Physicochemical Assessment and Effects of Pharmaceutical Wastewater in Nigeria

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A total of 108 wastewater samples were collected and analyzed for physicochemical properties. The wastewater was collected from the point of discharge (PA), contact point with the external environment (PB) and downstream of Chanchaga river (PC). The results of this study revealed that Chanchaga river and its environment were polluted by wastewater discharge from the factory. Some physicochemical parameters were above the World Health Organization (WHO) acceptable limit. Physicochemical analysis revealed the presence of nitrate, sulphate and phosphate. One way Analysis of Variance (ANOVA) showed that there were significant differences in the levels of the physicochemical parameters studied at 5% level. The mean values for temperature, sulphate and phosphate for PA and PB were not significantly different from each other. Heavy metals detected were iron and zinc. The concentration of the heavy metals was generally low. The mean concentration for iron and zinc ranged from 0.185 mg/L to 0.741 mg/L and 0.335 mg/L to 0.367 mg/L respectively. The results of this study revealed that discharged untreated pharmaceutical wastewater into the environment and Chanchaga river pollutes the river with some heavy metals. This poses risk to human health, especially to the communities that use water from the river for domestic purposes.

Keywords: Pharmaceutical wastewater, Physicochemical, Environment, River

Introduction

Pharmaceutical wastewaters are liquid wastes generated by pharmaceutical industries during the manufacture of drugs. The steps involved in the compounding of drugs generate air emission, liquid waste and solid waste (Ulamen and Robert, 2006).

Some pharmaceutical wastewaters are known to contain high concentration of organic compounds, total solids, mercury, cadmium, isomers of hexachlorocylohexane, 1, 2–dichloroethane and solvent. The properties of pharmaceutical wastewater vary from one industry to another. Properties like the Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS), phenol content and pH of pharmaceutical wastewater vary due to factors such as, the manufactured product, materials used for drug production, and the processing methods (Anonymous, 1993; and Ekhaise and Omavwoya, 2008).

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Technological advancement has brought about a high rate of industrialization in most of the developing countries. However, solid wastes and wastewaters generated in industrial process in developing countries such as Nigeria are either incompletely treated or not treated due to lack of effective waste treatment plants. The wastewater in most cases are discharged into large lakes, canals or drains and rivers (Chukwura and Okpokwasili, 1997; Grover and Kaur, 1999; Odiete, 1999; and Lateef, 2004).

Among such wastes discharged as partially-treated or untreated in Nigeria are pharmaceutical wastewaters. Drugs are designed to stimulate a physiological response in humans, animals, bacteria and other organisms (Kummerer, 2003). Many pharmaceuticals and personal care products (as well as their metabolites and by-products) can enter the environment, and finally the food chain following ingestion or application by the user or administration to domestic animals. Aquatic environment serves as the major ultimate receiving end for these chemicals of which little is known with respect to their actual or potential adverse effects. During the past decade, there was a growing concern about the adverse effects that the use and disposal of pharmaceuticals might potentially have on human and ecological health (Kummerer, 2003).

In the last 15 to 20 years, there have been several reports of increased pharmaceuticals wastewater in the environment and water supply (Richardson and Bowron, 1985; and Halling-Sorenson *et al.,* 1998). Although the reported levels are very low, effects were observed with a noteworthy example of hormone disruption in fish due to the presence of estrogens in the environment (Halling-Sorensen *et al.*, 1998). Drug substances may reach the environment via use or disposal. Patients usually excrete drug or its metabolites which then pass to sewage treatment plant. There, it may be (partially) degraded, it may be absorbed in the sludge or it may remain in the effluent. After processing in the sewage treatment plant, the sludge is either incinerated or spread on the land, which may then leach into the soil and eventually into the groundwater. Pharmaceutical wastes may enter the groundwater and surface water via a sewage treatment plant or by leaching from a land fill site (Halling-Sorensen *et al.*, 1998).

