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Pollution Indicators in Gaborone Industrial Effluent

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Abstract: The objective of this study was to determine pollution indicators in and around Gaborone industrial effluent, generate relevant baseline information on industrial effluents; and determine the major sources of industrial pollution in Gaborone, Botswana. The results of the study showed that effluent quality discharged by the four different industry types in Gaborone, Botswana, differed significantly. Brewery, chemical, paints, food and beverage industries had significantly high COD, BOD and suspended solids above the maximum permissible limits. While the chemical and paints industries could be a potential source of lead pollution in Gaborone. Temperature and acidity generally were not a problem for industrial effluents. The pharmaceutical industries met all the maximum and minimum guidelines for wastewater discharge. COD, BOD, suspended solids and heavy metal levels should be monitored strictly by the Gaborone City Council in order to prevent environmental pollution and reduce health hazards caused by pollutants.

Key words: Industrial wastewater, quality, COD, BOD and lead, Gaborone, Botswana

INTRODUCTION

Industries are major sources of pollution in all environments. Based on the type of industry, various levels of pollutants can be discharged into the environment directly or indirectly through public sewer lines. Wastewater from industries includes employees' sanitary waste, process wastes from manufacturing, washwaters and relatively uncontaminated water heating and cooling operations. The processing wastewater is a major area of concern[1]. These may vary widely with the type of industry. In some cases, pre-treatment to remove certain contaminants may be mandatory before the wastewater is accepted into municipal or urban sewage system. In contrast to the relatively consistent characteristics of domestic sewage, industrial wastewaters vary greatly in their characteristics, even for similar industries. These differences may call for assessment of pre-treatment before discharge to the municipal sewage system.

Industrial wastewaters range from high biochemical oxygen demand (BOD) from biodegradable wastes such as those from human sewage, pulp and paper industries, slaughter houses, tanneries, chemical industry, to those from plating shops and textile mills, which may be toxic and require on-site physico-chemical pre-treatment before discharge into municipal sewage system. Pollutants include disease causing micro-organisms (pathogens such as bacteria and viruses), organic pollutants (pesticides), plant nutrients (fertilizers, detergents), organic matter (sewage), solids, oil, high concentration of dissolved salts, heavy metals (cadmium, lead), colour, foam, heat, toxic chemicals (cyanide), casinogenic compounds (arsenic) and radioactive materials (nuclear reactor waste).

Pollution occurs when the discharge of wastewater consists of some or all of the above substances and impair the quality of natural ecological balance and in its broadest sense includes all changes that curtail natural utility and exert deleterious effect on life[2]. Pathogens disturb public health when sewage that contains pathogens is discharged into receiving waters used for recreational or water supplies for domestic use. Degradation of water quality is the unfavourable alteration of the physical, chemical and the biological properties of water that prevents its domestic, commercial, industrial, agricultural, recreational and other beneficial uses[3].

In order to assess the effectiveness of wastewater treatment, a method is needed to determine the amount of oxygen-demanding wastes in water. The amount of oxygen consumed by micro-organisms in decomposing

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organic waste is proportional to the amount of waste present. The biochemical oxygen demand (BOD) of water is the total amount of oxygen consumed by micro-organisms in decomposing waste. The standard procedure is to measure the amount of oxygen consumed in 5 days (BOD_5). BOD indicates the level of organic matter pollution, the greater the value, the greater the problem of decomposition. Pure water has a BOD_5 value of 1 mg L^{-1}, while untreated municipal sewage has a BOD_5 of 100-400 mg L^{-1}. Effluent from industrial or sewage treatment plants of a BOD_5 of less than 20 mg L^{-1} is considered acceptable[4].This activity which is undertaken by bacteria depletes dissolved oxygen. In lakes and rivers, when the BOD_5 falls below 1.0 mg L^{-1}, most fish do not survive. When all dissolved oxygen disappears, anaerobic conditions sets in resulting in a nauseating or objectionable smells, unattractive appearance and dead fish. Solids or suspended solids are organic and inorganic particulates in wastewater which can be sediments or suspended that results in unsightly deposits or odorous sludge banks. This leads to reduction of sunlight through water consequently affecting temperature and productivity (primary).

In addition to the above mentioned pollutants, plant nutrients such as phosphates and nitrates are pollutants because huge quantities enter the hydrosphere in runoff from fertilized fields, municipal sewage and industrial effluents. Phosphate containing detergents are the principal offenders in municipal sewage, contributing to 70% of the phosphorus present[5]. In presence of other favourable abiotic factors such as temperature, pH, sunlight, a little over 0.01 mg L^{-1} phosphates and 0.1 mg L^{-1} nitrate speed micro-organism growth and thereby greatly accelerating eutrophication of natural waters. Nitrogen and phosphorus are the major causes of eutrophication. Eutrophication affects aesthetics on lakes, rivers and results in odour and appearance problems. It is also known that algae can be toxic to animals such as cattle, affects taste of water, plug filtration units and raise the costs of water treatment[6]. Various processes including biological processes and physico-chemical processes have been proposed for removal of nitrogen or phosphorus from wastewater.

