An Environmental Assessment of Solid Wastes at the Koggala Export Processing Zone in Sri Lanka

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ABSTRACT

Industrial zones and industrial parks are the major aggregation bodies of modern development in Sri Lanka. Koggala Export Processing Zone (KgEPZ) is one of the key areas, which is situated outside Colombo in which more than 20 industries operate. As an industrial zone, KgEPZ disposes high amounts of industrial waste daily in which solid waste comprises the majority. These wastes may pose a potential hazard to human health and to the environment when they are improperly treated, stored, transported or disposed off or managed. This study outlines the nature, types, composition and properties of industrial solid wastes disposed from the KgEPZ. Further disposal methods of solid wastes, design and development of models for effective industrial waste management, treatment and regulations for disposal of industrial waste are being discussed.

This study indicated that the total waste generations from the factories were 7,425 kg per day, from which 51% was disposed directly into the main dump yard of the zone. The highest portion of the solid waste generated in the KgEPZ is fabric waste, comprising 56% of the total waste, followed by food waste (28%), and paper and cartons (5%). The chemical analysis of the waste samples obtained from the zone indicates that some chemical components can pose health and environmental risks. Waste recycling and composting activities will be encouraged in the KgEPZ since this approach is considered to be the corrective measure in attaining sustainability in waste management. Appraisal of the whole situation with reference to the Sri Lankan scenario is attempted, so that a better cost effective strategy for waste management can be evolved in the future.

INTRODUCTION

Environmental pollution is the major problem associated with rapid industrialization, urbanization and rise in living standards of people. Industrialization has caused serious problems related to environmental pollution. (Levienvan and Nalaka, 2000). The problems related to disposal of industrial solid waste are associated with lack of infrastructural facilities and negligence of industries to take proper safeguards (Beg et al., 2003). In Sri Lanka, generation of Industrial Solid Waste (ISW) is increasing; however its management is very poor. With increasing demand for raw materials for industrial production, the nonrenewable resources are dwindling every day. With the expansion of the production scale in modern society, the confrontation between the human needs and the environment becomes more acute. This leads to a huge burden on energy, natural resources and the environment. All of these have threatened mankind’s subsistence and development.

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The large and medium industries located in identified (conforming) industrial areas have some arrangements to dispose solid waste. However, the problem persists with small-scale industries. In Sri Lanka, in a number of cities and towns, small-scale industries find it easy to dispose waste haphazardly. It makes difficult for local bodies to collect such waste, as it is not their responsibility. In some cities, industrial, residential and commercial areas are mixed, and therefore all waste gets intermingled (Austine et al., 2000). Hence, the Government bodies such as the Central environmental Authority (CEA) require working out a strategy for organizing proper collection and disposal of industrial solid waste.

Similarly, in waste management, functional elements such as discharge, collection, transport, treatment, final disposal and illegal dumping may result in the pollution of air, soils and water bodies. Lack of such effective methods for the treatment of industrial waste has caused severe socio-economic and ecological problems (Halla and Majani, 1999; Perera 2003).

Management of Industrial Solid Waste is not the responsibility of local administrative bodies. Industries generating solid waste have to manage such waste by themselves and are required to seek authorization from CEA under the relevant rules (CEA 1995). However, through joint efforts of CEA’s, local bodies and the industries, a mechanism could be evolved for better management. Therefore, the ecological degree of the material’s whole life periodicity is an indication that can evaluate the environmental quality.

In Sri Lanka, one of the key institutions involved in promoting industrial development and environmental management is the Board of Investment (BOI). The BOI was established under the Greater Colombo Economic Commission (GCEC), Gazette No: 4 of 1978 with the objective of attracting foreign capital and investors, promoting industrial development and generating employment. The BOI develops and manages industrial zones and industrial parks to facilitate export oriented industrial growth in the country. Presently such zones can be found in Katunayake, Biyagama,
Koggala, Pallekelle, Malwatte, Wathupitiwala, Seethawaka, Mawatagama, Polgahawela, Horana and Mirijjawila (BOI, 2009).

The BOI assumes responsibilities for identifying, approving, acquiring and developing sites, approving industries and monitoring and managing sites. It develops infrastructure within the industrial estates as well as power, water, telecommunication facilities and sewerage lines, and also provides services that may include maintenance of the public areas and infrastructure to provide overall security and central treatment of solid and liquid waste. The BOI has its own Environment Department in order to address the environmental issues and to provide guidance to the investors in implementing measures to mitigate any adverse environmental impact.