Although pharmaceuticals and their metabolites in excreta will be diluted before entering the sewage treatment plant, and even though leaching from a landfill site may be limited, it should be kept in mind that drugs usually are relatively stable—after all, they were developed to remain intact in the human body, at least for a certain period. And then, as they were developed with the objective of causing physiological effect in humans, other organisms may be sensitive to their mode of action as well (Richardson and Bowron, 1985).

There was no wastewater treatment system constructed for managing the wastewater from the factory. The wastewater was discharged in the environment without treatment through a pipe. Consequently, the wastewater flows along a drainage channel and mixes with wastewaters from human settlements around the factory, this eventually empties into Chanchaga river. This poses serious environmental and public health risk. Worst still, there are villages downstream that use the water in this river for their domestic purposes. Besides, pollutants in pharmaceutical wastewater may be mutagenic or toxic and consequently, lead

to several human diseases such as cancer, arteriosclerosis, cardiovascular disease and premature ageing (Grover and Kaur, 1999). It has been shown that disposal of untreated pharmaceutical wastewaters into the environment has great implications on public health, because of the ability to select and enhance the development of resistant bacteria (Lateef, 2004; and Lateef *et al.*, 2005).

There is increase in the number of pharmaceutical industries in Nigeria, more hazardous wastes are generated and discharged into the environment and there is a dearth of information on the potential effects that such may have on biota (Lateef and Yekeen, 2006). There is therefore a need to assess pharmaceutical wastewater with a view to determine the impact of discharged wastewater on public health. The results of the findings will evaluate the physicochemical qualities of pharmaceutical process wastewater and recommend measures for treating the wastewater. In addition, the results will also provide useful data that will guide the public health policy formulation of a company. It is believed that such information will assist in the timely formulation of new regimes of environmental regulation to prevent the discharge of untreated wastewaters into the environment, thereby mitigating the risks associated with the exposure to such matrices. This research had the general aim of evaluating the physicochemical qualities of a pharmaceutical process wastewater with a view to determining the impact of the discharged wastewater on public health as well as the safety of the wastewater coming out from the pharmaceutical industry with specific objectives to: determine the physicochemical properties of the pharmaceutical wastewater.

Materials and Methods

A total of 108 samples were aseptically collected in duplicate for analysis using sterile sample bottles from the designed point of discharge (outlet), (PA), 200 m away from point of discharge and, in contact with the external environment designated point B (PB) and at Chanchaga river, 500 m downstream of the river designated point C (PC). At PA, the wastewater was allowed to run for few minutes through a pipe before sterile sample bottles were used to collect it and quickly corked. At PB the sample bottle was held facing the wastewater current for the collection. Water sample from Chanchaga river was collected 15 cm below the water surface by holding the sample bottles to face the water current. The wastewater samples were collected between 10 am and 12 pm each month for a period of three months (June-August, 2009) and transported to the laboratory in an ice box. The samples were analyzed for physicochemical properties within four hours of collection.

Physicochemical Analysis

The wastewater and water samples were analyzed for temperature, pH, total dissolved solid (TDS), dissolved oxygen (DO), turbidity, BOD, COD, nitrate (NO_3^-), sulphate (SO_4^{2-}), and phosphate (PO_4^{3-}), following standard procedures (APHA, 1985). Other parameters such as the concentrations of zinc (Zn), iron (Fe), chromium (Cr), lead (Pb) and copper (Cu) were analyzed using the Buck Scientific Atomic Absorption Spectrophotometer (AAS) model 210 VGP. All chemicals used were of analytical grade.

Statistical analysis

A one way Analysis of Variance (ANOVA) and Duncan Multiple Range (DMR) test were used to determine whether there is a significant difference among the values obtained for physicochemical parameters. Statistical Package for the Social Sciences (SPSS package) 15.0, 2006 version was used for data analysis. The statistical analyses were carried out using mean and standard deviation/standard error mean.

