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Quality of Wastewaters from Selected Laboratories in a Tertiary Institution, Nigeria

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Abstract

The compositions of laboratory wastewaters are so complex and similar to industrial wastewaters, thus may require more than a conventional biological treatment. In this paper, grab and composite samples of wastewaters from all identifiable and accessible discharge points emanating from the laboratories in Ahmadu Bello University (ABU), Zaria were collected over a period of four weeks. The wastewaters collected were analyzed and compared with FEPA (1991) and WHO (1989) standards to ascertain if they can be completely treated by the existing waste stabilization ponds, with particular attention to some biological and physicochemical parameters as well as some heavy metals. The study revealed the average pH as 3.9 – 9.5, BOD_5 33.50 – 120 mg/L, COD 72.50 – 277.50 mg/L, Nitrate 6.13 – 31.55 mg/L, Phosphate 15.19 – 51.78 mg/L, Oil and grease 0.07 – 14.50 mg/L and three heavy metals (Cr, Cd and Pb) were from 0.111 mg/L up to as high as 37.89 mgL. Lead values ranged from as low as 0.0026 to 0.026 mg/l which were all within the stipulated standard. The coefficient of variation (CV) of all the parameters studied in the various laboratories ranged from 0.02 to 0.99. This suggests that there are variations in the compositions of wastewaters generated. The study revealed that the characteristics of the laboratory wastewaters from ABU suggest that they are biodegradable based on their chemical oxygen demand/biological oxygen demand ratio and shows good indication for biological treatment except for wastewaters generated from Pharmacy laboratories.

Keywords: Laboratory wastewater; COD/BOD_5 ratio; pH; biological treatment

Introduction

Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residence, commercial properties, industry or agriculture and can encompass a wide range of potential contaminants and concentration (Fillaudeau, 2005). According to the fourth World Water Development Report, currently only 20% of globally produced wastewater receives proper treatment (UNESCO, 2012).

Laboratory wastewaters are used water from education and research activities as well as industrial and agricultural development laboratories (Dong *et. al.*, 2014). It includes wastewater generated from school science laboratories, medical laboratories, quality assurance testing laboratories among others. They are usually composed of readily biodegradable and non-biodegradable organic matter; and inorganic metallic and nonmetallic constituents (Mhlanga and Brouckaert, 2012). The similarity between laboratory and industrial wastewater is often overlooked especially in developing countries like Nigeria where wastewater collection systems are not well developed thereby leading to the mixing of laboratory and domestic wastewater before discharge. Wastewater from laboratories has neither regular discharge cycles nor regular discharge quantities and its composition is so complex that it is difficult to dispose of by biological treatment processes. (Dong *et. al.*, 2014). This varied nature of laboratory wastewater due to the various sources from which it is generated makes it necessary to be characterized in order to determine the class of wastewater it belongs to and the appropriate treatment required for it.

In 1979 a waste stabilization pond (WSP) was designed and constructed in Ahmadu Bello University (ABU), Zaria; as the first of its kind to be implemented in Nigeria (Muhammad *et al.*, 1980). Since construction, the sewerage system in ABU became a separate system in which wastewater and storm water are collected via separate pipes. The storm water is collected via the storm sewers and flows into the Kubanni reservoir while the wastewater is collected via the sewer pipes and drained into the WSP for treatment. In addition to the separate system, some edifices have a separate septic tanks to take care of the wastewater generated (Lukman, 2009).

A recent study by Tukura *et al.*, (2011) reported that the Kubanni reservoir sediments contain appreciably high levels of heavy metals. Wastewaters generated from the laboratories within the university are more or less similar to industrial effluents due to the nature of activities involved in the wastewater generation such as chemical reactions, qualitative and quantitative analysis in which both organic and inorganic chemicals are used. This makes the laboratory wastewater one of the likely sources of these heavy metals that are found in the Kubanni reservoir.

The best option in the treatment of highly contaminated and toxic industrial wastewater is to treat wastewater at the source and sometimes by applying onsite treatment within the production lines with recycling of treated effluent (Hu et al., 1999). Since industrial wastewater differs from domestic sewage in general characteristics, pre-treatment is required to produce an equivalent effluent (Meric et al., 1999) especially where they are to be eventually mixed before treatment.

