Toxicity Assessment of Municipal Solid Waste: A Case Study

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Abstract - *The Study emphasis impact assessment of municipal solid waste management system (MSWMS) for compost processing unit at Mysuru city on the environment. Attempt has been made to identify the major toxic pollutant emission from the compost unit by GaBi software. Environmental impacts from the composting unit and the scenario with respect to other major cities has been evaluated. Finally the fate of the composting unit has been studied by integrating the inventories for GaBi software. This work is formulated as per principles, framework of Life Cycle Assessment (LCA) and work carried according to the phases and applications of an LCA (IS/ISO 14040, 2006). The first mandatory element is the selection of a manageable number of impact categories of resource use and second is environmental impact indicators. The selected impact categories are evaluated considering the indicators such as Human toxicity potential (HTP), Fresh water aquatic eco-toxicity potential (FWAETP) and Terrestrial eco-toxicity potential (TETP) other categories as per necessities. The selected categories are quantified for their impact contribution with different inputs and emissions obtained or analyzed from the study area.*

Key Words: **LCA, Toxicity, GaBi, HTP, FWAETP, TETP**.

1. INTRODUCTION

"Municipal solid waste" (MSW) is a term usually applied to a heterogeneous collection of waste produced in urban areas, the nature of which varies from region to region. The characteristics and quality of the solid waste generated in a region is not only a function of the living standard and lifestyle of the region's inhabitants, but also the abundance and type of region's natural resources. Urban waste can be further sub divide into two major components- organic and inorganic. The organic fraction of MSW is an important component, because of its potentially adverse impact upon public health and environmental quality. A major adverse impact is its attraction of rodents and vector insects for which it provides food and shelter. Unless an organic waste is appropriately managed, its adverse impact will continue until it has fully decomposed or otherwise stabilized. Uncontrolled or poorly managed intermediate decomposition products contaminate air, water and soil resources. Solid waste management (SWM) of Mysuru is managed by Mysuru City Corporation (MCC). The total solid waste generated by the Mysore city ranges from 380-400 tons/day. The city practices door to door basis collection in all 65 wards and the waste is segregated only in ward 28. At present 3 tons of waste are being segregated and processed in ward-28 (ASCI 2011). At the present, there is no sanitary landfill facility in the city for disposal of the MSW generated and is processed in the compost facility. The non-biodegradable component of the MSW collected and the rejects from the compost facility are being dumped in the open areas adjacent to the compost facility.
Life cycle assessment (LCA) methodology for municipal solid waste management.

Belagali et al., (2014) in their study, they determined the characterization of essential nutrients and heavy metals during municipal solid waste composting. In their paper the composting process was studied for Municipal Solid Wastes in order to characterize the essential plant nutrients and heavy metals during the degradation process. The process was studied in pre-monsoon, monsoon and post-monsoon seasons and samples were collected during 10th to 60th days of composting process. Primary macronutrients like nitrogen, phosphorus, potassium, secondary macronutrients calcium and magnesium and micronutrients/trace minerals like chlorine, manganese, iron, zinc, copper, molybdenum, nickel were analyzed. Heavy metals like lead, cadmium, chromium, were analyzed by atomic absorption spectrophotometer. From the study the concentrations of essential plant nutrients were found to be under the limits of EPA standards and Canadian Council of Ministers of the Environment (CCME) standards. Heavy metals were also found in trace quantities and humification process caused decrease in heavy metal concentration. From their study, it was observed that composting process was faster during monsoon season and compost produced was better source of plant nutrients.

Yadav et al.,(2013) has made an attempt to evaluate the environmental performance of municipal solid waste management options for Dhanabad, Jharkand, India was enumerated by LCA which an analytical tool (software) for assessing the environmental acceptability of municipal solid waste management (MSWM) options. LCA is currently being used in several countries to evaluate different strategies for integrated solid waste management and to evaluate treatment options for waste fractions. According to the characteristics of solid wastes, and availability of disposal options, Also the identification of opportunities for pollution prevention and reductions in resource consumption while taking the entire solid waste life cycle was conducted. The primary elements of solid waste management are generation, collection, transportation, treatment, and disposal. Different scenarios were developed and reported as alternatives to the current waste management systems. The most prominent is material recovery facility (MRF) and other methods involve source reduction, reuse, recycling, composting, incineration, energy recovery, on-site burial, open burning and bioremediation. They had set a goal to determine the most environmentally friendly option of MSWM system with the help of LCA.

