Investigation of disposal processes by manufacturing companies in Gaborone

Dikabo Mogopodi[1], Banyaladzi Paphane[2], Terrance B. Mmolawa[3], Oratile Lenamile[4]

Department of Basic Sciences, Botswana University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana

Abstract— *Industrial processes create variety of solid and liquid wastes; which may contain pollutants that have potential harm to humans, animals and the environment. Hence the challenge for disposal of waste for industries cannot be ignored. In these studies, a survey was conducted in the capital city of Botswana; Gaborone to investigate waste management practices for selected manufacturing companies. The findings indicate that companies disposed waste in different ways; 50% out-sourced waste collection services, while 8.3% disposed to waste treatment plants, 33.3% in sewage lines and the other 8.3% in the open flat land. Only 33.3% uses ponds to deal with its effluent and consequently recycle it. Of the companies surveyed, 33.3% of the companies indicated that they have hazardous wastes. Preliminary investigations on contaminates that find their way into the city's sewage system shows that, Pb concentrations did not exceed maximum allowable concentrations of 5.0 mg/L, whereas Cd and Cr concentrations exceeded the maximum allowable concentration of 0.01 mg/l and 0.1 mg/l in irrigation water respectively.*

Keywords— Effluent, pollutants, waste management.

I. INTRODUCTION

Gaborone, the capital city of Botswana has experienced rapid growth in its economy and in its population. With the rapid industrial development and expansion of cities comes the increased challenge of waste generation and hence waste management. Therefore, appropriate waste handling, storage, collection and disposal practices become necessary in order to minimise environmental and public health risks. Improperly managed waste usually results in downstream costs being higher than what it would have cost to manage waste properly in the first place [1]. In Africa data on waste management is not readily available and in Botswana a few studies have focused on waste management [2,3] and none of these have exclusively concentrated on waste generated by industries. There is however a rational agreement as evidenced by waste management strategy and policy development by Botswana government that, inefficient waste management in the country threatens public health. With industries being the fundamental waste generators, it is of critical importance to determine ways in which they manage their waste particularly in the city in order to analyze industry trends and implement appropriate policy mechanisms. A report by Botswana central statistics office [4] has indicated that the greatest waste generators are urban areas and this is associated with rising demands for goods in urban areas. The city of Gaborone alone generates 85 tonnes of waste per day [5]. Waste generation is estimated to increase at a rate of 7 % per annum [6].

Industrial waste is a cause for concern as it is a common cause of pollution. Common contaminants which are either organic or inorganic include petroleum hydrocarbons, polychlorobiphenyls, polycyclic aromatic hydrocarbons, [7] heavy metals [8], surfactants, toxins and salts [9] which can be introduced into the essential elements of the ecosystem including soil, water and biodiversity causing severe degradation in the ecosystem. A wide variety of unsafe inorganic contaminants which may be produced include heavy metals, such as arsenic, lead, cadmium, and mercury. These metals can accumulate in agricultural soils; become available for plant uptake and run off into water ways. As crops and plants extract these toxic metals from the soil and enter the food supply chain, the chance of impacts on human health increases. These metals are known to be potentially toxic to humans contributing to cancer, developmental effects, birth defects, reproductive problems and liver and kidney damage [10]. Industrial waste of organic composition on the other hand can result in the presence of excess nutrients in water which consequently lead to algal blooms, oxygen deficits and increase in color and turbidity in water sources [11]. The understanding of waste management process in companies is therefore an important step in ensuring human and environmental health. The goal is to minimize the pollution introduced into natural waterways and into the environment.

Scarcity of water is another major problem in Botswana [12]. The industrial processes utilize a lot of water as raw material and consumption often exceed capacity to replenish water. Thus industries play a major role and are hence significant from the water consumption and effluent discharge point of view. Amongst other types of waste produced by industries, industrial

effluent is one of the main important ones. If the effluents are discharged into natural watercourses, surface and ground water pollution will result. This will be a huge problem in Botswana as the country is largely dependent on groundwater sources for their livelihood, particularly the farming community and rural populations in Botswana. The introduction of toxic substances from industrial effluents to agricultural environments will only add to their concentrations in underground water and cause damage to aquifers which the country is working so hard to protect. To overcome challenges associated with waste management and raw materials depletion, many industries are following the hierarchy of waste management; that is reducing the waste quantity, reusing or recycling and often recovering their waste as well treating their waste before disposal. If these strategies are implemented, Botswana will maintain its pristine and healthy environment to be enjoyed by future generations. Therefore from this view point a study was carried out to investigate industrial waste management practices in selected industries in Gaborone and assess whether industries are knowledgeable in waste management practices.

