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A Study on Estimating the Leachate Pollution Index at Ghazipur Landfill Site

Surajit Bag[1], Rambharosh Dubey[2] , Niladri Mondal[3]

[1]*Research Scholar University of Petroleum& Energy Studies, Dehradun*
[2]*Research Scholar Indian Institute of Engineering Science & Technology, Shibpur*
[3]*Scientific Officer Eureka Forbes Ltd, Kolkata*

ARTICLE INFO	ABSTRACT

corresponding Author:
Rambharosh Dubey[2]

In recent years managing solid wastes has been one of the burning problems in front of state and local municipal authorities. This is mainly due to scarcity of lands for landfill sites. In this context experts suggest that conversion of solid waste to energy and useful component is the best approach to reduce space and public health related problems. The objective of the study is twofold. First authors assessed the current status of solid waste management practices in India. Secondly authors identified a major sanitary landfill site in Ghazipur located near Delhi-U.P border in India and collected leachate samples over a period of one year to determine the leachate quality and identify the dominant pollutants. Further an assessment of leachate pollution potential of the active and closed dumping ground of uncontrolled municipal solid waste landfill site is done using leachate pollution index. Finally the conclusions are drawn which will assist policy makers in designing sustainable waste management programs

KEYWORDS: ***Solid waste management (SWM), Waste to Energy technology, Leachate pollution index (LPI). JEL Classification: Environment and ecology (Q5); Renewable Resources and Conservation (Q2); Health (I1)***

Introduction

The population of India has increased by more than 181 million during the decade 2001-2011 (Census 2011). Urban India generates 68.8 million tonnes per year of municipal solid waste at aper capita waste generation rate of 500 grams/person/day (SWM India 2011). Municipal Solid Waste Management involves activities associated with generation, storage, collection, transfer & transport, processing, recovery and disposal of solid waste, which are environmentally compatible adopting principles of economy, aesthetics, energy and conservation. It encompasses planning, organisation, administration, financial, legal and engineering aspects involving inter- disciplinary relationships. This article asses the current status of Solid Waste Management (SWM) in India. Thorough review of Literature review is done based on secondary data available from websites and research papers. Secondly authors have identified a major sanitary landfill site in Ghazipur near Delhi-UP border and assessed the Leachate pollution index to understand the pollution level of the leachate which is finally going inside the ground and water bodies. This site has been selected because recently the Supreme Court of India has sent the matter of MSW disposal to the Delhi high court as it requires immediate attention. This paper is structured into four additional sections. The next section presents the literature review which helps to understand the current scenario of SWM in India. The third section introduces methodology; the results are presented in section four. In section five the conclusions are drawn.

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Literature Review

Worldwide status of Solid Waste Management

Municipal solid waste generation in Asia in 1998 was 0.76 million tons per day (Jin *et al.*, 2006), with an annual growth rate of 2– 3% in developing countries and 3.2–4.5% in developed countries.

Starting in the 1990s, Asia has been host to a number of national and regional initiatives in solid waste management. The World Bank's Metropolitan Environmental Improvement programme is credited for solid waste management improvements in large cities in Asia, such as Beijing, Bombay, Colombo, Jakarta, Metro Manila and, later, Kathmandu. Between 1994 and 1998, the South-East Asia Local Solid Waste Improvement Project, a Canadian International development agency (CIDA) assistance programme, successfully assisted communities in the Philippines, Thailand and Indonesia in various aspects of SWM, including organizing waste-pickers and junk shops; setting up a 'waste bank' for recyclables; siting landfills; and providing training on hazardous waste management.

Densely populated cities in Singapore, Japan, Thailand, Malaysia, South Korea, Indonesia, China and the Philippines are under pressure to upgrade their solid waste systems, bring their waste streams under control, and shift from pure disposal to recovery of both energy and materials (UN-HABITAT report).

In United States the city of Antonio will be the first city to harvest methane gas from human waste on a commercial scale. This is a great concept and is the future of clean and sustainable energy.

Ahmmad and Haque (2014) recommended that solid waste produced in the Dhaka city of Bangladesh can be used as a renewable energy source. By adopting gas collection process instead of incinerator process more energy can be extracted from waste.

