ORIGINAL ARTICLE

DETERMINATION OF BIOLOGICAL OXYGEN DEMAND RATE CONSTANT AND ULTIMATE BIOLOGICAL OXYGEN DEMAND FOR LIQUID WASTE GENERATED FROM STUDENT CAFETERIA AT JIMMA UNIVERSITY: A TOOL FOR DEVELOPMENT OF SCIENTIFIC CRITERIA TO PROTECT AQUATIC HEALTH IN THE REGION

Zeleke Alebachew[1], BSc, Worku Legesse[2], PhD, Tadesse Kassie[2], BSc, Bishaw Deboch[2], MSc

ABSTRACT

BACKGROUND: *Except Addis Ababa, all towns of Ethiopia discharge every form of liquid waste anywhere. This wastewater ultimately enters to streams and rivers. Deficiencies of sanitary services and absence of regulation and scientific criteria for enforcement has presented an increasing environmental and public health hazards in major towns of Ethiopia. The aim of this study was to determine the strength of Jimma University cafeteria waste and propose the need for scientific criteria and treatment options before discharging into water bodies.*

METHODS: *Liquid waste generated from student cafeteria at Jimma University was sampled from December - March 2003 to determine Biological Oxygen Demand rate constant (k) and ultimate biological oxygen demand by incubating samples at three different temperatures. Rate constant was determined following Thomas Method and the potential impact of the waste on streams was evaluated.*

RESULTS: *The rate constant (k) determined at 3 three temperatures was of similar magnitude and the Ultimate Biological Oxygen Demand was found to be under the category of a strong waste (1047.33 mg/L) capable of destroying the self-purifying capacities of receiving water bodies. The rate constant (k) generated based on local samples and environmental conditions can serve as feasible and reliable scientific criterion to optimize treatment facilities such as oxidation ponds in the region.*

CONCLUSION: *Liquid wastes generated from Jimma University student cafeteria is found to be under the category of strong waste that can degrade the quality of the Awetu-Gilgel Gibe river system and thereby limit its actual and potential use. Determination of Biological Oxygen Demand and rate constant (k) for other sources and consequent provision of wastewater treatment option is necessary to protect water resources downstream.*

KEYWORDS: Biological Oxygen Demand, rate constant, dissolved oxygen, liquid waste.

[1]School of Environmental Health, Gondar University, P.O. Box 196, Gondar, Ethiopia.
[2]School of Environmental Health, Jimma University, P. O. Box 378, Jimma, Ethiopia.
*Correspondence to Dr Worku Legesse

INTRODUCTION

The disposal of wastes always constituted a serious problem in the world. With the development of urban areas, it became necessary, from public health and aesthetic considerations, to provide drainage or sewer systems to carry such wastes away from the area (1). On disposal of wastes surface water is obviously highly susceptible to contamination. One particular category of pollutants, oxygen-demanding wastes, has been such pervasive surface-water problem, affecting both running and still water demanding special attention (2).

The 5-day Biological Oxygen Demand (BOD) is the best single strength measure of wastewater or polluted water containing biodegradable wastes and it is the best indicator of organic water pollution. When organic waste is discharged into water bodies with out being stabilized, leads to depletion of dissolved oxygen (DO) in the water and limit water bodies' ability to support desirable aquatic life (3,4).

The worst condition of pollution of receiving water body occurs in dry season when stream flows low and water temperature is high (5). This is because when temperature increases solubility of oxygen decrease and low flow rate of stream reduce its capacity to dilute the waste. Without considering the effect municipal and Industrial wastewaters are largely being discharged with out treatment in to the surface of receiving water body through out developing world (6). The problem of wastewater is expected to be of great concern in Ethiopia where adverse impacts have been reported for rivers and streams flowing through big towns (7,8). Determination of a single 5-day BOD alone does not permit calculation of ultimate Biological Oxygen Demand (BOD∞) and rate constant (k) as described in Tebutt, 1992. Therefore, the advantage of determination of BOD strength and rate constant is apparent: It helps to optimize wastewater treatment facilities such as oxidation pond and also serves as scientific criteria to ensure compliance.