II. MATERIALS AND METHODS

2.1 Survey of waste management practices for selected manufacturing companies

2.1.1 Description of the sample and Research design

The target population was 15 industries which included manufacturing industries and one water treatment plant in Gaborone, the capital city of Botswana. The companies were picked from different locations of Gaborone; 5 from Gaborone north, 5 from Gaborone central and 5 from Gaborone South even though only 12 questionnaires were returned. The companies included battery manufacturing companies, chemical producing companies, food processing (which were poultry processing, milling company and drink producing company) and those of non-food solid products (that is cement producing, plastic and soap industries) as well as fibre glass processing company. The researchers used quantitative non-experimental design for sampling and research design (Johnson and Christensen, 2000).

2.1.2 Sampling procedure

The research design used was case study to allow an interactive data gathering of data. Probability sampling method in the form of simple random sampling was used to select 15 industries as the population study. Then seven of the industries which were part of the sample were chosen using purposive sampling so as to obtain homogenous groups of manufacturing industries. The survey was directed to staff holding managerial or supervisory posts or middle management.

2.1.3 Survey Instrument and Design

A self-administered questionnaire was used to collect data from the sampled companies in order to obtain information about participant's feelings, perceptions and attitudes. The questionnaire consisted of two parts of closed ended questions. The first part was used to describe the demographic characteristics of the respondents such as gender, while the second part was used to enquire on waste handling and disposal processes. The questions were tested for content validity by circulating it among 5 lecturers at the Botswana University of Agriculture and Natural Resources, Basic Science Department to examine the questionnaire for errors and for content validity. The reliability of the instrument was determined by conducting a pilot test on 3 industries which were not part of the sample but similar to the sampled group in Gaborone area. The feedback from the pilot test was used to improve the final questionnaire. The format of reliability that was used is test re-test. Then results of the 2 test re-test were correlated to test the consistency of the respondents on the same questions.

2.1.4 Data collection procedure

Data was collected through a self-administered questionnaire to provide a personal conduct with the participants.

2.1.5 Data analysis technique

Statistical Package for Social Sciences version 16 (SPSS) was used to analyze quantitative data. Descriptive analyses in the form of frequency were used on demographic data and on likert scale responses.

2.2 Water and plant analysis of samples collected from sewage plant treatment

2.2.1 Sampling

Because companies indicated disposal of effluent to the Gaborone City's sewage network, a study was conducted to quantify the heavy metals in present in treated sewage water collected from the irrigation system at Oodifarms.

2.2.2 Laboratory Analysis of Sewage Water

The water samples were filtered through a 0.45 mm whatman filter paper to remove all the suspended solids and acidified with 2% nitric acid. The minerals in water were analyzed according to the method developed by American Public Health Association (1976), modified by Lewis (1987). Stock standards (certified single elements purchased from Sigma Aldrich) for Pb, Cd and Cr were used to prepare working standards. For calibration purposes, four standards were used and ultra-pure water acidified with 2 % HNO3 was used as a calibration blank. Inductively coupled plasma optical emission spectrometry (ICP-OES) was used to determine heavy metal levels in sewage water.

III. RESULTS AND DISCUSSION

3.1 Demographics characteristics of respondents

Results as shown in TABLE 1 indicate the demographic characteristics of respondents. Gender data showed some biasness in people holding managerial or supervisory posts from companies in Gaborone because 92% of respondents were males and only 8% were female.

The most common age of participants ranged between18 and 44 years with 67%, followed by 33.3% of age 45 years and above. This could be due to the fact that the working class is concentrated around 18 to 44 years of age. This age bracket represents the youth age within the population with potential to be trained in waste management practices.