Results

The physicochemical parameters studied are showed in Table 1. The mean for temperature ranged from 25.7 °C to 26.5 °C; pH from 7.0 to 7.5; TDS from 28.2 mg/L to 275.5 mg/L; DO from 11.6-14.0; turbidity from 15.5 NTU to 46.4 NTU; BOD from 10.10 mg/L to 21.89 mg/L; COD from 22.2 mg/L to 45.3 mg/L; nitrate from 16.6 mg/L to 277.2 mg/L; sulphates from 7.1 mg/L to 11.8 mg/L; phosphate from 0.0029 mg/L to 0.0047 mg/L; zinc from 0.0335 mg/L to 0.367 mg/L; and iron from 0.185 mg/L to 0.741 mg/L. Chromium, lead and copper were not detected. The results showed some degree of variation among the sampling points. Some parameters fall within the acceptable limits of effluent discharge into surface water as specified by the Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO) while others were not within the acceptable limits. A one way ANOVA carried out in the values obtained showed that there were significant differences in the levels of the physicochemical parameters studied at 5% level of significance ($p < 0.05$) while the values for temperature, sulphate and phosphate for PA and PB were not significantly different from each other.

Table 1: Mean Values for Physicochemical Parameters

Parameters	Month	PA	PB	PC
Temperature (°C)	June	$25.3^{b} \pm 0.37$	$25.8^{ab} \pm 0.11$	$26.4^{a} \pm 0.15$
	July	$25.8^{b} \pm 0.29$	$25.9^{b} \pm 0.27$	$26.7^{a} \pm 0.14$
	August	$26.0^{a} \pm 0.26$	$25.8^{a} \pm 0.26$	$26.4^{a} \pm 0.13$
	Mean	$25.7^{b} \pm 0.18$	$25.8^{b} \pm 0.13$	$26.5^{a} \pm 0.08$
pH	June	$7.06^{b} \pm 0.16$	$7.3^{b} \pm 0.09$	$7.7^{a} \pm 0.09$
	July	$7.1^{b} \pm 0.12$	$7.2^{ab} \pm 0.09$	$7.4^{a} \pm 0.10$
	August	$6.8^{b} \pm 0.19$	$7.1^{b} \pm 0.06$	$7.4^{a} \pm 0.05$
	Mean	$7.0^{c} \pm 0.09$	$7.2^{b} \pm 0.05$	$7.5^{a} \pm 0.05$
Total Dissolved Solid (mg/L) (TDS)	June	$212.8^{b} \pm 0.58$	$275.4^{a} \pm 4.11$	$26.8^{c} \pm 0.34$
	July	$245.1^{b} \pm 7.37$	$281.5^{a} \pm 3.89$	$29.0^{c} \pm 0.29$
	August	$226.2^{b} \pm 5.28$	$269.7^{a} \pm 6.07$	$28.9^{c} \pm 0.38$
	Mean	$228.0^{b} \pm 3.69$	$275.5^{a} \pm 2.81$	$28.2^{c} \pm 0.25$

Table 1 (Cont.)