At the preliminary stage of the zone implementation, the project envisages setting up of industries on agriculture, gem and jewellery, fisheries, soft toys and novelties, electronics, handicrafts, food beverages, tobacco, textile, leather products, rubber and plastics, PVC products, non-metallic mineral products fabricated metal products and machinery. Today more than 20 industries operate in Koggala Export Processing Zone (KgEPZ). Further KgEPZ has also some other industries such as raw materials for perfumes, tensile gauge products, weighing unit products, melamine products, plastic water tanks, plastic toys, boat manufacturing and rubber product storage.

As an industrial zone, KgEPZ disposes high amounts of industrial and domestic waste daily, especially solid wastes. These wastes may harm the environment as well as the health of the employees in the KgEPZ and therefore environmental analysis of solid waste in Koggala EPZ is of paramount importance. This research work is aimed at finding out the best disposal method for KgEPZ by identifying the waste, waste types and composition of the solid waste in KgEPZ.

**Study Area**

Located in the South, the Koggala Export Processing Zone (KgEPZ) was established to fulfill the requirement of establishing industries outside the capital Colombo. The zone is situated 16 km south to the Port of Galle that is envisaged as the nucleus for the development of the Southern Province of Sri Lanka. The location of the KgEPZ covers about 8 km² bound to the Koggala Lake in the north, Pol Oya in the west and a strip of coastal land in the south (Fig. 1).

The mean annual precipitation of the area shows a bimodal distribution with most of the rainfall occurring during the southwest monsoon period from May to July and northeast monsoon from September to November. The annual average rainfall of the area is 2235 mm, having a minimum of 1572 mm and a maximum of 2890 mm. The mean annual evaporation in the area ranges from 88 mm to 158 mm whereas the monthly evaporation is higher during the months of March, while the lowest recorded is in August. The annual average temperature of the area is about 26 °C.

The KgEPZ is associated with typical coastal morphological features such as sand dunes. Inland area to the north and northwest of the lake has an undulating ridge and valley upland topography. Crystalline basement rocks are overlain by unconsolidated sediments and mainly consist of sands, gravels and sand clay.

**MATERIALS AND METHODS**

Solid waste samples were collected once in five days between September 2010 and November 2010 from the different industries of the KgEPZ. These industries include garment manufacturing, tensile gauge and weighing unit production, plastic water tank manufacturing, plastic toy figuring and boat production. Solid waste samples were collected into polyethylene containers from the garbage disposal units of each factory and from the main dump yard. Samples of the leachate were collected from the main dump yard once in seven days between September 2010 and November 2010 into high density plastic bottles.
The wastewater samples were collected once in seven days into 250 ml plastic hydro bios water samples from five different sites in the zone. Wastewater sampling sites included leading drainage channels of the zone, the biological treatment plant and internalized wastewater treatment plant of the tensile gauge and weighting unit producers of the zone.

Wastewater samples were immediately transported in ice chests to the laboratory and processed without delay to assess the baseline chemical parameters. Other physiochemical parameters were analyzed consequently. Standard analytical procedures were followed throughout the laboratory work.

All samples were analyzed mainly for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), nitrate, Dissolved Oxygen (DO), Dissolved Sulphates (DS), Moisture content (MC), Total Volatile Solids (TVS), Carbon (C), Content and the nitrogen (N) phosphates and heavy metals.

RESULTS AND DISCUSSION

Composition of the Solid Waste in KgEPZ

As shown in figure 2, a high portion of the solid waste generated in the KgEPZ is fabric waste, which represents 56% of the total waste generated, followed by food waste 28%. Another 5% of the total waste generation represents the paper and cartoons followed by wood and garden waste, which is 4% whereas plastic waste represents 3% and 2% of metal waste. Electronics wastes, glass and the rubber-leather waste represent 1.5% of the total waste generated in the study area.

The compositions of the solid waste samples were measured using different industries in the KgEPZ.

- Plastic water tank manufacturing
- Boat manufacturing
- Plastic toy figuring’s manufacturing
- Tensile gauge products and weighting unit products
- Garment manufacturing and Main dump yard

has been studied during this work.

![Figure 2: Types of waste generated in the KgEPZ.](image)

Physico-chemical Properties of Solid Waste in KgEPZ

The pH of the solid waste samples in the KgEPZ showed high levels of pH, particularly in the solid wastes of plastic shell manufacturing which was 10.7 and 9.8, respectively during the sampling period (Fig. 3). Much higher acidity levels were represented by the plastic toys figuring waste dumps (pH=4.2). Acidity in plastic toy figuring is due to the acids used in the manufacturing process for the cleaning purposes.