TABLE 1
DEMOGRAPHICS CHARACTERISTICS OF RESPONDENTS

Gender	**Frequency**	**Percent**
Male	11	92
Female	1	8
Total	12	100.0
Age categories		
18 - 34 35 - 44 45 - 54 Above 55	4	33
	4	33
	2	17
	2	17
Total	12	100
Occupation		
Sales Manager	2	17
Production Manager	5	42
Managing Director	1	8
Bio-Security Officer	1	8
Risk project manager	2	17
Risk Control Officer	1	8
Total	12	100

3.2 Nature of Companies

The companies were grouped into 3 categories as shown in TABLE 2. The outcome of the study has shown that 75% of the companies sampled produce non-food products. These non-food processing industries heavily relied on the use of chemicals and therefore chemical waste handling and disposal become very important. The main materials used are also shown in TABLE 2; 58 % of the manufacturing companies involved in the study used solids such as fibre glass, cement and crop grains as their main material for production. 33 % used liquid and 8 % used both liquid and micro-organisms especially viruses to make animal vaccines.

TABLE 2
NATURE OF COMPANIES AND TYPE OF MAIN/RAW MATERIALS USED

Nature of company	Frequency	% of total companies surveyed
Food processing	3	25
Non food solid producing	6	50
Non food liquid producing	3	25
Total	12	100
Main materials used		
Liquid	4	33.3
Solid	7	58.3
Liquid and microorganism	1	8.3
Total	12	100

3.3 Classification of waste disposed by companies under study

3.3.1 Classification by state (liquid or solid)

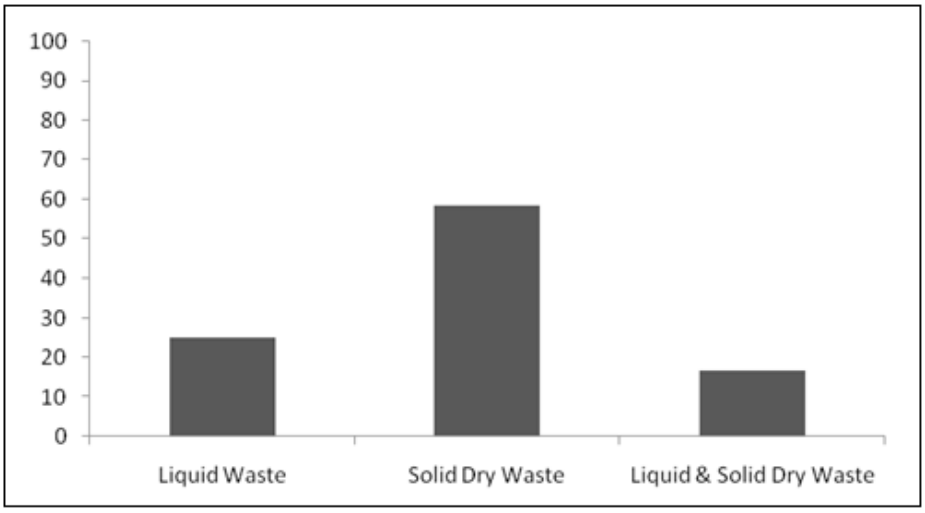

FIGURE 1: Category of waste produced by companies under study

More than 50% of the companies produce solid waste, 25% produce liquid waste and 17% produce both liquid and solid waste as shown in Fig. 1. It is not surprising that the production of solid waste was highest because 58 % of the companies studied used solid as their major raw material. When substantial amount of solid is used this will result in substantial amount of solid waste. A study by Kgati and Bolaane (2001) [13] attributed the deterioration of environmental quality in Botswana to improper solid waste collection and disposal methods used in Botswana. Solid waste is a global problem and in 1996 the Economic Commission for Africa report named Botswana as one of the largest producer of solid waste in Africa.

Some of the solid waste produced has potential of being toxic. Cement for instance, contains a lot of chemicals including calcium oxide, silica, aluminia and iron oxide which have the potential of being environmentally destructive. It contains traces of free crystalline silica, and exposure to respirable free crystalline silica may aggravate lung diseases. Moreover, adding water to cement results in hydration and produces caustic calcium hydroxide which contains trace metals known to cause cancer [14]. Fiberglass dust also is an acute physical irritant to the eyes, skin and respiratory tract. It is normally used with other chemicals during fabrication such as organic peroxide, cobalt compounds and acetone. All these chemicals are health hazards when inhaled and are also flammable or explosive [15]. Moreover the majority of municipal plants in Botswana treat the settled sewage liquid using aerobic biological processes where microorganisms which will only consume biodegradable soluble organic contaminants and leave out the inorganic contaminants. Thus hazardous materials of chemical nature are left untreated. When this happens the inorganic contaminants will move into the food chain and consequently affect living organisms [16].