Low concentration of acids, caustics (soda), cyanide, arsenic and other heavy metals are toxic to man and other living organisms as well as the microbial population which are used in water treatment plants. Also some of these chemicals are destructive to the sewers because of corrosion.

Chemical oxygen demand (COD) is used to determine pollution level in wastewater. COD gives a good indication of the amount of oxygen needed to stabilise the waste in the water. It oxidises ethanoic acid and polycarbohydrates that are not stabilised by bacteria. COD removals have been used as marks of efficiency or levels of waste stabilisation in reactors. It has been reported COD removal of 41.0 ton COD day^{-1} in three treatment plants in South Africa and 30.9 ton COD day^{-1} in two treatment plants in Argentina and 100.8 ton COD day^{-1} in one treatment plant in Kenya[7]. The objective of this study was to determine pollution indicators in and around Gaborone industrial effluent, generate relevant baseline information on industrial effluents and determine the major sources of industrial pollution in Gaborone, Botswana.

MATERIALS AND METHODS

During this study, eight industries classified as brewery, food and beverage, pharmaceutical, paint and chemical. Their industrial effluents were monitored through regular monthly grab sample collections for six months. Grab samples were collected twice a month concurrently at specified periods during peak production periods of the industries understudy. Handling of samples followed the ISO/IEC 17025:19999 (E) procedures. Each of the industries discharged approximately 100 m^3 of effluent monthly.

The dependent variables analyzed were total suspended solids, chemical oxygen demand, biolchemical oxygen demand, pH, temperature, dissolved oxygen and lead concentration. standard methods were followed in determining the above variables[8]. Sample measurements were determined in triplicate. The Effluent pH and temperature (°C) were measured using WTW pH-Electrode SenTix 41. Dissolved oxygen was measured with WTW Cell Ox 325. All probes were calibrated prior to measurement with the appropriate traceable calibration solutions in accordance with manufacturers instructions. For lead determination, the effluent samples were digested as follows. The samples were acidified with concentrated nitric acid (55%) at the time of collection by adding 5 mL of acid per litre of sample. Then 100 mL of well-mixed sample was transferred to 250 mL beaker. Then 5 mL of distilled water 1:1 hydrochloric acid was added. The samples were then heated in a water bath maintained at 80°C until the volume reduced to 20 mL. The samples were then filtered to remove any insoluble material. The sample pH was adjusted to a pH of 4 by adding 5.0 N NaOH a drop at a time while mixing and checking the pH after each drop of NaOH. Then the samples were quantitatively transferred to a 100 mL volumetric flasks and diluted with deionized water. The samples were then analyzed for lead using atomic absorption spectrophotometer (AA-6650 Shimadzu).

Data collected was subjected to analysis of variance using the general linear models (Proc GLM) procedure of the statistical analysis system program package. Proc Univariate procedure was carried out on residuals to support the assumptions of normality made by the researchers. Where a significant Fisher test was observed, treatment means were separated using the Least Significant Difference at $p = 0.05$.

RESULTS AND DISCUSSION

Gaborone is one of the fastest growing cities in Africa. Presently, eight major industries classified as brewery, food and beverage, pharmaceutical and chemical and paints exist in Gaborone and its environs. Three of these are small scale packaging industries while the rest are large scale abattoirs and breweries. Gaborone City Council monitors the effluent quality from the industries based on discharge guidelines incorporated in the Trade Effluent Agreement signed by industries, upon which they are permitted to empty into council sewers.

The effluent pH differed significantly with the type of industry (Table 1). The pharmaceutical industry effluent had a higher effluent pH than brewery, chemical and paints and food and beverage industries (Table 1). However, the effluent pH from the brewery, chemical and paints and food and beverage industries did not differ significantly, though the effluent discharged to the public sewer from the brewery was more acidic, while that from chemical and paints and food and beverage industries was more neutral (Table 1). The pH of the effluent discharged into the public sewer from all the industries under study were within the maximum permissible limits of pH 6.0-9.5 (Table 1). The pH of the effluent affects the availability of plant nutrients and heavy metals and growth of algae and micro-organisms.

The effluent temperature from the four type of industries in Gaborone did not significantly differ and were below the maximum permissible limit of 35°C (Table 1). Heat or thermal pollution, contributes to oxygen depletion in three ways; firstly relatively small increases in temperature kill certain species of fish, leaving oxygen-demanding wastes to decay; secondly high temperatures raise the metabolic rate of surviving fish and micro-organisms, leading to increased oxygen consumption and thirdly oxygen is less soluble at higher temperatures. Most thermal pollution comes from the discharge of water that has been used for cooling in industrial plants and power plants.