Woch et al., (2015) has conducted a case study of one forest division of Poland. The objective was to determine the potential of forest woody waste biomass as a source of renewable energy and the findings show that energy output would allow energy for large number of people.

As per June 2013 Report of 'ecoprog GmbH', there are 2,200 waste to energy plants in the world. They have a disposal capacity of about 255 million tons of waste per year. By 2017, another 180 plants with a capacity of 52 million tons will be added. Modern waste to energy technologies has been commercially deployed, especially in Europe, Japan, Australia, China and the USA.

Energy potential from Solid waste management in India

There is enormous potential of solid waste to energy potential in India. Various components of municipal solid waste (MSW) have an economic value and can be recovered, reused or recycled cost effectively. Currently, the informal sector picks up part of the resources from the streets and bins to earn their living. However, a sizeable portion of organic waste as well as recyclable material goes to landfills untreated. Over 81% of MSW annually is disposed at open dump sites without any treatment. With planned efforts to Reduce, Reuse, Recover, Recycle, Remanufacture and appropriate choice of technology, the country can profitably utilize about 65% of the waste in producing energy and/or compost and another 10 to 15% to promote recycling industry and bring down the quantity of wastes going to landfills/ dumps under 20% (Planning Commission report 2014). Technology choices can be incineration, pyrolysis and biomethanation. The selection of waste to energy technologies therefore offers different approach of managing waste. However bimethanation is the most efficient technique compared to incineration and pyrolysis. Incineration is mainly criticized due to emission of toxic air and ash which pollutes air. Biomethanation involves anaerobic digestion and generates methane by breaking down the organic waste using bacterial in confined spaces. The criterion of biomethanation is supply of organic waste of high quality. Thus involvement of waste pickers is important to segregate organic and inorganic waste before the organic waste is taken as an input in biomethanation process. The output of this process yields sludge which can further be used for making compost (Forsyth 2006). Ongoing research in the area is coming up with other techniques such as (Brar et al., 2014) presents methodology of power generation using methanol fuel cells and the environmental and socio-economic aspects of biogas plant in a small community.

Solid Waste Management status in India

The composition of MSW generated in Indian cities mainly dominated by the biodegradable

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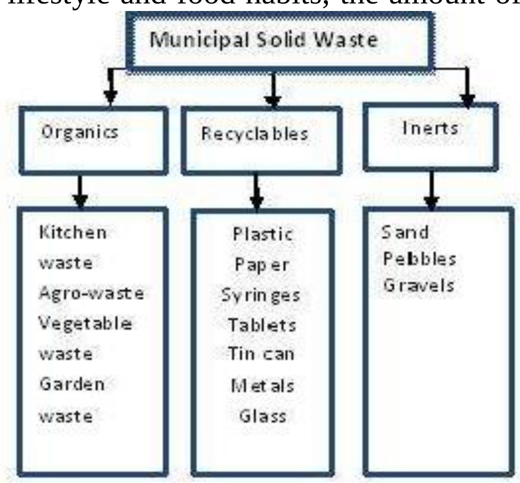
portion in the bulk of MSW. This is mainly due to food and yard waste. With rising urbanization and change in lifestyle and food habits, the amount of municipal solid waste has been increasing rapidly and its composition has been changing.



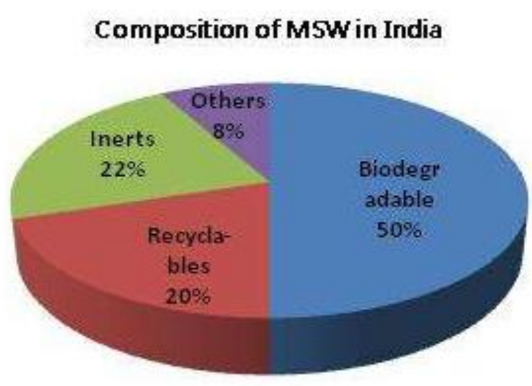


Fig 1 Composition of MSW in Indian cities (Source: Planning commission of India report, 2014) The Ministry has been promoting the use of technologies for energy recovery from municipal, industrial and commercial wastes and solar energy, for meeting certain niche energy demands of urban, industrial and commercial sectors in the country. The programmes being implemented during the year include:

i) Energy Efficient Solar /Green Building Programme;

ii) Energy Recovery from Urban, Industrial and Agricultural Wastes; and

iii) Bioenergy and Cogeneration in Industry (Ministry of new and renewable energy annual-report 2014-2015). During the current year, the Ministry has continued the implementation of the Programme on Energy from Urban, Industrial and Agricultural Wastes/Residues aimed at a variety of materials, such as municipal solid wastes, vegetable market and slaughterhouse wastes, cattle dung, agricultural residues and industrial wastes. Financial assistance is being provided for projects of various types. Planning commission report (2014) has suggested population based Technological options to Manage MSW in a Variety of Towns and Cities.

Research Problem

The literature review provides an overview of the enormous challenges in managing solid waste in India. Presently the estimated 68.8 million tons of MSW generated annually in urban areas pose a serious threat to the municipal authorities due to lack of poor infrastructure and other issues. The existing policies, programs and management do not address the imminent challenges of managing waste which is projected to be 165 million tons by 2031 and 436 million tons by 2050. The processing of solid waste in a scientific manner will not only generate revenue and usable component but also improve the public health system.

Moreover the knowledge of leachate characteristics is essential to evaluate the leachate pollution potential of a landfill site. It is strongly felt to monitor leachate composition of both the active and closed dumping grounds of the uncontrolled landfill site in Uttart Prdesh, India. There is dearth of published data on the dominant pollutants and leachate pollution potential of the referred landfill site. The present study would be helpful in developing proper leachate management program for the identified landfill.

Methodology

In order to determine the leachate characteristics and pollution potential of the Ghazipur landfill site in Delhi-UP border, leachate samples were collected every month from both the dumping grounds for a period of one year from Jan 2014 to Feb 2015. Six representative samples of leachate were collected from each of the active and closed mound of the landfill site in pre acid- washed HDPE bottles of 1litre capacity from the leachate streams flowing out from the base of the waste dump and were mixed homogeneously to yield a composite sample representing each site. For the

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determination of the heavy metals, 100 ml of the collected leachate samples were acidified with 5N nitric acid at pH < 2. All the chemicals used were of analytical grade (AR) purchased from Merck Company.

After collection, leachate samples were transferred shortly to the laboratory and stored under dark at $4^{o}C$. The selected parameters were subsequently analysed with three replicates. The physico-chemical and biological parameters were analysed according to the internationally accepted standard methods (APHA, AWWA, WPCF 20^{th} edition). The various parameters determined in leachate includes: pH (using ECO Test pH 2, Eutech Instruments), Electrical conductivity (EC) (using Deluxe conductivity meter- 601 from Electronics India), Total dissolved solids (TDS) (Gravimetric method), sodium (Na^{+}) and potassium (K^{+}) (flame photometric method), chloride (Cl^{-}) (Argentometric method), bicarbonate ($HCO3^{-}$) (using titrimetric methods), cyanide (CN^{-}) (using nano-colorimeter 500D), phosphate ($PO4^{3-}$- P) (stannous chloride method), ammoniacal-nitrogen (NH3-N) (using Expandable ion analyzer EA940), total Kjeldahl nitrogen (TKN) (Semi-Micro-Kjeldahl Method), five days biochemical oxygen demand (BOD5) (Azide modification of the Winkler method), chemical oxygen demand (COD) (open reflux digestion method), phenolic compounds (using UV-VIS spectrophotometer), total coliform bacteria (TCB) (Multiple tube fermentation technique) and the concentrations of arsenic (As), cadmium (Cd), total chromium (Cr), copper (Cu), total iron (Fe), mercury (Hg), manganese (Mn), nickel (Ni), Lead (Pb), and Zinc (Zn) were estimated using a graphite furnace (HGA Graphite Furnace) associated with Perkin Elmer Analyst 400 Atomic Absorption spectrometer (AAS) by electrothermal atomization.