3.3.2 Classification by nature (hazardous or non-hazardous waste)

Results as shown in Fig. 2 indicated that 33.3% of the companies produce hazardous wastes. Hazardous materials produced include sulphuric acid, clinical wastes, used turpentine, fibre glass off cuts, used viruses and used oil. Production of hazardous waste was not exclusive to non-food industries as some food processing industries also indicated that they produce

hazardous waste. 42% of the companies did not answer the question on whether or not they produce hazardous waste and thus they could not answer subsequent question on how they dispose such hazardous waste. Obviously this is a sensitive issue which could be tied to the respondents knowing that there is existence of non-compliance or it just might be a personal choice. Furthermore, the brewing company indicated that they have measures in place to assess hazards present in effluents and detected contents of their effluent before it is discharged to the municipal sewerage line.

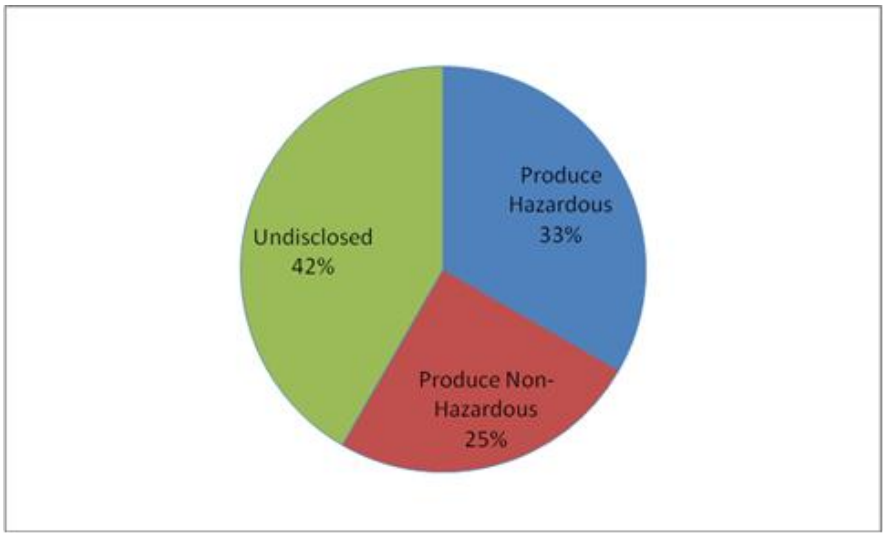

FIGURE 2: Nature of waste produced by companies under study (Hazardous and non-hazardous waste)

3.4 Waste management methods of waste by companies

TABLE 3
WASTE MANAGEMENT METHODS USED BY COMPANIES UNDER STUDY

Waste management methods	Percent
Flash through the drainage system	16.7
Dispose to waste treatment plant	8.3
Use of big containers	16.7
Outsource a company	50.0
Dispose to waste treatment plant &Out source a company	8.3
Total	100.0

A total of 58.3 % of the companies indicated that they out-source services from other companies for waste collection and disposal. This is a smart move because engaging specialists make one to focus on his core business as specialists will take care of the waste including hazardous waste material. 17 % of the companies indicated the use of special containers specially designed for safe handling and transportation of hazardous wastes such as tankers which are used for hazardous liquid waste in order to avoid spillage of such waste in public areas and in trucks. Safe transportation of hazardous waste is an important national issue, the movement of hazardous materials encompasses greater safety concern because hazardous waste can be used for terrorism purpose in this era.

A total of 33.3 % of the companies flash their liquid waste through the drainage where it will be taken to the city sewage waste water treatment plant. The challenge is that these companies do not have instruments which check the properties of this liquid waste. It is vital to have knowledge of waste contents because it assists in separating wastes and knowing how and where to dispose it. When every waste material is disposed inappropriately, chances of pollution are minimised. 17% of the companies used big containers for storage of waste. Containerization is an important aspect in maintaining the integrity of the waste. This waste in containers as the respondents indicated is then subsequently collected by other companies so as to use the waste as raw material for recycling. Some of this waste included paper and plastic material. Materials exchanges are an effective and inexpensive way to find new users and uses for waste. Byproduct recovery as a fall out of manufacturing process creates ample scope for revenue generation thereby offsetting the costs substantially. In Botswana, private sector that are currently recycling generate over 3 million BWP in annual turnover. Recycling plays a big part in the environment particularly when recycling wastes which are non-biodegradable and hard to get rid of. Furthermore the volumes of recycled materials are usually lower than those generated from recycled waste.