Jimma University generates large quantity of waste from various sources mainly from student cafeteria kitchen and it is the one, which needs strict liquid waste management. The Cafeteria waste is discharged into *Kochi* stream without any form of treatment and enters to *Awetu* stream and ultimately to Gilgel Gibe river, which is the main tributary of the River Gibe. Such waste discharge without any form of treatment not only becomes a potential health hazard to the nearby communities, the waste may also upset the ecological integrity of the River *Awetu* by reducing the Dissolved Oxygen (DO) downstream.

MATERIALS AND METHODS

Study area: Jimma town has an altitude of 1760 m above sea level. The average annual rainfall is 1749 mm with a mean temperature ranging from 11.4°C to 26.7°C. The main campus of Jimma University is located 3 Kms away from the center of the Jimma town on the road to Aba Jiffar Palace. Routine sampling of waster water from the main campus cafeteria that provides food service for a total of 8000 students was taken from December 2003 to March 2004.

Study design: A cross sectional study was conducted by taking samples from the liquid waste generated by the main campus cafeteria. Measurement was taken during the dry period to assess the maximum effect of pollutant due to low flow rate of stream and less solubility of oxygen in dry period.

Samples were collected using tightly covered plastic bottle. To avoid addition of oxygen from atmosphere, sampling bottles were filled with the sample with out leaving air space.

From cafeteria waste each sample was collected at the first manhole, which receives all, wastes those coming in different line from the cafeteria. Each sample was collected at different time for each experiment carried out at 25°C, 30 °C and 35 °C. Several pre tests were carried out to estimate appropriate dilution factor for the waste sample to avoid total consumption oxygen before test period. Trials were done at, 5%, 4%, 3%, 1%... 0.17%. Finally successful dilution factors were obtained as 0.33% at 25°C and 0.17% at 30°C and 35°C. In all cases, laboratory analysis was made in less than 3hours after samples were collected as described in the standard methods (1).

The Standard Methods for the Examination of Water and wastewater (1) was followed in this study except modifications made at incubation temperatures. DO was determined by azide modification of the Winkler method. BOD determination was carried out using ordinary incubators. In the procedure BOD_5 at 20°C was determined indirectly due to lack of special BOD incubator, which maintains the temperature at 20°C. The testes ware carried out at 25°C, 30°C and 35°C using an ordinary incubator. Water bath incubator was employed to run the test at 25°C since room temperature exceeded the minimum temperature that can be thermostatically controlled by the incubators during the test period. BOD_5 at 20°C was measured indirectly by computing from the three test temperatures.

The determination of k and Ultimate BOD at 25°C, 30°C and 35°C was carried out using Thomas method of graphical determination of rate constant and Ultimate Biological Oxygen Demand (BOD∞) described in Tebutt (9). Finally, statistical comparison between slopes was made following the method given in Zar (14) after simplifying the calculation using a Macro Program written on Excel.

RESULTS

After determination of BOD values over a period of three days at 25°C Thomas fitting technique has been used to determine rate constant and ultimate BOD as shown in Table 1. A similar approach was used to determine the above variable at the remaining test temperatures (30°C and 35°C). The rate constants incubated at three temperatures (k_{25}, k_{30}, k_{35}) were found to be 0.38, 0.34d^{-1}, and 0.28d^{-1} respectively (see table 2) Similarly, the Ultimate Biological Oxygen Demand determined at different temperatures was found to be 1076.55, 1047.33 and 1176.49 in that order and is presented in Table 2. Statistical test between the slopes for the three temperatures showed no significant variation.

Table 1. Determination of $(t/BOD_t)^{1/3}$ from liquid waster generated from Jimma University main campus student cafeteria at incubation temperature of 25°C. December 2002- March 2003

Day (x_i)	$(t/BOD_t)^{1/3}$ (y_i)	$(x_i - x_{mean})$	$(x_i - x_{mean})^2$	$(y_i - y_{mean})$	$(y_i - y_{mean}) * (x_i - x_{mean})$	BOD (mg/L)
0.5	0.0993927	-1.25	1.5625	-0.0254214	0.0317767	509.22
1.0	0.1141191	-0.75	0.5625	-0.010695	0.0080212	672.86
1.5	0.1225353	-025	0.0625	-0.0022788	0.0005697	815.28
2.0	0.1307834	0.25	0.0625	0.0059693	0.0014923	894.07
2.5	0.1376898	0.75	0.5625	0.0128757	0.0096567	957.71
3.0	0.1443646	1.25	1.5625	0.0195505	0.244381	997.10