Sanjeev et al., (2015) has analyzed characterization of leachate at various landfill site of Delhi, India. In their paper the study deals with the concentration of various parameters of leachate collected from three almost saturated sanitary landfill sites at Bhalaswa, Ghazipur and Okhla. Leachate from a landfill varies widely in composition depending on the age of the landfill and the type of waste that it contains. It can usually contain both dissolved and suspended material. It has been found that Bhalaswa landfill leachate have highest concentration of different parameters such as total dissolve solid, total solid and electrical conductivity i.e., 9636 mg/l, 10070 mg/l and 14632 mho/cm respectively. These results will be helpful in future for determination of impact on ground water due to percolation of leachate.

2. MATERIALS AND METHODS:

The international standard addresses the environmental aspects and impacts of a product system. Economic and Social aspects are outside the scope of the LCA as per (IS/ISO 14040, 2006). Other tools may be combined with LCA for more extensive assessments.

2.1 Study area

Mysuru is located between 12.18˚ North latitude and 76.42˚ East longitude Mysuru landfill, dump site and composting plant is in a single boundary at Vidyaranyapuram which is situated at foothill of the Chamundi temple, near the Mysuru - Nanjangud highway towards south of the city. Landfill site and composting unit together covers an area of 12 acres and operational unit for composting unit is about 7 acres. The subcontracting for operation and maintenance of compost plant is handled by IL&FS Environmental Infrastructure and Services Limited (Infrastructure Leasing & Financing Services). The company is handling the compost process unit and generates good quality organic compost of 30metric tons every day and seasonal variations can be observed i.e. during rainy season, the production of compost is on average of 10-15 metric tons per day. Leading vendors for compost are cement industries like Coramandel, Zuari and Cripco Pvt Ltd. Local farmers also contribute for revenue by buying compost for agriculture purposes. Annual revenue of around 6lakhs is received by MCC every year.

2.2 Sampling

Totally 6 leachate samples from compost plant were collected within first week of the months: Dec 2015 to May2016. The parameter values of Ammonical nitrogen, Total Nitrogen, Chloride, Fluoride and Heavy metals Cyanide and Mercury, were obtained as Inventory data for the interpretation of results in GaBi software from the CPCB (Central Pollution Control Board) Mysuru, these results are converted into kg/ton of waste. A simple method of Lysimeter was followed to collect the leaching sample **(Kane et al., 2010).** A conical flask with a sieve plate and a connecting pipe to collect the sample to it was used. The flask was placed adjacent to the heap, in an interval of every hour during day time samples were collected from the conical flask through hand pump. Pumped leachate samples were collected in glass bottle of 500ml, and were transferred to laboratory to analyze physic chemical parameters and heavy metals content. Raw leachate was filtered in Watts' man filter paper and diluted to 1:100 ratios. Ambient air quality monitoring in and around compost plant of Mysore city corporation is been carried out by Karnataka State Pollution Control Board Regional Office, Mysore. Air monitoring in an interval of every two months period is been carried under the guidance and supervision of EO, DEO and AEO. Samples are collected at south-west of compost plant near Surya Batteries, Vidyaranyapuram Mysuru. Analysis reports are maintained both at CPCB as well as at the MCC (Mysuru City Corporation) office. Air monitoring dates were obtained for the months of December 2015, February and April 2016.

2.3 GaBi 6 software

The system is a leading tool for life cycle engineering, creating life cycle modeling and balances. GaBi software is developed by (P.E.INTERNATIONAL AG).Word GaBi derived from German word "Ganzheitliche Bilanz" which means: Holistic Balance". Life cycle engineering or assessment is a method for the assessment of the technical, economic and environment impacts of products, services and systems. GaBi software is a modular system made up of plans, processes and flows. As a result, the GaBi system has a clear and transparent structure. Data on the life cycle inventory, the life cycle impact assessment and the weighting models are separated from each other to utilize for the specific assessment in this product as per (ISO: 14044).

The methodology used to perform the LCA (life cycle assessment) of MSWMS (municipal solid waste management system) involves certain methods such as CML (University of Leiden in the Netherlands in 2001) and ReCIPe 1.08 revised version of 2013. Etc. impact categories are selected to identify Environmental toxicity which is measured as three separate impact categories to examine freshwater, air and land. The Characterization factors of selected categories Eco-Toxicity, Human toxicity, and Terrestrial eco-toxicity potential are expressed using the reference unit of kg 1.4-dichlorobenzene equivalent (1.4-DB). Which are used by different countries and equivalent values for various pollutants are derived respectively. Certain methods are derived for global values. These all methods are available in the nexus site in the form of databases. These databases are included in the GaBi software.