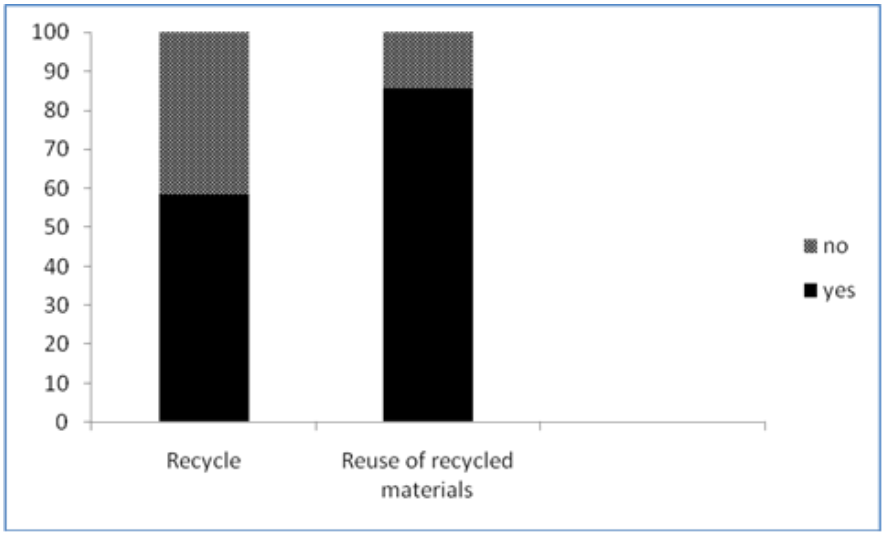

FIGURE 3: Indications of whether companies recycle their materials and whether they re-use materials

As shown in Fig. 3; 58.3 % of the companies indicated that they recycle their waste and 85.7 % of these indicated that they reuse the recycled materials. Of the companies that recycle waste, 17% recycle liquid waste and 33% recycle solid waste. Among this was a brewing industry which indicated that it recycles its effluent and uses it for irrigation and cleaning. Being very rich in organic matters, the utilization of effluents from alcohol manufacturing in agricultural fields creates organic fertilization in the soil which raises the pH of the soil, increases availability of certain nutrients and capability to retain water and also improves the physical structure of soil. Before use, the company indicated that the effluent is diluted 2-3 times before application on crops. The irrigation with brewery industry wastewater seems to be an attractive agricultural practice which not only augments crop yield but also provides a plausible solution for the land disposal of the effluents. One cubic meter of methanated effluent from alcohol brewing contains nearly 5 kg of potassium, 300 grams of nitrogen and 20 grams of phosphorus [17].

More than 80% of participants were in agreement that recycling reduces cost of buying materials as recycled materials can be reused in the company as shown in Fig. 4. Recycling makes industrial processes more resource-efficient.

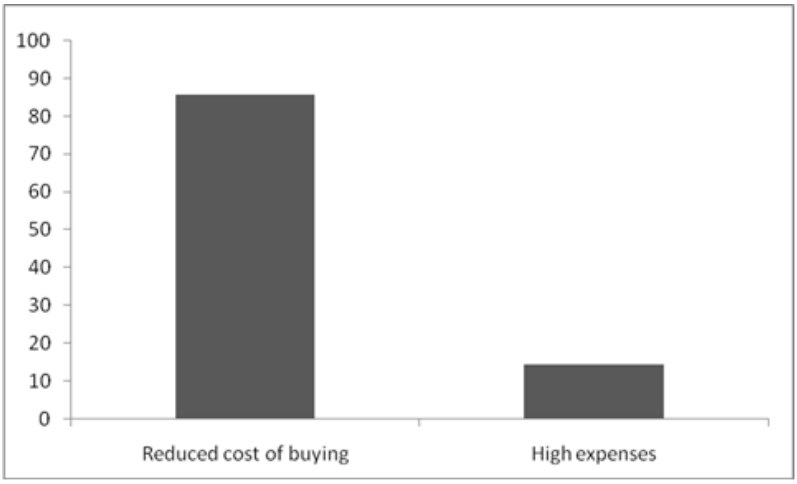

FIGURE 4: Result of recycling materials economic projection

A poultry processing company showed that it uses ponds to deal with its effluent and then treat it to produce water which is reused for irrigation. They also indicated that they produce sludge which is dried and used as organic fertilizer. This can enhance soil nutrients. Poultry manure is known to improve soil retention and uptake of plant nutrients and increases the number and diversity of soil micro-organisms [3] and this is particularly attractive for Botswana soils which are known to have low phosphorous content.