Table 2. Determination of slope, rate constant and ultimate BOD for liquid waste generated from Jimma University main campus student cafeteria at three incubation temperatures, December 2002-March 2003

Parameter/temperature	25°C	30°C	35°C
Slope (b)	0.0173611	0.0181485	0.0177526
Standard error	0.0009381	0.00102919	0.00112319
$t_{0.05}(2)_{10}$	p>0.5(p=0.57)	p>0.2(p=0.27)	p>0.2(p=0.26)
Intercept (a)	0.0944320	0.0894672	0.0872865
k (rate constant) d^{-1}	0.38	0.34	0.28
k_{20} (converted to 20°C)	0.3807691	0.3443745	0.2787159
Ultimate BOD (BOD∞)	1076.55	1112.82	1176.49

Rate constant (k) and ultimate BOD (L) determined using graphical determination method by plotting the graph $(t/BOD_t)^{1/3}$ against time (t) is shown in Fig.1. All the three plots essentially have a similar pattern of increase with time and the difference between slopes is not statistically significant $t_{0.05}(2)_{10}$ p>0.05 (Table 2). In order to compare the K values at the three temperatures determined in this study with typical values in literature, conversion was made to k_{20} and is shown in Table 2! Relatively highest value was recorded for incubation temperature at 25°C, the lowest being for incubation temperature at 35°C.

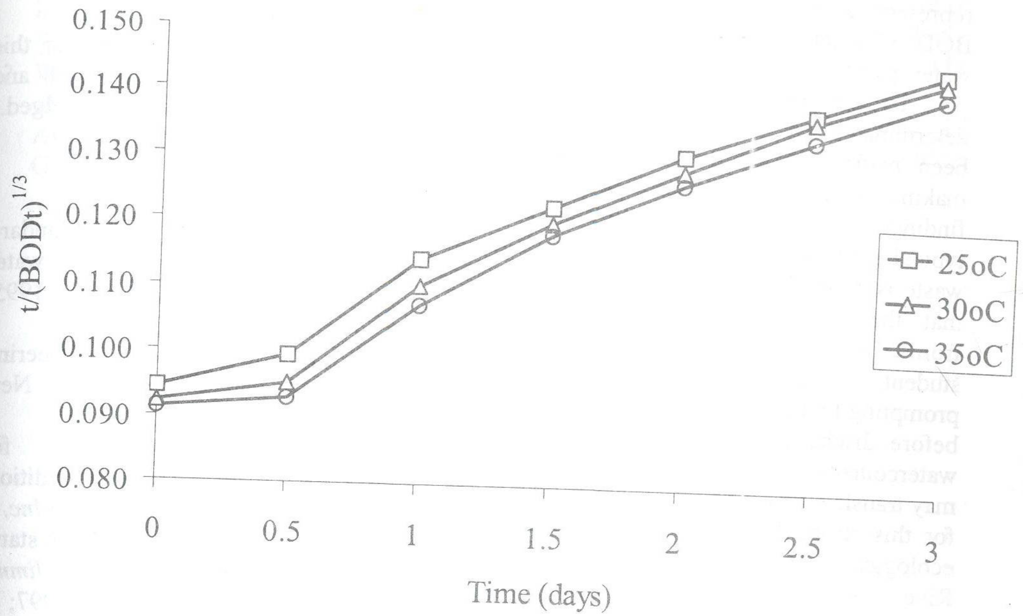

Fig 1. Incubation period (days) versus $(t/BOD_t)^{1/3}$ to determine rate constant (k) and BOD∞ for cafeteria waste generated from Jimma University main campus student cafeteria, December 2002-March, 2003

DISCUSSION

As presented in the result section of this study, the main campus student cafeteria ultimate BOD is considerably high. Sandy Carencro's stated that raw sewage that has greater than 750mg/L of BOD5 is very strong waste (11). EPA put maximum allowable BOD_5 effluent standard to dispose waste in to water body to be 30mg/L (6). This indicates that Jimma University main campus cafeteria wastewater needs substantial wastewater treatment to reduce BOD if compliance with EPA effluent criteria is a strict requirement.

