist of various departments, each of which carries out different operations and produces one type of specific wastewater. The wastewater contains acids used in desizing, dyeing bases like caustic soda used in scouring and mercerization. It also contains inorganic chlorine compounds and other oxidants, e.g. hypochlorite of sodium, hydrogen peroxide and peracetic acid for bleaching and other oxidative applications. Organic compounds are also present, e.g. dyestuff, optical bleachers, finishing chemicals, starch and related synthetic polymers for sizing and thickening, surface active chemicals are used as wetting and dispersing agents and enzymes for desizing and degumming. Salts of heavy metals are also present, e.g. of copper and zinc, and iron (iii) chloride used as printing ingredients. All these wastes are passed into an effluent tank and then drained into a drainage system.

MATERIALS AND METHODS

Textile wastewaters was collected from 3 textiles factories located in Kaduna. Kaduna lies at 10.52°N and 7.44°E. It is the capital city of Kaduna State and is situated in the central part of northern Nigeria (Kaduna, 2008). Concerning industry, it is one of the most developed cities in Northern Nigeria and textile industries are its dominating industries. Here the first textile industry in Nigeria was established (Jibrin, 2004; Yusuff and Sonibare, 2004). River Kaduna, a major river in the city receives the effluents from these industries, adding to the pollution load already present in the environment and a good reason for the importance of this research. This work is aimed at characterizing the wastewater obtained from 3 textile industries in Kaduna to assess their pollution potentials and to recommend appropriate treatment processes for the wastewaters. The wastewater flowchart of these industries is shown in Figure 1.

Sampling of wastewaters

Composite samples of the wastewaters were obtained from primary sedimentation tanks of the factory. Plastic bowls of 1 l capacity each were used to take samples manually over 12 h sampling period with 2 h interval starting at 7. 00a.m. and ending at 7.00p.m.

Table 1. Characterization of the effluents from three textile processing factories in Nigeria.

Parameters	F(1)	F(2)	F(3)	FEPA standards
pH	9.36± 0.02	8.98 ± 0.03	9.44 ± 0.04	6.9
Temp °C	31.8 ± 2.0	29.7 ± 3.0	29.1 ± 1.0	NA
Conductivity µS	740 ± 8.5	850 ± 4	940± 12	NA
TSS mg/l	370 ± 3	260 ± 1	180 ± 3	30
TDS mg/ l	650 ± 12	530 ± 13	1,200 ± 15	2000
TS mg/l	1020 ± 32	790 ± 27	1,380 ± 50	2000
DO mg/ l	4.49 ± 0.01	8.01 ± 0.03	3.44 ± 0.03	NA
BOD_5 mg/l	342.8 ± 0.6	123.2 ± 0.8	456.0 ± 1.6	50
COD mg/l	542.4 ± 1.3	224.6 ± 1.0	738.4 ± 10.3	NA
Nitrate Nitrogen mg/l	56 ± 3.2	51 ± 2.0	43 ± 2.4	10
PO_4 mg/l	2.13 ± 0.03	1.14 ± 0.01	0.73 ±0.01	5.0
Ca mg/l	67.32 ± 0.03	68.12± 0.02	74. 31 ± 0.04	75
Mg mg/l	43.11 ± 0.02	42.11 ± 0.02	31.03 ± 0.01	50
Na mg/ l	71.04 ± 0.11	41.23 ± 0.01	73.34 ± 0.01	NA
K mg/l	10.01 ± 0.03	24.21 ± 0.01	14.22 ± 0.13	NA
Cu mg/l	2.2 ± 0.02	4.5 ± 0.02	3.6 ± 0.4	1.00
Zn mg/l	8.7 ± 0.01	7.3 ± 0.2	6.1 ± 0.3	5.0
Fe mg/l	27.21 ± 0.13	37.00 ± 0.31	28.0 ± 0.01	0.3
Mn mg/l	3.80 ± 0.12	13.20 ± 0.01	0.90 ± 0.02	0.05
Pb mg/l	1.90 ± 0.02	1.70 ± 0.01	1.12 ± 0.03	0.05
Cr mg/l	0.70 ± 0.02	0.50 ± 0.08	0.24± 0.01	0.05

NA = Not Available
F(1) = Effluent from factory 1
F(2) = Effluent from factory 2
F(3) = Effluent from factory 3

This coincided with the working period in the factory and sampling was most convenient during this period. Composite samples were collected from each industry once a week for 7 weeks and analyzed. Where analysis could not be carried out immediately, samples were preserved in a refrigerator maintain at 4°C. At this temperature, biodegradation is minimal.

Every week the weekday for the sample collection was changed to account for cyclic and intermittent variations occurring at the work site.