The study indicates that of the companies that had their waste material in a liquid form, 50% treated their waste before disposing it to minimise harm to the end source. 33.3% showed that it uses ponds to deal with its effluent and consequently

recycle it. By treating the effluent prior to disposal, the toxicity is decreased and this can reduce potentially harm to the environment. Treatment can also make a waste amenable for reuse or recycling.

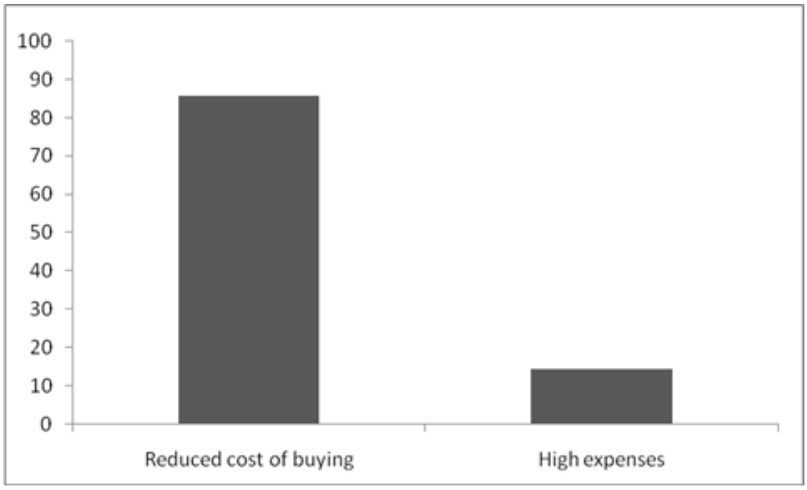

FIGURE 5: Result of recycling materials economic projection

Of the companies that treated disposed effluent, 17 % disposed treated effluent in natural streams, 67 % in sewage lines and the other 17% in the open flat land as shown in Fig. 5. If the effluent is not well treated considering that it goes into natural streams, it has potential to harm living organisms and domesticated animals and plants in that area.

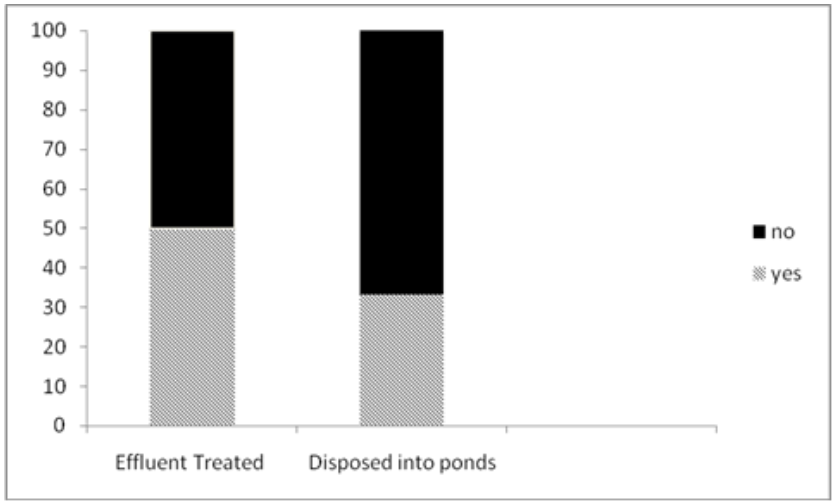

FIGURE 3: Evaluation of treatment and disposal by various industries

3.4.1 Concentration of Heavy Metals in Water collected from the city sewage waste water treatment plant

TABLE 4
HEAVY METALS CONCENTRATION (mg/L) OF SEWAGE WATER

Sample No	Lead	Cadmium	Chromium	Nickel
1	0.13	0.027	0.75	0.16
2	0.11	0.087	0.05	0.03
3	0.16	0.057	0.16	0.06
4	0.04	0.001	0.01	0.01
5	0.09	0.003	0.07	0.05
6	0.35	0.007	0.39	0.03
7	1.31	0.013	0.54	0.07
8	0.21	0.009	0.02	0.02
MRC*	**5.0**	**0.01**	**0.10**	**0.20**

Maximum Recommended Concentration in Irrigation water (FAO, 1992)