Parameters	Month	PA	PB	PC
Dissolved Oxygen (mg/L) (DO)	June	$12.4^{b} \pm 0.02$	$14.1^{a} \pm 0.03$	$10.8^{c} \pm 0.03$
	July	$12.9^{a} \pm 0.21$	$14.0^{a} \pm 0.36$	$13.4^{a} \pm 1.11$
	August	$12.2^{b} \pm 0.06$	$13.8^{a} \pm 0.14$	$10.5^{c} \pm 0.13$
	Mean	$12.5^{b} \pm 0.08$	$14.0^{a} \pm 0.13$	$11.6^{c} \pm 0.43$
Turbidity (NTU)	June	$51.3^{a} \pm 0.09$	$3.5^{b} \pm 0.05$	$0.9^{c} \pm 0.01$
	July	$37.9^{a} \pm 3.29$	$20.0^{b} \pm 5.54$	$37.0^{a} \pm 2.76$
	August	$50.1^{a} \pm 0.24$	$23.0^{c} \pm 3.38$	$43.7^{b} \pm 1.00$
	Mean	$46.4^{a} \pm 1.48$	$15.5^{c} \pm 2.55$	$27.2^{b} \pm 3.31$
Biological Oxygen Demand (BOD)	June	$9.46^{c} \pm 0.027$	$10.48^{b} \pm 0.397$	$21.85^{a} \pm 0.064$
	July	$10.13^{c} \pm 0.229$	$11.68^{b} \pm 0.300$	$21.95^{a} \pm 3.143$
	August	$10.71^{c} \pm 0.348$	$13.08^{b} \pm 2.948$	$21.89^{a} \pm 1.764$
	Mean	$10.10^{c} \pm 0.568$	$11.75^{b} \pm 1.994$	$21.89^{a} \pm 1.764$
Chemical Oxygen Demand (COD)	June	$45.3^{a} \pm 0.51$	$27.0^{b} \pm 0.35$	$21.2^{c} \pm 0.39$
	July	$48.7^{a} \pm 1.34$	$33.3^{b} \pm 2.00$	$23.8^{c} \pm 2.36$
	August	$41.8^{a} \pm 0.50$	$25.8^{b} \pm 0.36$	$21.5^{c} \pm 0.47$
	Mean	$45.3^{a} \pm 0.69$	$28.7^{b} \pm 0.87$	$22.2^{c} \pm 0.81$
Nitrate (mg/L)	June	$308.1^{a} \pm 0.49$	$154.7^{b} \pm 0.49$	$3.1^{c} \pm 0.01$
	July	$282.8^{a} \pm 16.46$	$153.5^{b} \pm 3.25$	$27.0^{c} \pm 3.36$
	August	$240.6^{a} \pm 16.37$	$144.4^{b} \pm 1.75$	$19.8^{c} \pm 0.55$
	Mean	$277.2^{a} \pm 8.87$	$150.9^{b} \pm 1.44$	$16.6^{c} \pm 2.02$
Sulphate (mg/L)	June	$6.9^{a} \pm 0.19$	$7.5^{a} \pm 0.19$	$8.5^{a} \pm 1.16$
	July	$9.9^{b} \pm 0.71$	$9.4^{b} \pm 0.51$	$15.0^{a} \pm 0.30$
	August	$4.5^{c} \pm 0.23$	$7.1^{b} \pm 0.09$	$12.0^{a} \pm 0.85$
	Mean	$7.1^{b} \pm 0.45$	$8.0^{b} \pm 0.25$	$11.8^{a} \pm 0.66$
Phosphate (mg/L)	June	$0.0026^{c} \pm 0.0002$	$0.0035^{b} \pm 0.004$	$0.0050^{a} \pm 0.003$
	July	$0.0027^{b} \pm 0.0001$	$0.0028^{b} \pm 0.0001$	$0.0046^{a} \pm 0.0001$
	August	$0.0034^{b} \pm 0.0001$	$0.0027^{c} \pm 0.0001$	$0.0046^{a} \pm 0.0001$
	Mean	$0.0029^{b} \pm 0.0001$	$0.0030^{b} \pm 0.0001$	$0.0047^{a} \pm 0.0001$
Zinc (Zn) (mg/L)	June	$0.314^{b} \pm 0.004$	$0.347^{a} \pm 0.006$	$0.357^{a} \pm 0.006$
	July	$0.343^{b} \pm 0.11$	$0.339^{b} \pm 0.006$	$0.379^{a} \pm 0.006$
	August	$0.347^{a} \pm 0.006$	$0.364^{a} \pm 0.008$	$0.364^{a} \pm 0.007$
	Mean	$0.335^{c} \pm 0.005$	$0.350^{b} \pm 0.004$	$0.367^{b} \pm 0.004$

Table 1 (Cont.)

Parameters	Month	PA	PB	PC
Iron (mg/L)	June	$0.165^{c} \pm 0.029$	$0.785^{a} \pm 0.023$	$0.546^{b} \pm 0.024$
	July	$0.190^{b} \pm 0.031$	$0.645^{a} \pm 0.062$	$0.604^{a} \pm 0.019$
	August	$0.198^{c} \pm 0.015$	$0.794^{a} \pm 0.015$	$0.570^{b} \pm 0.013$
	Mean	$0.185^{c} \pm 0.015$	$0.741^{a} \pm 0.025$	$0.573^{b} \pm 0.012$
Chromium (mg/L)	June	ND	ND	ND
	July	ND	ND	ND
	August	ND	ND	ND
	Mean	ND	ND	ND
Lead (Pb) (mg/L)	June	ND	ND	ND
	July	ND	ND	ND
	August	ND	ND	ND
	Mean	ND	ND	ND
Copper (Cu) (mg/L)		ND	ND	ND
		ND	ND	ND
		ND	ND	ND
		ND	ND	ND