After determining the leachate characteristics, LPI and Sub-LPI values for both the dumping grounds in Ghazipur were calculated using the following equation.

$$LPI = \sum_{i=1}^{n} w_i p_i \quad (1)$$

where LPI = the weighted additive leachate pollution index, w_i = the weight for the ith pollutant variable, p_i = the sub index score of the ith leachate pollutant variable, n = number of leachate pollutant variables used in calculating LPI and

$$\sum_{i=1}^{n} w_i = 1$$

Data Analysis

The physical, chemical and biological characteristics of the leachate samples collected from both the dumping grounds at Ghazipur uncontrolled landfill site are analyzed. The concentrations of the analysed parameters like TDS, COD, BOD5, Cl^{-}, TKN, NH3-N, Hg, Pb and TCB exceeded the permissible limits as specified by the MSW Rules, 2000 (The Gazette of India, 2000) notified by Ministry of Environment and Forests (MoEF) for both the leachate samples of the active and closed dumping ground at Ghazipur to be disposed in inland surface water. Moreover, the concentrations of total Cr and Zn also surpassed the standard discharge values in the leachate samples of the active dumping ground.

The pH of the leachate samples were in the range of 7.8 - 8.4 for the active dumping ground and 8.1 - 8.6 for the closed dumping ground at Ghazipur landfill site. The leachate samples were in the alkaline range. The pH of leachate becomes alkaline in nature as the free volatile fatty acids are used up by the methane producing bacteria. Although waste deposition continues in the landfill site, characteristics of the acidogenic leachates were not observed as the ratio of the old and stabilized waste to the newly deposited waste are high. EC varied in the range of 9557.14 – 41600 mg/L with a mean value of 26228 mg/L for the active dumping ground and 12500 – 52600 mg/L with a mean value of 30775 mg/L for the closed dumping ground. Conductivity of the leachate samples is mainly due to the presence of the major ions like Calcium, magnesium, sodium

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and potassium. TDS varied in the range of 5660 - 15700 mg/L with a mean value of 10014 mg/L for the active dumping ground and 2320 - 9240 mg/L with a mean value of 5987.50 mg/L for the closed dumping ground. Leaching of ions may be responsible for the high values of TDS. Cl^- concentrations spanned between 2103 - 6735 mg/L for the active dumping ground and 2223 - 6062 mg/L for the closed dumping ground at Ghazipur. Chloride is one of the inorganic macro components whose sorption, complexation and precipitation reactions are negligible. Thus it can act as a conservative pollutant. Like Cl^-, Na^+ can also act as a conservative pollutant since Na^+ does not undergo complexation and precipitation reactions. K^+ can also be used as a conservative pollutant and dilution indicator in the leachate system. Thus high concentrations of Na^+ and K^+ were found in both the dumping grounds with mean values being 2196.42 mg/L and 1794.30 mg/L respectively for the active dumping ground and 2105.64 mg/L and 1297.61 mg/L respectively for the closed dumping ground. At the pH range of 7.0-8.6, HCO_3^- ions are mainly responsible for the alkalinity of the leachate samples. High values of bicarbonate concentrations were observed with the mean values being 51049.38 mg/L for the active dumping ground and 22073.46 mg/L for the closed dumping ground. PO_4^{3-} - P is mainly released into the leachate by the biological degradation of the organic matter containing phospholipids and phosphoproteins. PO_4^{3-} - P concentrations varied in the range of 1.20 – 56.10 mg/L with the mean value being 18.88 mg/L for the active dumping ground and 3.70 – 20.99 mg/L with the mean value being 9.09 mg/L for the closed dumping ground.