Based on the fact that 33.3 % of the companies indicated that they flash their liquid waste through the drain where it will be taken to the city sewage waste water treatment plant, preliminary screening was conducted to quantify the heavy metals in treated sewage water collected from the city sewage waste water treatment plant using ICP-OES. The results were considered significant at $P < 0.05$ levels. The heavy metals concentration ranges of sewage water are as shown in TABLE 4. The data showed that Pb concentration ranged from 0.04 to 1.31 mg/L. whereas, Cd concentration ranged from 0.001 to 0.087 mg/L. Cr concentration ranged from 0.01 to 0.75 mg/L and Ni concentration ranged from 0.01 to 0.16 mg/L. The data were classified into safe and unsafe classes for irrigation by using maximum permissible concentration (MRC) of FAO [18]. This data shows that, Pb concentrations did not exceed maximum permissible concentrations of 5.0 mg/l, whereas Cd and Cr concentrations exceeded the maximum allowable concentration of 0.01 mg/l and 0.1 mg/l in irrigation water respectively.

3.4.2 General perception of participants on waste management

TABLE 5
DESCRIPTIVE STATISTICS FOR GENERAL PERCEPTION QUESTIONS

	N	Minimum	Maximum	Mean	Std. Deviation
Waste is separated into recyclable & non-recyclable before disposal	12	1	4	2.67	1.073
Better to handle effluent by disposing it at water treat plant than treat on site	11	1	4	2.18	1.328
In particular, type of raw material used reduce the difficulty of waste disposal	12	1	4	3.17	1.115
There are special ways of disposing hazardous waste materials so not to harm environment	12	1	4	3.42	.900
The company is currently doing something to minimize amount of effluent disposal	12	1	4	3.17	1.030
There are waste materials in the company which other companies can make use of	12	2	4	3.33	.888
All employees are properly empowered with necessary skills of disposing waste	12	1	4	3.08	1.084
The company flushes all its liquid waste in the city sewage system line	12	1	4	2.17	1.337
There are specific sites licensed to accept waste or effluent	12	1	4	3.33	.985
There are special legal requirements for transporting waste generated by the company	12	1	4	3.25	.965
The ways used by the company to dispose waste meet legal requirement	12	1	4	3.58	.900
Company have difficulty in understanding some waste management laws	11	1	2	1.55	.522

Through the average mean of data analysis in TABLE 5, the general perceptions of the participants was that they are well aware of good waste management practices and were knowledgeable in the laws and standards associated with it. The perception study also showed that participants had knowledge on correct methods of waste disposal as they appreciate the need to separate waste and out-source relevant companies to deal with waste. In a study investigating motivating factors and barriers to recycling behaviour, it was found out that a lack of knowledge and a lack of personal salience and efficacy were barriers that interfered with the motivating effect of a person's sense of responsible action and conservation ethic [19]. Knowledge therefore can be considered the first step in realizing the cultural transformation that is necessary for waste management reforms. Thus based on the companies' awareness on waste management issues it is believed that they will have an internal sense of responsibility to engage in best waste management practices. Companies also perceived recycling waste material as a good practice and agreed that waste has to be separated into recyclable and non recyclable materials as evidenced by mean of 2.67 which suggest that a culture of waste segregation exists. Source separation is important in order to ensure the quality of the final recycled product. It must be noted though despite participants embracing the principles of reclycling, 50% of the companies showed that they do not recycle. This suggests that they could be barriers that exist such as lack of finances which need to be investigated. Companies are of the view that their waste materials can be useful to others companies shown by a mean of 3.33. Companies agreed that the type of raw material has an effect on the method of waste disposal shown by a mean of 3.17. All the companies have indicated that they regularly sensitise their workers about waste (mean 3.08).

IV. CONCLUSIONS

The study is an important step in appreciating waste management issues in the industry. It can be seen from the results of the survey that companies are knowledgeable in waste management practices. This results of sewage water analysis showed that Cd and Cr concentrations exceeded the maximum allowable concentration of 0.01 mg/l and 0.1 mg/l in irrigation water respectively. Further work needs to be done to probe into the quantities of waste generated, companies' waste management policies and investigate on barriers that may hinder the adoption of good waste management practices. Similar studies should be conducted in rural areas in order to develop appropriate interventions. The current findings can be used as a foundation to facilitate more effective and appropriate waste management practices like recycling and reuse.

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