Note: Key: a, b, c: values with different letters on the same row were significantly different from each other ($p < 0.05$). The average values were ± Standard Error of Mean (SEM) from readings taken in three days.
PA: Pharmaceutical wastewater (point of discharge: outlet)
PB: Discharged wastewater in contact with external environment
PC: Chanchaga river (downstream)
ND: Not Detected
mg/L: milligram per litre
NTU: Nephelometric turbidity unit.

Discussion

The present study revealed that judging from the standards set by the FEPA (1991) and WHO (1985) on effluent discharged into surface water sources, the mean temperature, pH, TDS, turbidity for values of PB and PC in June, BOD, COD for values of PB and PC, nitrate for values of PC, sulphate, iron, phosphate and zinc values fall within the acceptable limits. However, DO, turbidity for values of PA, and PC for values in July and August, COD for values of PA and nitrate for values of PA and PB were not within the acceptable limits. These results are similar and in agreement to those reported by Ulamen and Robert (2006); Stephen and Ijah (2006); Osibanjo and Adie (2007); Lateef *et al.* (2007); Ekhaise and Omavwoya (2008); Nwidu *et al.* (2008); Oyeleke *et al.* (2008) for pharmaceutical wastewater, river water source, hospital wastewater, hospital solid waste and wastewater in contact with the external environment.

The temperature of the water is influenced by the intensity of the sun (Obire *et al.*, 2003). Studies have shown that temperature is a key factor that influences abundant bacterial growth in water bodies (Lobitz *et al.*, 2000). The weekly mean water sample temperature for the three sites (PA, PB and PC) is ideal for the prolonged survival of the bacteria isolated from the study sites. This observation may account for high prevalence of coliforms especially *E. coli* and other bacteria isolated throughout the sampling period as this range of temperature obtained from this study (24.2 to 27.0 °C) favors their survival (Bezuidenhout *et al.*, 2002). Changes in pH, BOD and DO during the rainy season (June to August) for PB and PC are attributed to increased effects of surface run off, soil erosion and the presence of organic matter from sewage or washed from the land into the receiving water bodies river and the external environment (Odokuma and Okpokwasili, 1993). The range of pH values for PC were all within the acceptable limit, and agree with that reported by Obire and Amusan (2003) and Obire *et al.* (2003). There was an increase in the BOD with the advent of rains, as a result of the increase in biodegradable matter introduced into the river and the external environment. The pH for PB and PC are slightly alkaline. The BOD is reported (Moore and Moore, 1976) to be a fair measure of cleanliness of any water on the basis that values less than 1-2 mg/L are considered clean, above 2-3 mg/L fairly clean, 5 mg/L doubtful and 10 mg/L definitely bad and polluted. This shows that the overall quality of water from Chanchaga river used for domestic purposes by the communities is bad and highly polluted. The pH and BOD of PA studied showed some degree of variation. This finding is in agreement with Anonymous (1993) who reported that pH and BOD of pharmaceutical wastewater is however not consistent because of the product manufactured, materials used and the processing details while other workers (Lateef *et al.*, 2007; Ekhaise and Omavwoya, 2008) also reported changes in pH and BOD values in pharmaceutical wastewater and hospital wastewater respectively. The pH of PA is slightly alkaline and acidic.