Optimal pH values for composting range from pH 5.5 to 8.0 as bacteria favor a near neutral pH, whereas fungi favor an acidic pH range. The pH of the Main dump yard waste composted in the KgEPZ ranged between pH 5.8 and 8.2. The effects of extreme pH on the composting process were directly related to the effect of pH on microbial activity or, more specifically, on microbial enzymes. Initially the pH was acidic as a result of degradation of the cell sap of the plant residues. The pH dropped further as a result of acid forming bacteria. It is then increased and became alkaline and finally dropped back to near neutral as a result of humus formation.

Electrical conductivity (EC) of the solid waste samples obtained from the KgEPZ is high in the tensile gauge products and weighing unit products samples. Their EC value was higher than the other factories in the zone (Fig. 4).
lower EC values was shown by the Plastic water tank production. However the overall EC of the KgEPZ ranged between 0.1 to 1.6 mS/cm. Electrical conductivity is the most common measure of salinity and was indicative of the ability of an aqueous solution to carry an electric current. Plants were detrimentally affected both physically and chemically, by excess salts in some soils and by high levels of exchangeable sodium in others. Soils with an accumulation of exchangeable Na were often characterized by poor tilt of the area and low permeability making them unfavorable for plant growth.

**Figure 3.** Variation of the pH values of the solid waste samples obtained from different industries in KgEPZ (PS – Plastic water tank manufacturing; BBY– Boat manufacturing; UPMP – Plastic toy figuring’s manufacturing; FLIN- Tensile gauge products and weighting unit products; AOGM– Garment manufacturing; AOMDY – Main dump yard).

**Figure 4.** Variation of the electrical conductivity of the solid waste samples obtained from different industries in KgEPZ (abbreviations as shown in the Fig. 3).
The temperature of the KgEPZ did not show any fluctuation during the study period and the temperature is perhaps the most contentious of all the parameters controlling the rate of composting of solid waste. Ultimately, the composting process is determined by the temperature profile. Changes in temperature are commonly used as a measure of microbiological activity underlying the composting process. Thus, the temperature profile of composting can be used to determine the stability of organic material.

The temperature dictates the distribution of active microorganisms in degradability of the solid waste materials. The benefit of elevated temperatures (>60 °C) in promoting microbial activity and inactivation of pathogens has been a continual source of debate and controversy. The key period of the composting process is based predominantly on microorganisms which grow in the temperature range from 25 to 60 °C. The temperature of the solid waste samples varied between 27 °C to 30 °C. This is actually similar to the room temperature of the area and there was no major effect on solid waste degradation by the temperature of the solid waste samples.

Minimum moisture content of 50 to 55 % is usually recommended for high rate composting of solid waste. The moisture content of solid waste varies depending on the porosity of the reactor feed, free air space, aeration, temperature, and other related physical factors. In the KgEPZ, the moisture content of the solid waste was lower because of the high amount of garment fabrics. High moisture content was shown by the main dump yard solid waste sample due to the high portion of food waste in the sample composition. In plastic water tank manufacturing, boat manufacturing, plastic toy figuring manufacturing and the garment manufacturing a significantly low moisture content, which was less than 40 % was observed. However the tensile gauge products and weighting unit products show that the high moisture content was more than 60 % due to food waste.

Total nitrogen content (Fig. 5) was low in the plastic toy manufacturing waste rather than other industries in the zone due to cleaning materials, thinner based substances and paints. Other industries in the zone had high value of the total nitrogen. The highest value of the total nitrogen was 0.89 %. However, in the boat manufacturing company, the major production waste of the boat manufacturing was not digested with the Kjeldhal digestion. The major production waste was the fiber materials and the wood materials. Wood materials digested by the Kjeldhal method and the fibers remained in the digestion tubes after 45 minutes of digestion. This might be the reason for low total nitrogen levels in the samples.

The carbon contents of the solid waste samples were more than 25 % in the KgEPZ. The carbon content of the solid waste sample was high in the tensile gauge products and weighting unit products. In the tensile gauge products and weighting unit production process, there was no disposal of high amounts of industrial waste, and these waste consisted of food waste and the garden waste. Therefore the carbon content may be higher as compared to others.

Lower carbon content was shown by the plastic toys manufacturing (27 %), and the carbon content of the waste materials in the KgEPZ varied between 77 % and the 27 %. However, the garment manufacturing showed a drop in the carbon content graph during the initial period of sampling. In the garment industry, fabric materials may vary with the production item; hence the different garment industries have different levels according to their production material. The waste samples obtained from the boat manufacturing plant mainly the fiber materials; however, had not combusted during the combustion period of 12 hours at 550 °C. The C:N ratio of the different types of waste generated from different industries of the KgEPZ is shown in Table 1.