3. RESULTS AND DISCUSSION

The segregated waste is feed into the receiving conveyor and conveyed to 85mm trommels. All input component of waste in terms of single unit as kg is programmed into software. The major mass reduction of segregated wastes takes place in the 1sttrommels and accounted about 70%. The further windrowing inventory of output mass is carried as input and is feed into the next trommels or unit operation. The mass in each process is reduced accordingly with respect to performance of windrow process. The reduced mass is set as flow connectivity between each unit operations. The integrated trommels of 20mm & 4mm are considered as 2nd trommels .The mass reduction of SFC (semi finished compost) takes place and accounted about 50% in the 2ndtrommels. The final compost is 30 MT which is a daily average production of compost at the unit.

3.1 Fresh Water Aquatic Eco-toxicity Potential (FAETP)

The GaBi model identifies the impacts of toxic substances on freshwater aquatic ecosystems and CML-Freshwater Aquatic Eco toxicity Potential (FAETP) shown in (Table 3.1). Using the inventory of leachate emissions from the compost unit and the transfer of toxic pollutants to the water describing fate, exposure and effects is been represented. The graph shows that nickel emission into fresh water ecosystem is about -32x10^{-4} Kg DCB eq/ton of waste followed by the copper and cadmium with the impact values -18x10^{-4} and -16x10^{-4} Kg DCB eq/ton of waste respectively. The impact value of nickel is higher than most of other pollutants emissions. The software predicts all possible mode of entry of nickel products with its initial concentration of 2x10^{-10} kg/ton of waste or 0.08 mg/l into fresh water.
The ReCIPe 1.08-Freshwater Aquatic Eco toxicity Potential (FAETP) is shown in the (Table 3.1). The ReCIPe 1.08 method represents the concentration of zinc is higher than that of all other pollutants with the impact value of -90x10^{--07}Kg DCB eq/ton of waste, followed by the mercury with its impact value of -80x10^{--07}Kg DCB eq/ton of waste. Both the toxic pollutants zinc and mercury are significantly responsible for causing the impacts on the fresh water aquatic eco toxicity. The software predicts all possible mode of entry of zinc and mercury products to the

environment with the initial concentrations of $4.1x10^{-08}$kg/ton of waste or 16.4 mg/l and $2.5x10^{-12}$kg/ton of waste or 0.001 mg/l respectively into the fresh water.

Table-3.1: Major Toxic Emission from different Methodologies.

Sl .n o	Impact Categories	CML Methodology		ReCIPe 1.08 Methodology	
		Pollutant with its Initial concentration	Impact Values in Kg DCB eq/ ton of waste	Pollutant with its Initial concentration	Impact Values in Kg DCB eq/ ton of waste
1	Fresh water Aquatic Eco toxicity Potential (FWAETP)	Nickel 0.08 mg/l	$-32x10^{-4}$	Zinc 16.4 mg/L	$-90x10^{-07}$
2	Terrestrial Eco toxicity Potential (TETP)	Arsenic 0.015 mg/l	$-9x10^{-4}$	Mercury 0.001 mg/l	$-6x10^{-6}$
3	Human Toxicity Potential (HTP)	Arsenic 0.1 µg/m³	$-13x10^{-4}$	Arsenic 1 µg/m³	$-24x10^{-03}$

3.2 Terrestrial Eco Toxicity Potential (TETP)

CML methodology for Terrestrial eco-toxicity Potential (TETP) impact category signifies the impacts on land (soil) at the compost unit. The leaching effects to the soil describe the terrestrial toxicity in terms of its infertility of the soil. The toxicity analysis of leachate emission to the soil is done by the interpretation of TETP impact values obtained by the GaBi model as represented as CML- Terrestrial Eco Toxicity Potential (TETP) the (Table 3.1). The inventory of leachate emissions is interpreted to identify the major toxic pollutant release from the compost leachate. The GaBi model represents arsenic emission into soil is about $-9x10^{-4}$ Kg DCB eq/ton of waste. The impact value of arsenic is predominant than all other pollutants emission. The software predicts all possible mode of entry of arsenic products with its initial concentration of $3.75x10^{-11}$ kg/ton of waste or 0.015 mg/l into the soil.
ReCIPe1.08 methodology for Terrestrial eco-toxicity Potential is shown in the (Table 3.1). The ReCIPe 1.08 method represents the concentration of mercury is higher than that of all other pollutants with the impact value of $-6x10^{-6}$Kg DCB eq/ton of waste, followed by the cyanide with its impact value of $-1x10^{-06}$Kg DCB eq/ton of waste. Both the toxic pollutants mercury and cyanide are significantly responsible for causing the impacts on soil. The software predicts all possible mode of entry of mercury and cyanide with their initial concentration $6.2.5x10^{-12}$ kg/ton of waste or 0.001 mg/l and $1.35x10^{-05}$ kg/ton of waste or 0.05 mg/l into the soil.