The concentration of COD for the active dumping ground (5653 mg/L) was slightly higher than the closed dumping ground (2775 mg/L). Similar results were also observed for BOD5. Low concentrations of COD and BOD5 indicated the prevalence of methanogenic phase. This indicates that the leachate were in their intermediate stage as BOD5/COD ratio were in between 0.1 - 0.5. These intermediate biodegradability (BOD5/COD) values were due to the continuous process of waste deposition. High concentrations of ammoniacal nitrogen were observed in both the active (1681.67 mg/L) and closed dumping grounds (1341.28 mg/L) at Ghazipur. Decomposition of the proteins may be responsible for the release of ammonia from the solid waste. TKN ranged between 631 – 9139 mg/L for the active dumping ground and 891 – 3961 mg/L for the closed dumping ground. High TKN values indicated the presence of reducing environment. Very low concentrations of cyanide and phenol were observed in both of the dumping grounds with the mean values being 0.03 mg/L and 0.25 mg/L respectively for the active dumping ground; 0.02 mg/L and 0.18 mg/L respectively for the closed dumping ground as industrial wastes were not disposed in the concerned landfill site. As the septic tank sludge are directly released on the Ghazipur landfill site, very high concentrations of TCB were found in the range of 4×10^7 - 11×10^7 MPN/100 ml for the active dumping ground and 6×10^6 - 9×10^6 MPN/100 ml for the closed dumping ground.
Leachates of the Ghazipur landfill site were in the methanogenic phase as relatively low concentrations of COD, slightly alkaline pH, intermediate biodegradability (BOD5/COD) and high concentrations of NH_3-N were observed. Leachates in the methanogenic phase are also characterized by low concentrations of heavy metals due to the adsorption and precipitation reactions with the co-existing sulphides, carbonates and hydroxides. But high concentrations of some of the heavy metals were observed in the leachate samples of the Ghazipur landfill site as the concentrations of the sulphides, carbonates and hydroxides were low or insufficient for the adsorption or precipitation reactions. Thus high concentrations of Hg and Pb were found in both the dumping grounds at Ghazipur with the mean values of 0.87 mg/L and 0.6 mg/L respectively for the active dumping ground; 1.20 mg/L and 0.69 mg/L respectively for the closed dumping ground. The occurrence of Hg in leachate indicated the disposal of household batteries, fluorescent lamps, medical thermometers, thermostats etc. along with MSW. Anthropogenic sources like Pb batteries, Pb based paints and pipes may be attributed to the high levels of Pb in leachate. Leachate from the active dumping ground exhibited high mean values of total Cr (3.22 mg/L) and Zn (7.61 mg/L). The

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sources of Cr in the leachate samples may be attributed to the presence of Pb-Cr batteries, coloured polythene bags, discarded plastic materials and empty paint containers in the disposal site. Agro-chemicals like fertilizers and pesticides are the major sources of Zn. Total Cr and Zn were present with the mean values of 1.19 mg/L and 3.26 mg/L

for the closed dumping ground. Leachates were very dark blackish brown in color which may due to the changes in the oxidation state of Fe^{+2} (ferrous ion) to Fe^{+3} (ferric ion). Fe^{+3} eventually form ferric hydroxide colloids and fulvic complexes attributing the blackish brown color of the leachate. Total Fe was found in the range of 0.80 – 11.25 mg/L for the active dumping ground

and 1.02 – 9.37 mg/L for the closed dumping ground which may be due to the presence of Fe and steel based scrap. Other heavy metals which were examined and found to be below the permissible limit of leachate discharge standards as per the MoEF rules were As, Cu and Ni with the mean values being 0.03 mg/L, 0.32 mg/L and 0.51 mg/L respectively for the active dumping ground; 0.22 mg/L, 0.27 mg/L and 0.43 mg/L respectively for the closed dumping ground. The presence of heavy metals in leachate can be attributed to the disposal of unsegregated MSW in the landfill site.

LPI and Sub-LPI: The mean concentrations of the eighteen leachate pollutants for calculating LPI for the active and closed dumping grounds are estimated. The sub-index scores of the i^{th} leachate pollutant i.e. p_i value, were obtained from the sub-index curves as described by Kumar and Alappat, (2005). Thus on the basis of the p_i values, TCB and ammoniacal nitrogen scored the highest value of 100 indicating the maximum pollution potentiality in both the dumping ground at Ghazipur. TKN scored a pollution rating of 100 and 94 for active and closed dumping ground respectively. Mercury had the p_i value of 81 (active dumping ground) and 92 (closed dumping ground) which implies that it was one of the dominant leachate pollutants present in the Ghazipur landfill site. COD, BOD5 and Cl^{-} had the moderate p_i values of 66, 45 and 34 for the active dumping ground; 55, 32 and 31 for the closed dumping ground respectively. TDS and total Cr had the p_i value of 20 and 17 respectively for the active dumping ground. The p_i values of all other parameters for the active dumping ground (50% of the parameters) remained within 8 and for the closed dumping ground (77% of the parameters) remained within 13 indicating least pollution potentiality.