Carbon and nitrogen are the most important elements in the biodegradation process of solid waste, as one or the other is normally a limiting factor. Carbon serves
Table 1: C:N ratio of the different types of waste generated from different industries of the KgEPZ.

<table>
<thead>
<tr>
<th>Type of Industry</th>
<th>Total Nitrogen</th>
<th>Carbon content</th>
<th>C:N ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic shell production</td>
<td>0.784</td>
<td>48.6</td>
<td>62:1</td>
</tr>
<tr>
<td>Boat manufacturing</td>
<td>0.697</td>
<td>51.9</td>
<td>75:1</td>
</tr>
<tr>
<td>Plastic toys figuring’s</td>
<td>0.288</td>
<td>42.4</td>
<td>147:1</td>
</tr>
<tr>
<td>Tensile gauge products and weighting unit</td>
<td>0.827</td>
<td>64</td>
<td>77:1</td>
</tr>
<tr>
<td>Garment manufacturing</td>
<td>0.661</td>
<td>43.2</td>
<td>65:1</td>
</tr>
<tr>
<td>Main dump yard</td>
<td>0.76</td>
<td>36.3</td>
<td>47:1</td>
</tr>
</tbody>
</table>

Figure 5: Variation of the Total nitrogen content in the solid waste samples obtained from different industries in KgEPZ (abbreviations as shown in the figure 3).

primarily as an energy source for the microorganisms, while a small fraction of the carbon is incorporated in their cells. Nitrogen is critical for microbial population growth, as it is a constituent of protein which forms over 50% of dry bacterial cell mass.

If nitrogen is limiting, microbial populations will remain small and it will take a longer time to decompose the available carbon. Excess nitrogen, beyond the microbial requirements, is often lost from the system as ammonia gas or other mobile nitrogen compounds and can cause odors or other environmental problems. While the typically recommended C:N ratios for solid waste are 25:1 to 40:1 by weight, these ratios may need to be altered to compensate for varying degrees of biological availability.

In the KgEPZ, the solid waste samples obtained from the main dumping yard consist of all kinds of waste materials generated from the zone such as fabrics, food waste, paper and garden waste. The C:N ratio obtained from the solid waste sample of the main dump yard was similar to the C:N ratio of other production wastes received from all the industrial sites. Woodchips and the garden waste had a high C:N ratio and most of the carbon in a large wood chip would not be available to microorganisms during the time frame of the typical composting processes. This might be the reason for the high C:N ratio of the plastic toy industry.

Total Volatile Solids (TVS) of garment manufacturing were higher than that of the other industries in the zone. Garments consist of different kinds of volatile material particulates as the textile dyes and the paints. Further, the tensile gauge products and weighing unit showed high levels of TVS in the zone since some organic and phenolic solvents were used for their production cleaning purposes. The TVS of the region varied in between 83% to 26%.

Chemical Characteristics of Leachate and Waste Water

The results of the chemical analyses carried out for waste leachates and wastewater collected from waste dumps are shown in...
Table 2. The mean temperature of the leachate samples and the wastewater samples did not show any significant difference. However, the pH value of the samples was comparable with the BOI tolerance limits for industrial and domestic wastewater discharged into marine coastal areas. However, EC of the samples (2250 µs/cm) exceeded the BOI standards.

The BOD was the measurement of the dissolved oxygen used by microorganisms in the biological oxidation of organic matter. A high BOD value suggests that more waste products or pollutants were present in the effluent. The BOD in leachate (9.8 mg/L) was lower than the concentrations present in other wastewater samples. The BOD in the outlet of the wastewater treatment plant (9.8 mg/L) was higher than the concentrations present in the inlet of the wastewater treatment plant. This might be a result of release of organic matter from the biological treatment basin into the discharge pond or it could be due to the accumulation of the faecal waste deposition from the surrounding communities. Generally, the concentrations of BOD for samples were all below the BOI standard.

The mean levels of total dissolved solids and the total suspended solids obtained from the analysis of the leachate and the recommended levels did not exceed in the wastewaters. Phosphate and nitrate contents observed in this study were lower than the WHO (2004) standard limit and nitrates were present in higher concentrations in the leachate sample as compared to others. Similarly, the concentrations of sulfates were below the BOI recommended standards of drinking water (Sri Lanka Standards for potable water – SLS 614, 1983). None of the heavy metals showed significantly high levels in the analysis. Liquid waste generated at the KgEPZ was mainly the septic wastewater and the domestic wastewater. Liquid waste treatment plant is currently in operation at the zone and they discharged their wastewater after purifying them according to the BOI standards.