As stated in the literatures (11, 12) typical k_{20} values of raw sewage ranges from 0.15 to 0.3d^{-1}. This indicates that k_{20} value of the cafeteria waste measured at 25 and 30°C were somewhat greater than the typical values reported in literature. On the other hand k at 35°C, was observed to fall with in the range reported by other workers. Nevertheless, variation in elevation of the slopes was not statistically supported suggesting that it is possible to obtain comparable BOD data at temperatures other than the standard incubation temperature, i.e. 20°C. The value of BOD reading at 35°C in this study falls within the range reported in literature (13). There are two advantages in using this incubation temperature: Firstly, results are relatively quickly obtained. For instance, incubating samples at 35°C requires only 2 and half days compared with incubation at 20°C, which requires 5 days. Secondly, the provision of special BOD incubators, which are expensive and unavailable in developing countries such as Ethiopia, could be avoided using ordinary incubator. Maintaining incubation temperature at 20°C where room temperature usually exceeds 20°C for most of the year may represent a major setback to determine BOD of water samples if routine national water quality monitoring is initiated.

To our knowledge, no attempt of determination of k and ultimate BOD has been made for liquid waste in Ethiopia making it is difficult to compare our findings with national figures. In literature, typical ultimate BOD values for a strong waste is about 250mg/L (5, 12) suggesting that the cafeteria wastewater generated from Jimma University main campus student cafeteria is a very strong waste prompting to a need for treatment of wastes before discharging to the nearby running watercourses. Postponing taking action may translate to a substantial economic loss for this strong BOD waste may upset the ecological integrity of the *Gilgel Gibe* River, which is much valued as a source of drinking water supply and hydroelectric power generation in the region.

Conclusion and Recommendation

With the present trend of increase in the annual intake of students by Jimma University, the number of accommodation and lounge facilities required to serve the student population is expected to rise and so does liquid waster generation. This preliminary study on liquid waste generated from main campus student cafeteria suggests that the waste is very strong and a treatment system that can achieve about 97% BOD removal efficiency is required to meet EPA effluent standards. Therefore, it is recommended that the amount and strength of all wastewater generated from Jimma University should be determined and treated before discharging in to a water body. Taking cost and climatic conditions as selection criteria, construction of waste stabilisation ponds appears one viable option.

ACKNOWLEDGMENTS

The financial assistance provided for this study by Jimma University Research and Publication Office is highly acknowledged.

REFERENCES

1. APHA, AWWA, and WEF. Standard methods for the examination of water and waste water, 16th Edition. 1995, New York.
2. Cross SC. Environmental engineering in tropics. 2nd Edition 1993, New York: John Wiley and Sons.
3. Clarion S. Chemistry for environmental engineering. 4th Edition. 1994, New York: MCG raw-hill *Inc,*
4. Degene H, Legesse W. Pollution status of awetu stream. *Bulletin of Jimma Institute of Health Sciences.* 1997; 7: 79-85.
5. Gilbers M. Introduction to environmental engineering and Science. 2nd Edition 1997: Stanford University.
6. Gordon FM. Elements of water supply and wastewater disposal. 2nd Edition. 1975, New York: Toppan company Ltd.
7. Howard P. Environmental engineering. 1985, New York: MCG raw-Hill.
8. Richard F. Water, waste and health in hot climate. 1994, New York: Awolley-Inter science.
9. Tebbutt THY. Principles of water quality control. 4th Edition, 1992, Oxford: Pergamon Press, Inc.
10. Salvato JA. Environmental engineering and sanitation. 4th Edition. 1992, New York: Wiley - Inter science.

11. Cross SC. Environmental engineering in tropics 2nd ed. New York: John Wiley and Sons, 1993: 306.
12. WHO. Guideline value for the safe use of wastewater and excreta in Agriculture and Aquaculture, 1989, Geneva.
13. Tool HR. Manometric measurement of the Biological Oxygen Demand. *Water and Sewage Works Journal,* 1967; **114** 211-218.
14. Zar JH. Biostatistical Analysis. 4th Edition. 1999, New Jersey: Prentice Hall International.