The concentration of DO was higher in PB as compared to PA and PC and were all above the permissible level or limit. This could be due to an increased waste disposal and other human activities that may enhance the growth and proliferation of organisms leading to consumption of available oxygen in PC while the presence of nutrients in PA may contribute to an increase in bacteria leading to consumption of available oxygen. These findings are comparable with the earlier report of Ekhaise and Omavwoya (2008), who had reported higher concentration of DO in one of the sampling points as compared to other sampling points that were within the allowable limit while Lateef *et al.* (2007) reported that DO values of one of the pharmaceutical wastewater studied falls within the acceptable limit of 5.00 mg/L as compared to the other that is higher in DO values. The concentration of TDS in PA, PB and PC were all within the acceptable limit, and agree with that reported by Lateef *et al.* (2007) for pharmaceutical wastewater and Obire *et al.* (2003) for river water, although the TDS was higher in PB followed by PA as compared to PC. This could be attributed to the influence of the degradative activity of the microflora (Ekhaise and Omavwoya, 2008).

The mean monthly values for turbidity in PA, PB and PC were not within the acceptable limit except for some values in PB and PC in June, but considerably high turbidity values

were obtained in the intense rainy months of July and August which were not within the acceptable limit. The range of values for turbidity were higher than the standards. This is due to the high levels of suspended particulate matter carried by the flowing river. Turbidity is also influenced by seasons. The rise in turbidity with rains may be due to surface runoff introducing both organic and inorganic materials on the environment (PB) and into the river (PC). The rise in turbidity of PA may be due to the presence of liquid waste containing particulate matter, high concentration of organic compounds, total solid wastes and the constituents used in the compounding of drugs in the factory. The values for turbidity recorded in this work were higher than those reported by Lateef *et al.* (2007) for pharmaceutical wastewater and were within the acceptable limits.

The mean monthly values for COD in PB and PC were within the acceptable limit while PA values were not within the acceptable limits. The COD is an indication of organic matter susceptible to oxidation by chemical oxidant (Nwidu *et al.,* 2008). Although, PB and PC values for COD were within the acceptable limit, they still contain some amount of organic matter. This could be from the large amount of refuse and human excreta disposed into the river. High COD values for PA may be due to high concentration of organic matter in the pharmaceutical wastewater that are susceptible to oxidation by chemical oxidant (Nwidu *et al.,* 2008). High COD values were reported by Lateef *et al.* (2007) and were not also within the acceptable limit which agrees with the present study for pharmaceutical wastewater.

The discharge of the untreated pharmaceutical wastewater from the factory to Chanchaga river may affect the quality of the river in the following ways: the discharge of biodegradable organic compounds (measured with parameters such as BOD, COD and TDS, may cause a strong reduction of the amount of DO, which in turn lead to reduced level of activity or death of aquatic organisms. The oxygen is further depleted as a result of microbial degradation of organic materials (Lui, 2000). The nitrate values for PC, sulphate values and phosphate values were within the acceptable limit while nitrate values for PA and PB were not within the acceptable limit. Their presence in water may be due to the components of domestic wastes entering the river and surface runoff of farm lands previously enriched with artificial fertilizers such as NPK, urea and superphoshate (Nevondo and Cloete, 1999; Gbodi *et al.*, 2001; and Obire *et al.,* 2003). Higher nitrate, phosphate and sulphate levels will not only favor algal bloom but also pose serious health risk to consumers of such untreated water (Gbodi *et al.*, 2001; and GCLPI, 2003). Macronutrients (nitrate and phosphate) may cause eutrophication of the river which will result in the overgrowth of algae and depleted oxygen levels in the river, leading to the death of aquatic animals. Higher nitrate concentration in PA is probably due to the constituents of some drugs produced in the factory. The richness of the pharmaceutical wastewater in nutrients particularly nitrate, sulphate and phosphate may contribute to the increase in the bacteria obtained (Lateef *et al.,* 2007). Lateef *et al.* (2007) and Ekhaise and Omavwoya (2008) reported the presence of these macronutrients which were within the acceptable limit in pharmaceutical wastewater and hospital wastewater respectively.