This study therefore sets out to characterize the wastewater generated from selected laboratories in the Ahmadu Bello University main campus to determine concentrations of some selected parameters including the heavy metals; and determine its consistency in composition (variations) so as to propose appropriate onsite pre-treatment requirements

before discharge into the central WSP.

Materials and Methods

Description of Study Area

Ahmadu Bello University (ABU) Zaria is a federal university located at Samaru, Sabon-Gari, Local Government Area of Kaduna State, on the western edge of Zaria bordering open countryside on Longitude 7°39'20.60" E, Latitude 11°08'50.10" N and an elevation of 662.2 m above the mean sea level (MSL). This is typical savannah, gently undulating grassland with single isolated trees. To the south and west, the campus is bordered by open countryside with occasional small villages. To the north, it is confined by Zaria-Sokoto road and to the south and east is the extensive ABU reservoir, with Jama'a Village and Zango forming most of the boundary to the east (Lukman, 2009).

The waste stabilization pond (WSP) which treats most of the wastewater generated within the institution lies in the south-west and further to the south of the WSP is the Kubanni reservoir where the effluents from the WSP are discharged (Figure 1).

There are thirteen (13) faculties in ABU at present and nine (9) of these faculties have one or more laboratories. However, not all the laboratories generate wastewater. Seven laboratories were selected for this study and are shown in Figure 2.

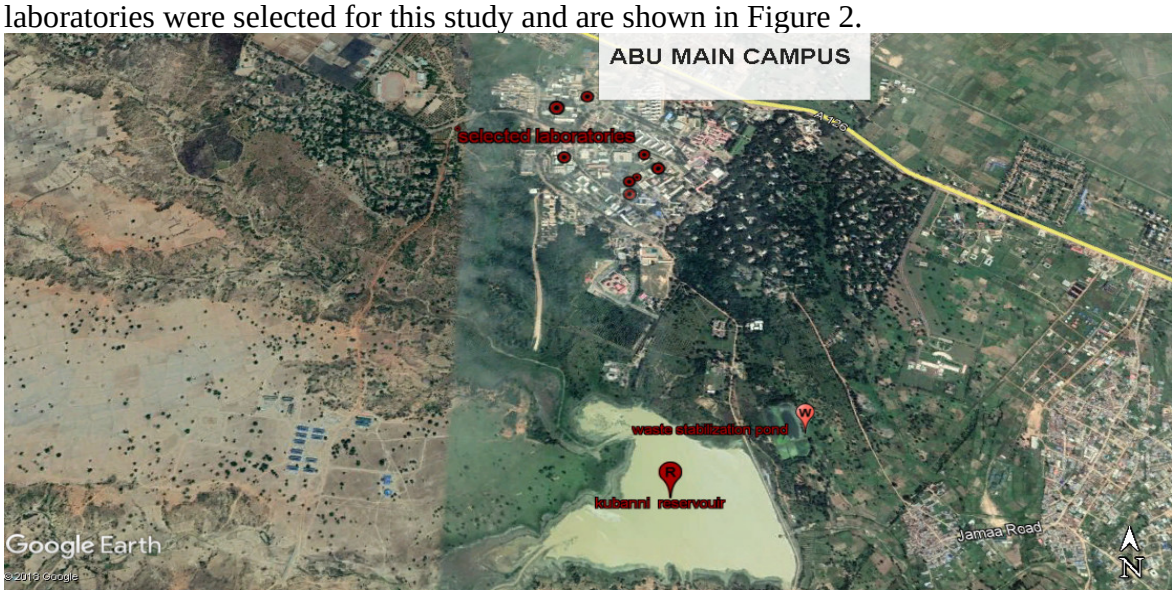

Figure 1: Satellite imagery of the Ahmadu Bello University showing the WSP and the Kubanni Reservoir.

Figure .2: Satellite imagery of the Ahmadu Bello University showing the selected laboratories.