Methods of samples analysis

All samples were analyzed as described in the standard methods for the examination of water and wastewater (APHA, 1995) and standard methods for water and effluents analysis (Ademoroti, 1996b). The pH was determined with a pH meter, temperature was measured with a thermometer, conductivity and TDS were measured using a TDS/conductivity/salinity meter. TS and TSS were determined by a gravimetric method, DO was determined by the sodium azide modification of the Winkler method, as well as the BOD after appropriate dilutions. The COD was determined by the dichromate digestion method, nitrate nitrogen by using the indophenol colorimetric method. Phosphate was determined by the use of a spectrophotometer, calcium and magnesium were determined by gravimetric method and potassium by a flame photometric method, heavy metals, Cu, Zn, Fe, Mn, Pb and Cr were determined using an atomic absorption spectrophotometer (AAS). Where the analysis was not immediately possible, samples were preserved to inhibit biodegradation (Manual of Practice No. OM - 1, 1980). All the reagents used for the analyses were of analytical grade and obtained from BDH chemicals limited poole England.

RESULTS AND DISCUSSION

Table 1 show results of the detailed analyses carried out on the effluents obtained from the 3 textile processing factory F(1), F(2) and F(3). The pH values were slightly alkaline being 9.36, 8.98 and 9.44 for F(1), F(2) and F(3), respectively, typical for textile processing factories.

The effluent has high levels of solids. The total solids (TS), total suspended solids (TSS) and total dissolved solids (TDS) were 1020, 370 and 650 mg/l for F(1), 790, 260 and 530 mg/l for F(2) and 1380, 180 and 1200 mg/l for F(3), respectively. The high values of solids in F(3) may be caused of other domestic activities going on at that point.

The concentration of dissolved oxygen (DO) in the effluents of F(1), F(2) and F(3) were 4.49, 8.01 and 3.44 mg/l, respectively. The BOD and COD were 342.8 and 542.4 mg/l for F(1), 123.2 and 224.6 mg/l for F(2), and 456 and 738.4 mg/l for F(3), respectively. From these results a ratio of COD: BOD was calculated, resulting in 1.58, 1.82 and 1.62 for F(1), F(2) and F(3), respectively. This indicates that these effluents are high in recalcitrant and hardly degradable compounds and may not undergo more than 50% substrate biodegradation, as it is known that organic matter with 50 - 90% substrate biodegradation has a COD: BOD ratio between 2 and 3.5 (Quano et al., 1978)

The concentrations of solids and the oxygen demand were quite high when compared to the effluent discharge standard set by Federal environmental protection agency (FEPA, 1988). The water of all 3 effluents also show a high conductivity, indicating that sufficient ions are present in the effluent. The high conductivity suggests that the effluent could be treated by physicochemical method of coagulation and flocculation (Asia and Ademoroti, 2002).

The levels of nitrogen, 56, 51 and 43 mg/l for F(1), F(2) and F(3) respectively and phosphate, 2.13, 1.14 and 0.73 mg/l for F(1), F(2) and F(3), respectively) were also higher than FEPA and WHO standard.

The amount of calcium (67.32, 68.12 and 74.31 mg/l for F(1), F(2) and F(3) respectively) and magnesium, 43.11, 42.11 and 31.03 mg/l for F(1), F(2) and F(3) respectively in the effluent were within the federal environmental protection agency (FEPA) and world health organisation (WHO) standards of 75 and 50 mg/l for calcium and magnesium respectively.

The levels of heavy metals present in the effluent were quite high. The amount of copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), lead (Pb) and chromium (Cr) obtained for F(1) were 2.2, 8.7, 27.21, 3.80, 1.9 and 0.70 mg/l as against the effluent discharge standard of 1.0, 5.0, 0.3, 0.05, 0.05 and 0.05 mg/l respectively for these parameters set by federal environmental protection agency (FEPA). The values obtained for F(2) were 4.5, 7.3, 37.0, 13.20, 1.7 and 0.5 mg/l and for F(3), the values were 3.6, 6.1, 28.0, 0.9, 1.12, and 0.24 mg/l for Cu, Zn, Fe, Mn, Pb and Cr respectively. These values are higher than the FEPA and WHO standards (FEPA, 1988; WHO, 1971).

Heavy metals if present even in low concentrations are toxic to living organisms, including humans as well as the microbial population present in the effluent treatment processes. Furthermore, heavy metals may limit the use of the effluent for irrigation in agriculture due to its toxicity (Page et al., 1987).

Conclusion

The results obtained from this study showed that the effluents from the textile processing factories was alkaline and had a high salt concentration.

The amount of nitrogen, phosphorus and heavy metals present in the effluent were significantly higher than the standards given by the federal environmental protection agency (FEPA). The results also showed that the values of the concentrations of solids and of the oxygen demands were quite high. The results of this study indicate that biological treatment may not be feasible for these effluents and that physicochemical method may be a better alternative.

Based on this study, we call for treatment of all effluents generated by the textile factories in Nigeria before its discharge into a natural water body. These effluents can be treated by chemical methods of coagulation and flocculation.

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