The dissolved oxygen concentration in the effluent from the four type of industries differed significantly (Table 1). The effluent from chemical and paints and food and beverage industries had significantly low dissolved oxygen compared to effluent from brewery and pharmaceutical industries and were significantly below the minimum permissible limits (Table 1). The low dissolved oxygen in the effluent discharged by chemical and paints suggests that the industries may be releasing toxic chemicals into the public sewer leading to death of organisms in the effluent hence increase in oxygen-demanding wastes. The low dissolved oxygen from effluent in the food and beverage industries suggests that the industries are releasing a lot of organic substances (food remains, meat, fruit and vegetable waste, sugars, etc) which are high oxygen-demanding wastes. The pharmaceutical industries effluent was high in dissolved oxygen compared to the other industries under study because they pretreat their effluent before releasing it to the public sewer. The dissolved oxygen level for the pharmaceutical and brewery industries were within the minimum permissible limits. The results of this study suggests that the Gaborone City Council should monitor closely the effluent from chemical and paints and food and beverage industries and enforce them to comply with the agreed guidelines for effluent discharge into Council sewers.

The chemical oxygen demand (COD) differed significantly among the industries under study (Table 1). Brewery and chemical and paints industries effluent had significantly high COD compared to the pharmaceutical industries and significantly above the maximum permissible limits. The COD values from effluent from brewery and chemical and paints industries were about 2 times and 5 times higher than effluent from food and beverage and pharmaceutical industries, respectively (Table 1). The biochemical oxygen demand (BOD) also differed significantly among the four industry types and almost followed the same trend as COD (Table 1). The effluent from brewery, chemical and paints and food and beverage industries had significantly higher BOD than pharmaceutical industries (Table 1). The BOD for brewery, chemical and paints and food and beverage industries were higher than the maximum permissible limits. The results based on COD and BOD suggests that brewery, food and beverage and chemical and paints industries are discharging organic pollutants into the Council sewers and/or releasing chemical toxicants leading to the death of organisms in the wastewater hence resulting in a high level of oxygen demanding wastes in the effluent. It has been reported that industrial pollution in China was extremely severe[7]. Many financially struggling industries discharge extremely high-strength effluents into the environment with limited treatment[7]. The Gaborone City Council should enforce the brewery, chemical and paints and food and beverage industries to pretreat their wastewater before discharge into the Council sewers in order to prevent environmental pollution.

Table 1: Characteristics of industrial effluent entering public sewer in Gaborone, Botswana

Industry	pH	Temperature (°C)	Dissolved O_2 (mg L^{-1})	COD (mg L^{-1})	BOD (mg L^{-1})	Suspended solids (mg L^{-1})	Pb (mg L^{-1})
Maximum limits	6-9.50	<35.0	6.0-9.5	<1000	<500	<1000	<1.500
Brewery	6.60b	25.5a	6.31b	6769a	2558a	2069a	0.000b
Chemical and paints	6.92b	28.5a	2.37c	6269a	960bc	2185a	0.072a
Food and beverage	7.02b	24.3a	4.50bc	3521ab	1816ab	974ab	0.000b
Pharmaceutical	9.30a	26.9a	9.00a	623b	350c	112b	0.000b
Significance	****	NS	****	*	**	**	****
LSD	1.14	6.27	2.52	4362	1381	1479	0.014

*, **, ***,****, NS Significant at p = 0.05, 0.01, 0.001, 0.0001, or Non-significant, respectively. Means separated using the Least Significant Difference at p = 0.05; means within columns followed by the same letter(s) are not significantly different

The suspended solids in the effluent from brewery and chemical and paints industries were significantly higher than the pharmaceutical industries and the maximum permissible limits (Table 1). However, the suspended solids level from brewery and chemical and paints industries did not differ significantly. The suspended solids from food and beverage industries was just below the maximum permissible limit (Table 1). The suspended solids of the effluent from the pharmaceutical industries was significantly lower and below the maximum permissible limit again showing the importance of pretreatment of wastewater by the industries before discharging it to the Council sewers.

Among the four types of industries under study, lead was only detected in the effluent from chemical and paints industries (Table 1). Though, the lead levels from the chemical and paints industries were below the maximum permissible level, it has the ability to increase in the food chain when disposed to the environment[4]. It is therefore, concluded that brewery, chemical and paints and food and beverage industries are the major sources of high COD, BOD and suspended solids discharge. While the chemical and paints industries could be a potential source of lead pollution in Gaborone. Temperature and acidity generally were not a problem for industrial effluents. COD, BOD, suspended solids and heavy metal levels should be monitored strictly by the Gaborone City Council in order to prevent environmental pollution and reduce health hazards caused by pollutants.

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