Samples Collection

Samples were collected from seven (7) laboratories located in the academic area of Ahmadu Bello University Zaria. The laboratories are the Biological Science, Chemistry, Microbiology, Pharmaceutical Sciences, Medicine, Chemical and Water Resources and Environmental Engineering laboratories. Both composite and grab sample of wastewaters were collected during the peak period of wastewater generation daily for a period of four (4) weeks. Some samples were collected directly from under the wastewater sink in the laboratories (where discharge points were not accessible).

Analysis of samples

The wastewaters collected were subjected to physico-chemical analysis (pH, dissolved oxygen, biological oxygen demand, chemical oxygen demand, nitrate, phosphate, oil & grease and heavy metals content) using standard methods as stated in APHA (1998). Selected heavy metals (chromium, lead and cadmium) concentrations were determined using a Perkins Elmer Atomic Absorption Spectrophotometer A500. The results obtained were compared with FEPA (1991) and WHO (1989) standards and subjected to descriptive statistics using Microsoft Excel 2003 (to determine measure of their central tendency and measure of their dispersion). Also, the consistency in composition (coefficient of variation) of the wastewater discharges from the selected laboratories were determined.

Results and Discussions

Results from the study are presented and discussed as follows:

pH

The pH recorded throughout the study ranged from 3.9 - 9.5. The mean pH for the four weeks sampling were 9.5, 8.4, 8.8, 7.7 and 8.9 for faculty of sciences and Medicine laboratories respectively with coefficient of variation of 2-5 % which shows that the effluents are quite stable within the mean pH values. However, Pharmacy, WREE and OCE had mean pH of 3.9, 3.9 and 5.0 with coefficient of variation of 26, 34 and 35 % which shows that the effluents had higher variation in pH. The pH values as shown in Tables 1-8 for the eight departmental laboratories fall within FEPA (1991) and WHO (1989) limits for effluent discharge except for Microbiology laboratories which had mean pH (9.5) which is slightly above FEPA (1991) and WHO (1989) upper limits of 9, while Pharmacy and WREE had mean pH (3.9) which is below FEPA and WHO lower limits of 6 and 5 respectively. The pH of the effluent may provide inert conditions that can inhibit chemical activities. pH affects the solubility of heavy metals, heavy metals precipitate when concentration of pH is high i.e. basic, in this case some of the pH conditions are within limits but need to be controlled during the removal of heavy metals (David *et al.*, 1994).

Table 1: Characteristics of wastewater from microbiology laboratories

Week	pH	BOD (mg/l)	COD (mg/l)	Oil and Grease (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Chromium (mg/l)	Lead (mg/l)	Cadmium (mg/l)
Mean	9.5	82.5	203.8	1.06	12.45	20.3	3.444	-	-
Standard deviation	0.24	9.57	10.31	0.39	3	4.3	-	-	-
Coefficient of variation	0.02	0.12	0.05	0.37	0.24	0.21	-	-	-
WHO Standard	9-May	50	250	10	100	0.5	0.5	0.5	0.1
FEPA Limit	9-Jun	50	120	10	20	5	<1	<1	<1

Table 2: Characteristics of wastewater from biochemistry laboratories

Week	pH	BOD (mg/l)	COD (mg/l)	Oil and Grease (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Chromium (mg/l)	Lead (mg/l)	Cadmium (mg/l)
Mean	8.4	90	238.8	1.46	14.85	45.71	-	-	-
Standard deviation	0.23	14.14	35.21	0.3	9.13	28.63	-	-	-
Coefficient of variation	0.03	0.16	0.14	0.2	0.61	0.63	-	-	-
WHO Standard	9-May	50	250	10	100	0.5	0.5	0.5	0.1
FEPA Limit	9-Jun	50	120	10	20	5	<1	<1	<1

Table 3: Characteristics of wastewater from chemistry laboratories

Week	**pH**	**BOD (mg/l)**	**COD (mg/l)**	**Oil and Grease (mg/l)**	**Nitrate (mg/l)**	**Phosphate (mg/l)**	**Chromium (mg/l)**	**Lead (mg/l)**	**Cadmium (mg/l)**
Mean	8.76	33.5	92.5	6.5	6.13	51.78	0.0045	0.0026	-
Standard deviation	0.33	5.26	12.58	2.89	1.74	25.26	0.0021	0.0021	-
Coefficient of variation	0.04	0.16	0.14	0.44	0.28	0.49	0.47	0.84	-
WHO Standard	9-May	50	250	10	100	0.5	0.5	0.5	0.1
FEPA Limit	9-Jun	50	120	10	20	5	<1	<1	<1