CONCLUSIONS

The total amount of solid waste currently generated in the KgEPZ was 7,425 kg per day. Fifty six percent (56 %) of the total solid waste generated in the zone was fabric waste and followed by food waste, which was about 28 % of the total waste. The current disposal methods of the solid waste products in a variety of ways and the existing disposal method reflect convenience, expedience, expense, and the lack of scientific technology. Therefore, for a better solid waste management of industrial solid waste, regular monitoring of nature of waste generated in the zone should be implemented.

Management of industrial solid waste is not a responsibility of governing bodies and industries are required to collect and dispose of their waste at specific disposal sites in each factory. Such collection, treatment and disposal are required to be monitored by the BOI. According to this study, there are no properly maintained specific areas in the main dump sites for the proper disposal of the waste. Since these industrial estates do not have adequate facilities for the proper disposal of their solid waste, a proper solid waste disposing and management system should be introduced. However, through joint efforts of BOI, industries, and the other stakeholders such as external waste collectors, a mechanism could be evolved for better management of solid waste in the KgEPZ. By introducing a buy-back system in which the producers are required to buy back the used packaging from consumers for disposal or recycling, the amount of solid waste can be reduced while increasing the recovery rate. Although no major ecological or health hazards are associated with the solid waste in the KgEPZ, a risk of the contamination of groundwater supplies due to leachates from open dumping of solid waste in the KgEPZ could be expected.
Table 2: Chemical parameters obtained (maximum value) for leachate sample and the wastewater sample obtained from the KgEPZ (units in mg/L unless otherwise specified).

<table>
<thead>
<tr>
<th>Chemical parameter</th>
<th>Leachate</th>
<th>FLIN WWT</th>
<th>WWTP inlet</th>
<th>WWTP outlet</th>
<th>Drainage channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>29.3</td>
<td>28.1</td>
<td>28.0</td>
<td>28.5</td>
<td>28.6</td>
</tr>
<tr>
<td>pH</td>
<td>8.57</td>
<td>7.03</td>
<td>5.75</td>
<td>6.78</td>
<td>8.35</td>
</tr>
<tr>
<td>Electrical conductivity (µS/cm)</td>
<td>3219</td>
<td>7378</td>
<td>3724</td>
<td>2683</td>
<td>4002</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td>12.9</td>
<td>13.4</td>
<td>16.3</td>
<td>27.1</td>
<td>18.8</td>
</tr>
<tr>
<td>Biochemical Oxygen Demand</td>
<td>9.8</td>
<td>10.6</td>
<td>15.3</td>
<td>19.0</td>
<td>16.6</td>
</tr>
<tr>
<td>Total dissolved solids (TDS)</td>
<td>284.2</td>
<td>573.1</td>
<td>890.7</td>
<td>634.2</td>
<td>158.9</td>
</tr>
<tr>
<td>Total suspended solids (TSS)</td>
<td>87.6</td>
<td>73.5</td>
<td>92.3</td>
<td>54.3</td>
<td>25.3</td>
</tr>
<tr>
<td>phosphates (PO₄³⁻)</td>
<td>3.23</td>
<td>0.97</td>
<td>4.56</td>
<td>1.27</td>
<td>0.83</td>
</tr>
<tr>
<td>Nitrate (NO₃⁻)</td>
<td>5.43</td>
<td>2.43</td>
<td>4.22</td>
<td>1.74</td>
<td>0.83</td>
</tr>
<tr>
<td>Sulphates (as SO₄²⁻)</td>
<td>0.57</td>
<td>0.03</td>
<td>0.28</td>
<td>0.17</td>
<td>0.35</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>0.108</td>
<td>0.085</td>
<td>0.069</td>
<td>0.023</td>
<td>0.033</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>0.180</td>
<td>0.235</td>
<td>0.034</td>
<td>0.024</td>
<td>0.030</td>
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<tr>
<td>Cadmium (Cd)</td>
<td>0.006</td>
<td>0.011</td>
<td>0.012</td>
<td>0.010</td>
<td>0.006</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>0.254</td>
<td>0.264</td>
<td>0.230</td>
<td>0.225</td>
<td>0.233</td>
</tr>
</tbody>
</table>

(FLIN WWT – internalized waste water treatment plant of the tensile gauge products and weighting unit products; WWTP inlet - the inlet of the waste water treatment plant; WWTP outlet - the inlet of the waste water treatment plant)

REFERENCES