The calculated LPI values for the active and closed dumping ground were 34.02 and 31.80 respectively. These two values are much higher than the LPI value of the treated leachate disposal standards, 7.378 (Kumar and Alaappat, 2003). These high LPI values signify that the dumping grounds were highly contaminated and the leachate should be properly treated before discharging it into the inland surface water. LPI of the closed dumping ground is still high since it was active till 2009 and any kind of post closure reclamation works had not been performed on the closed dumping ground.

The sub-LPI scores for the active and closed dumping ground as well as for the treated leachate disposal standards for inland surface water are estimated. For the active dumping ground, the values of LPI_{or}, LPI_{in}, and LPI_{hm} were 53.09, 51.73 and 16.37 respectively and for the closed dumping ground, were 46.74; 48.57 and 16.46 respectively. The three sub-LPI values for both the dumping grounds were much higher than the sub-indices values of the standards for treated leachate (LPI_{or}, 7.03; LPI_{in}, 6.57 and LPI_{hm}, 7.89) before disposal to the inland surface water.

TCB was the major pollutant in LPI_{or} contributing about 42% in active dumping ground and 48% in closed dumping ground. The major pollutants for the LPI_{in} were TKN and NH3-N which contributed about 40% and 38% respectively in active dumping ground and 40% and 41% respectively in closed dumping ground. Among the heavy metals, Hg was the dominant pollutant in LPI_{hm} which contributed about 60% in active dumping ground and 67% in closed dumping ground.

Conclusions

Most of the State/ULBs have yet to understand the benefits of integrated waste management which facilitates efficient utilization of different components of waste management and select suitable developers or agencies for collection, transportation, processing & disposal of waste.

The awareness amongst the States/ULBs about the benefits of integration of various technologies for MSW processing is lacking. This is necessary as different technological options are required for

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treating the different components of waste, such as Composting/ Biomethanation process for Organic component, incineration/ gasification/ Refused derived fuel (RDF) process for combustibles portion of waste, inert management facility for Construction and Demolition (C&D) waste, etc. Moreover state pollution control board do not have adequate infrastructure including personnel to maintain regular interaction with ULBs. Also dispute resolution mechanism must be a part of the contract Agreement clearly binding both the parties for resolution of dispute through a mutually agreed arbitrator.

From the analysis it is found that the Ghazipur landfill site is in the methanogenic phase with intermediate biodegradability, slightly alkaline pH with high concentrations of NH_3-N. The high LPI value of 34.02 for the active dumping ground and 31.80 for the closed dumping ground at Ghazipur implies that the dumping grounds were highly polluted and exceeded the LPI value for the leachate disposal standards (7.378) for the inland surface water. The sub-LPI scores of the active dumping ground, $LPIor$, 53.09; $LPIin$, 51.73 and $LPIhm$, 16.37 and closed dumping ground, $LPIor$, 46.74; $LPIin$, 48.57 and $LPIhm$, 16.46 indicate that the values are much higher than the leachate disposal standard values of 7.03, 6.57 and 7.89 respectively for inland surface water. As per the individual pollution rating, the major pollutants identified in the Ghazipur active and closed dumping grounds were TCB, TKN, NH_3-N and Hg. Therefore, immediate attention is required as the leachate pose threat to the sorrounding ecosystems and human health. Regular monitoring is essential to avoid the contamination of the sub-surface and the adjacent aquatic environment and an on-site leachate treatment plant should be installed to mitigate furthur environmental problems. Moreover a scientific sanitary landfill site should be designed for solid waste management. Proper selection of site is equally important from public health perspective and keeping the transportation issues in mind. The MSW (Management and Handling) rules need to be made tighter. Financial assistance to the ULBs' are also important. Finally the solid waste management sector must be given the status of an industry so that people involved in this job should feel proud for doing such a great activity for the society.

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