Table 4: Characteristics of wastewater from biological sciences laboratories

Week	**pH**	**BOD (mg/l)**	**COD (mg/l)**	**Oil and Grease (mg/l)**	**Nitrate (mg/l)**	**Phosphate (mg/l)**	**Chromium (mg/l)**	**Lead (mg/l)**	**Cadmium (mg/l)**
Mean	7.7	47.75	72.5	14.5	8.24	46.85	0.0168	0.0055	-
Standard deviation	0.31	10.37	25	4.51	0.46	21.21	0.0033	0.0033	-
Coefficient of variation	0.04	0.21	0.34	0.32	0.56	0.45	0.2	0.6	-
WHO Standard	9-May	50	250	10	100	0.5	0.5	0.5	0.1
FEPA Limit	9-Jun	50	120	10	20	5	<1	<1	<1

Table 5: Characteristics of wastewater from medicine laboratories

Week	**pH**	**BOD (mg/l)**	**COD (mg/l)**	**Oil and Grease (mg/l)**	**Nitrate (mg/l)**	**Phosphate (mg/l)**	**Chromium (mg/l)**	**Lead (mg/l)**	**Cadmium (mg/l)**
Mean	8.9	60	142	6.3	15	17.4	0.88	0.00004	-
Standard deviation	0.4	7.07	9.86	3.55	15	4.99	0.59	-	-
Coefficient of variation	0.05	0.11	0.06	0.56	0.9	0.28	0.8	-	-
WHO Standard	9-May	50	250	10	100	0.5	0.5	0.5	0.1
FEPA Limit	9-Jun	50	120	10	20	5	<1	<1	<1

Table 6: Characteristics of wastewater from pharmacy laboratories

Week	**pH**	**BOD (mg/l)**	**COD (mg/l)**	**Oil and Grease (mg/l)**	**Nitrate (mg/l)**	**Phosphate (mg/l)**	**Chromium (mg/l)**	**Lead (mg/l)**	**Cadmium (mg/l)**
Mean	3.9	85	277.5	0.07	8.23	46.86	-	0.74	-
Standard deviation	1.01	11.18	14.79	0.04	3.98	18.37	-	0.961	-
Coefficient of variation	0.26	0.13	0.05	0.52	0.48	0.39	-	1.3	-
WHO Standard	9-May	50	250	10	100	0.5	0.5	0.5	0.1
FEPA Limit	9-Jun	50	120	10	20	5	<1	<1	<1

Table 7: Characteristics of wastewater from WREE laboratories

Week	**pH**	**BOD (mg/l)**	**COD (mg/l)**	**Oil and Grease (mg/l)**	**Nitrate (mg/l)**	**Phosphate (mg/l)**	**Chromium (mg/l)**	**Lead (mg/l)**	**Cadmium (mg/l)**
Mean	3.9	117.75	223	0.94	9.13	15.19	20.86	0.217	-
Standard deviation	1.31	55.77	5.92	0.85	3.68	7.28	16.49	0.19	-
Coefficient of variation	0.34	0.47	0.03	0.91	0.4	0.48	0.79	0.88	-
WHO Standard	9-May	50	250	10	100	0.5	0.5	0.5	0.1
FEPA Limit	9-Jun	50	120	10	20	5	<1	<1	<1

Table 8: Characteristics of wastewater from OCE laboratories

Week	**pH**	**BOD (mg/l)**	**COD (mg/l)**	**Oil and Grease (mg/l)**	**Nitrate (mg/l)**	**Phosphate (mg/l)**	**Chromium (mg/l)**	**Lead (mg/l)**	**Cadmium (mg/l)**
Mean	5	120	266	0.95	31.55	16.13	0.0168	0.0055	-
Standard deviation	1.78	55.23	20.1	0.41	38.38	5.38	-	-	-
Coefficient of variation	0.35	0.46	0.08	0.44	1.22	0.33	-	-	-
WHO Standard	9-May	50	250	10	100	0.5	0.5	0.5	0.1
FEPA Limit	9-Jun	50	120	10	20	5	<1	<1	<1