3.3 Human Toxicity Potential (HTP)

CML methodology for Human Toxicity Potential (HTP) impact category covers the impacts on human health of toxic substances present in the environment. The health risks due to exposure in the workplace and its surroundings are considered. These risks are often included in a wider impact category encompassing each emission of a toxic substance to air, water and soil. The toxicity analysis of air emission from compost plant is done by the interpretation of results obtained by the GaBi model. The identification of major toxic pollutant release from the compost process is represented as ReCIPe 1.08- Terrestrial Eco Toxicity Potential (TETP) in the (Table 3.1). The inventory of air emissions from the compost unit are used to assess the toxicity impact in to the atmosphere. The model represented arsenic emission into atmosphere is about $-13x10^{-4}$ Kg DCB eq/ton of waste followed by the cadmium with the impact value of $-9x10^{-4}$ Kg DCB eq/ton of waste. The impact value of arsenic is higher than most of other pollutants emissions. The software predicts all possible mode of entry of arsenic products with its initial concentration of $6.45x10^{-16}$ kg/ton of waste or 0.1µg/m³ into the atmosphere.
Human toxicity potential using ReCIPe 1.08 methodology is shown in the (Table 3.1). . The ReCIPe 1.08 method represents the concentration of arsenic is higher than that of all other pollutants with the impact value of $-24x10^{-03}$Kg DCB eq/ton of waste, followed by the chromium with its impact value of $-14x10^{-03}$Kg DCB eq/ton of waste. Both the toxic pollutants arsenic and chromium are significantly responsible for causing the impacts towards human category on atmosphere. The software predicts all possible modes of arsenic and chromium entry to atmosphere with its initial concentration $6.45x10^{-16}$ kg/ton or 0.1 µg/m³of wastes. In summary, a total toxic value obtained by GaBi model is compared with different methodologies is represented as Comparative analysis of Toxic values with respect to their methodologies also represented in the (Table 3.2). The impact values from various

pollutant emissions to air water and land are analyzed to identify the higher toxicity potential. The (Table 3. 2) represents the final impact values of the compost leachate and air pollutants generated during turning period of windrow composting & initial characterization of compost leachate shows toxicity causing heavy metals pollutants such as arsenic, cadmium etc., in it. The over study inputs higher terrestrial eco toxicity from ReCIPe 1.08 methodology with the impact value of $-7.48\text{x}10^{04}$kg DCB eq/ton of waste. CML method indicates the lower impact potential towards the Fresh water Aquatic eco-toxicity with its total impact value of $-7.95\text{x}10^{07}$kg DCB eq/ton of waste in comparison with the ReCIPe 1.08. Human toxicity potential exhibits higher toxic value from CML method with its impact value of $-2.75\text{x}10^{06}$ kg DCB eq/ton of waste.

Table-3.2: Total toxic values of pollutants from composting.

Sl.no	Total Impact Values in Kg DCB eq/ ton of waste		
	Categories	CML Methodology	ReCIPe 1.08 Methodology
1	Fresh water Aquatic Eco toxicity Potential (FWAETP)	$-32\text{x}10^{-4}$	$-90\text{x}10^{--07}$
2	Terrestrial Eco toxicity Potential (TETP)	$-9\text{x}10^{-4}$	$-6\text{x}10^{-6}$
3	Human Toxicity Potential (HTP)	$-13\text{x}10^{-4}$	$-24\text{x}10^{--03}$

4 CONCLUSIONS

GaBi software predicts all possible modes of pollutant emissions affecting the selected categories of impact potential from the composting process. It also identifies the major toxic pollutant release in to the atmosphere. The values obtained from the interpretation shows the Shows Nickel and zinc emissions have the highest impact on freshwater aquatic eco toxicity category. Arsenic and mercury have the highest impact on terrestrial eco toxicity category. Arsenic emission is contributing highest impact on Human toxicity category. The study illustrate the impact toxic pollutants from present composting unit over the environmental aspects such as soil, air and aquatic life is very less. The result shows high environmental impacts especially on human health.

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