The concentration of heavy metals in this study revealed that zinc and iron levels in PA, PB and PC were within the acceptable limits while chromium, lead and copper were not detectable in PA, PB and PC throughout the sampling period. This is in conformity with other studies conducted in Niger Delta region (Ajayi and Osibanjo, 1981; Bariwen *et al.*, 2000; Izonfuo and Bariwen, 2001; Olajire *et al.*, 2003; and Asonye *et al.*, 2007) for river water source. Lateef *et al.* (2007) have reported the presence of zinc and iron in pharmaceutical wastewater which agrees with the present study. The report on chromium, lead and copper in this study is however contrary to those reported by Lateef *et al.* (2007) who detected lead and copper in pharmaceutical wastewater while Ekhaise and Omavwoye (2008) detected lead and chromium in hospital wastewater which were all within the acceptable limits. Iron and zinc are of nutritional importance to man. For instance, iron is required for the synthesis of haemoglobin while zinc is a required component of many enzymes (Itah *et al.*, 1996). Iron exposure at high levels has been shown to result in vomiting, diarrhoea, abdominal pain, seizures and possibly coma. A latent period, where the symptoms appear to improve, may occur. But it is followed by shock, low blood glucose, liver damage, convulsions and death, 12-48 h after toxic level of iron are ingested. Death may occur in children if they ingest sufficient iron to exceed the body's iron-binding capacity, the metal-binding proteins that make ionic iron available (Conrad, 2004).

Conclusion

The physicochemical properties showed negative impact of pharmaceutical wastewater on Chanchaga river. In view of the fact that little is known about the occurrence, fate and risks that are associated with antibiotics and pharmaceuticals entering the environment (Kummerer, 2003), measures to avoid the release of harmful substances should be incorporated in the design, operation, maintenance and management of pharmaceutical plants, as such efforts will yield both economic and environmental benefits. Exposure to pharmaceutical wastewater can represent a risk for health and endangers the well-being of the population. Research showed that after passing through wastewater treatment, pharmaceuticals are released directly into the environment (Kummerer, 2001). There is also a relationship between the accumulation of heavy metals in the environment and incidence of bacterial resistance. In fact, the potential impact of increased antibiotic resistance due to metal contamination seems to be particularly great considering the very large number of heavy metal-contaminated locations that can favor maintenance and transfer of antibiotic-resistant bacteria (McArthur and Tuckfield, 2000). There seems to be an increasing evidence that industrial effluents may contribute to the emergence, development and spread of resistant strains of bacteria (Aleem *et al.*, 2003; Adewoye and Lateef, 2004; Lateef, 2004; Lateef *et al.*, 2005; and Stepanauskas *et al.*, 2005). One study had estimated the cost of bacterial resistance to antibiotics alone to be between $150 mn and $30 bn annually, depending upon how many deaths occurred by resistance (Phelps, 1989).

As industrial wastes are being discharged into aquatic environment directly or through run off, they may bioaccumulate in the aquatic organisms. The ultimate effect will be shown at

higher trophic levels due to biomagnification along the food chain (Odiete, 1999). Thus, there is an urgent need for wastewater treatment facility to be installed to reduce the health hazard posed by wastewater on the users of the Chanchaga river.

Recommendations: Based on the results obtained, the following recommendations were made: (1) Pharmaceutical industries should be advised to treat their wastewater properly before being discharged into the environment and rivers; (2) regular studies should be carried out on water bodies that receive pharmaceutical wastewater in order to reveal and evaluate its physicochemical qualities; (3) the pharmaceutical industries should be monitored regularly in order to ascertain the quality of wastewater discharged into the environment; (4) yearly monitoring of physicochemical parameters of the river should be carried out; (5) sewage and wastewater from homes and industries located near Chanchaga river should be treated before being discharged into the river; (6) excessive fertilizer application on farm lands close to the bank of Chanchaga river should be discouraged as they are easily washed into the river by surface runoff; (7) communities around Chanchaga river should be enlightened on the implications of consuming contaminated water, especially by heavy metals; (8) proper hygiene should be maintained within the pharmaceutical factory and the environment; (9) target areas for sanitization should include infrastructure and facilities contained therein, equipment, surrounding areas and most particularly the staff; (10) appropriate technology should be developed for the treatment and recycling of the wastewater for irrigation; and (11) further research should be carried out particularly on heavy metal contents of the pharmaceutical wastewater and the receiving Chanchaga river.

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