Biochemical Oxygen Demand (BOD)

The BOD values obtained in all the laboratories ranged from 33.50 – 120.00 mg/L (Table

1-8). The highest mean BOD concentration was found in the WREE and OCE laboratories with 117.75 mg/l and 120 mg/L, respectively. Their coefficient of variation (CV) of 47 % and 46 % shows that the variations in the BOD of the effluent were high. Chemistry laboratory had the lowest BOD of 33.5 mg/L with CV of 16% while Biological Sciences had 47.75 mg/L BOD with a CV of 21 %. All the BOD concentrations recorded except for those from the Chemistry and Biological Sciences laboratories were outside the limits of FEPA and WHO of 50 mg/L. The BOD concentrations in the effluent samples are an indication of the biodegradable content of the effluents. It arises from activities of microorganisms which act on organic matter, animals and plant remains that are washed off and other organic materials such as animal feeds and fertilizers.

Chemical Oxygen Demand (COD)

Chemical oxygen demands in all the samples analyzed in this study were within the range of 72.50 to 277.50 mg/L. The mean COD concentrations were 203.8, 238.8, 92.5, 72.5, 142.0, 277.5, 223.0 and 266.0 mg/L for the Microbiology, Biochemistry, Chemistry, Biological Sciences, Medicine, Pharmacy, WREE and OCE laboratories respectively with corresponding CV of 5 %, 14 %, 14 %, 34 %, 6 %, 5 %, 3 % and 8 % as presented in Tables 1 to 8. Pharmacy and OCE laboratories had the highest COD concentrations; all the effluents were quite stable in terms of COD except for Biological Science laboratory within CV of (34%). The Chemistry and Biological Science laboratories effluent were within FEPA and WHO COD limits; that of Microbiology, Biochemistry, Medicine and WREE effluents were within WHO limits only while that of Pharmacy and OCE were outside both FEPA and WHO limits. It is noteworthy that the observed wide variation in wastewater characteristics was due to the varied laboratory sessions which are dependent on topics being taught at that point in time in the various laboratories.

Phosphates

The range of phosphates in all the samples collected was between 15.19 and 51.78 mg/l. The mean phosphate concentrations recorded are as presented in Tables 1-8. These tables showed that WREE laboratory had the least mean phosphate concentration of 15.19 mg/l while Chemistry laboratory had the highest mean concentration of 51.78 mg/l. The phosphate concentrations recorded were not stable as the CV ranged from 21 %-63 % in the four laboratories and were all well above the WHO (1989) and FEPA (1991) standards of 0.5 and 5 mg/L, respectively.

This high concentrations of phosphate in the laboratory wastewaters might have resulted from the chemicals used during experiments such as phosphoric acid and from detergents used in cleaning which are phosphorus based in most cases. Although, the phosphate concentrations are expected to be reduced at the WSP, inability to do so can pollute the receiving water body by predisposing it to eutrophication.

Nitrates

The nitrates values recorded all through the study ranged from 6.13 to 31.55 mg/L (Table 1-8). The highest mean nitrate concentration (31.55 mg/L) was found in effluents from OCE while the lowest concentration (6.13 mg/L) was from Biological Sciences. The effluents were not stable in terms of nitrates concentration as the CV ranged from 24 to 90 %. However, the mean nitrate concentrations of the effluents from all the laboratories were lower than the WHO (100mg/l) and FEPA (20 mg/L) limits except for nitrate concentration of OCE laboratory wastewater which had a mean concentration beyond FEPA (1991) limits but lower than WHO limit. These results indicate that there are no risks of eutrophication from excessive nitrates concentrations from ABU laboratory effluents.

Oil and Grease

The oil and grease concentrations in all the laboratories ranged from 1.06 to 14.50 mg/L (Table 1-8). The mean oil and grease concentrations in the laboratory effluents were 1.06, 1.46, 6.5, 14.50, 6.3, 0.07, 0.94, and 0.95 mg/L for Microbiology, Biochemistry, Chemistry, Biological Sciences, Medicine, Pharmacy, WREE and OCE respectively. This result shows that oil and grease concentrations in effluents from Biological science exceeded both FEPA and WHO standards while the other laboratories were well below the standards. Oil and grease from Biological Science could be as a result of high organic content in the wastewater. Effluent from Biological Science could be pre-treated before discharge by application of detergent which would help in breaking the oil and grease bonds and thus allow oxygen to dissolve in water thereby increasing the treatability of the effluent.

Heavy metals

Among the three heavy metals determined, cadmium was not detected in any of the laboratory effluents, lead was detected at trace level well below stipulated standards in Chemistry, Biological Science, Medicine, Pharmacy, WREE and OCE effluents but was not detected in Microbiology and Biochemistry laboratories (Tables 1-8). Chromium was detected at concentrations well above recommended standards in the effluents from Microbiology, Biochemistry, Medicine, Pharmacy, OCE and as high as a mean concentration of 20.86 mg/L in WREE effluent. Chromium was also detected in trace concentrations in Chemistry and Biological Sciences laboratory effluents. This confirms the suspicion that laboratories within the ABU campus could be contributing to the heavy metals' pollution of the Kubanni reservoir. According to Silva *et al* (2001), the main implications of heavy metals are their toxicity to human beings and other forms of plant or animal life as a result of the discharge or disposal of wastewaters to receiving water bodies or land and its inhibition to the microorganisms responsible for the biological treatment of wastewater under certain concentrations and exposure time.

Treatability/Biodegradability of the laboratory Wastewaters

The treatability of the effluents from the laboratories by the WSP which is the main wastewater treatment plant in ABU main campus was determined using the COD/BOD_5 ratio. The result of the COD TO BOD_5 ratio of the laboratory wastewaters as given in Table 9 revealed that all the effluents excluding the effluents from Pharmacy laboratories were biodegradable and showed good indication for biological treatment except for the presence of high concentration of chromium that was detected in Microbiology, Biochemistry, Medicine, Pharmacy, WREE and OCE laboratories. Hence, it is recommended that a pre-

treatment of the wastewater for heavy metals removal should be done before discharge into the WSP. In addition to pre-treatment, further treatability studies is required in Pharmacy effluent as indicated by the COB/BOD_5.

Table 9: COD to BOD_5 ratio

Laboratories	**COD (mg/l)**	**BOD_5 (mg/l)**	**Ratio**	**Remark** (Braile and Cavalcanti, 1979)
Microbiology	203.8	82.5	2.47	Good indication for biological treatment
Biochemistry	238.8	90	2.65	Good indication for biological treatment
Biological Science	47.75	72.5	0.66	Good indication for biological treatment
Chemistry	33.5	92.5	0.36	Good indication for biological treatment
Medicine	142	60	2.4	Good indication for biological treatment
Pharmacy	277.5	85	3.26	Requires treatability studies
W.R.E.E.	223	118	1.89	Good indication for biological treatment
O.C.E.	226	120	2.22	Good indication for biological treatment

Conclusions

Based on the Chemical oxygen demand/Biological oxygen demand ratio, it was concluded that the laboratory wastewaters generated from Biological Sciences and Chemistry can be treated biologically. Wastewater from Microbiology, Biochemistry, Medicine, Water Resource Engineering and Old Chemical Engineering laboratories requires special pre-treatment to remove chromium before biological treatment can be employed while wastewater generated from Pharmacy laboratories requires further treatability studies as it cannot be treated biologically. Also, the presence of high concentration of phosphates and chromium that was detected in the wastewaters from most of the laboratories suggests that pre-treatment of the wastewater is necessary before discharge into the WSP for treatment or the storm sewers as the case may be.

With regard to variability in the laboratory effluent characteristics, the study established that the most stable effluents were from Microbiology laboratories as the CV in most of the parameters measured were lowest. Also, the most stable parameters were pH and COD which had very low CV in almost all the laboratories throughout the study period.

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