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Incinerator Modelling at Ujjain for Solid Waste Management and Reuse of Waste Materials to Fly Ash Bricks

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ABSTRACT

The unprecedented population growth, rising in community living standard (changing lifestyle) and urbanization have left most municipalities in India grappling to find viable solutions to their waste management problems (health-pollution-degradation). While improper Solid Waste Management (SWM) is attributed to the systemic failure of policy makers and municipal authorities to identify the most sustainable approach to dealing with it so as to meet environmental and socio-economic aspirations, on the other hand large development projects funded by international organizations and most developed countries are carried out "from the top down" without taking into consideration the concerns of those who will be directly affected and the impact of public attitudes and behaviors. This study is not only relevant but also timely in the wake of global economic meltdown and rapid urbanization in order to achieve efficient and cost effective waste management. It is aimed at finding a new approach to involve people of different social, ethnic, gender and religious groups in the reconstruction of local waste management systems creating typical win-win situations. The objectives of this research are as follows: Investigate how gender (women) affect solid waste planning and the influence of different social status of the community in particular the role of households. Examines the level of community involvement in solid waste management in terms of policy formulation, implementation and evaluation. Assesses capacity building programs that enhance society's ability to solve waste management problems and identify appropriate technology options. Identify the resource potential of waste streams and the extent of waste utilization as a resource. Exploring possibilities for initiating small scale businesses at local level in order to alleviate poverty and make waste management a lucrative business. The case study area Ujjain is used to highlight waste management burdens and challenges which is a characteristic of most Indian cities. This research sought to answer one principal question: Can top-down approaches in MSW management be successful without sufficient community engagement and sense of ownership? Top-down approaches where considered in terms of policies, technology transfer and know-how.

INTRODUCTION:

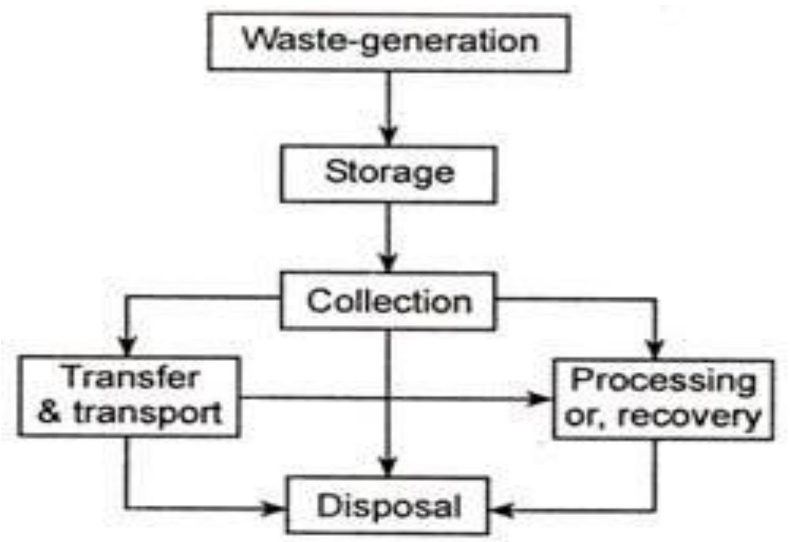
India is the second fastest growing economy and the second most populated country in the world. The population of India is expected to increase from 1029 million to 1400 million during the period 2001–2028, an increase of 42% in 26 at the rate of 5.2% annually About 852 million people live in rural areas and 325 million live in urban areas. The level of urbanization of the country has increased from 26.5% to 38% in the last 50-60 years and is expected to rise to 44% by the year 2026. An important feature of India's urbanization is the phenomenal concentration of the population in Class I cities1 (metropolitan cities), urban agglomerations/cities having a population of more than 1 million, as depicted by the increase in the number of metropolitans from 23 to 35 in the last decade . Rapid industrialization and population explosion in India has led to the migration of people from villages to cities, which generate thousands of tons of MSW daily. The MSW amount is expected to increase significantly in the near future as the country strives to attain an industrialized nation status by the year 2020 [Sahu Sonam *et. al.*, 2014].

Poor collection and inadequate transportation are responsible for the accumulation of Municipal solid waste (MSW) at every nook and corner. The management of MSW is going through a critical phase, due to the unavailability of suitable facilities to treat and dispose of the larger amount of MSW generated daily in metropolitan cities. Unscientific disposal causes an adverse impact on all components of the environment and human health Generally, MSW is disposed of in low-lying areas without taking any precautions or operational controls. Therefore, MSWM is one of the major environmental problems of Indian megacities. It involves activities associated with generation, storage, collection, transfer and transport, processing and disposal of solid wastes. But, in most cities, the MSWM system comprises only four activities, i.e., waste generation, collection, transportation, and disposal. The management of MSW requires proper infrastructure, maintenance and upgrade for all activities. This becomes increasingly expensive and complex due to the continuous and unplanned growth of urban centers. The difficulties in providing the desired level of public service in the urban centers are often attributed to the poor financial status of the managing municipal corporations [Sahu Sonam *et. al.*, 2014].

Solid Waste Management Practices and Challenges in India:

In India, MSWM is governed by MSWR. However, majority of ULBs do not have appropriate action plans for execution and enactment of the MSWR (CPCB Report, 2013).

Unfortunately, no city in India can claim 100% segregation of waste at dwelling unit and on an average only 70% waste collection is observed, while the remaining 30% is again mixed up and lost in the urban environment. Out of total waste collected, only 12.45% waste is scientifically processed and rest is disposed in open dumps. Critical examination of important parameters of MSWM practice with respect to Indian Scenario is delineated below [Joshi and Ahmed, 2016]:



Figures 1.1 Solid Waste Management System

Ujjain, like most other Indian cities has accorded a low priority status to municipal solid waste management. The population in 2011 was almost 5.15 lakhs is expected to 8.0 lakhs increase to around in 2021.

In solid waste terms, this means that the generation of solid waste will increase from 226 tons per day (2016) to almost 320 tons per day in 2021. Ujjain Municipal Corporation budget for 2015-16 was Rs 80 million on SWM. The expenditure is very high for this small town. 63 % of the SWM budget is allocated for collection, transportation and disposal facilities. Our study focus on reducing the solid waste management cost for small towns like Ujjain by providing them alternative options of waste management. On site composting of the organic waste (63 % of the total MSW) is one of the economical processes it can reduce the total cost of collection transportation and disposal of waste and the treated waste can be used in individual kitchen garden or can be sold in the market as the compost is available in market for about 80 Rs/Kg.

LITERATURE REVIEW

1. **Saifullah and Islam, (2016),** studied on MSW management in Dhaka City, Bangladesh. Dhaka is the capital city of Bangladesh, with the highest population density (129,501 people/square km) in the world. MSW generation in the city is 4634.52 tons/day. Overall operational and collection efficiency of DCC MSW management is 45% and 60%, respectively. 500 tons/day compost plant has been operating since September 1998. Worth of recoverable recyclable material is found US$ 82,428,449.9989. 1800 tons of MSW is dumped in the only official landfill site – Matuail. DCC spends 1.5% (601,350 Bangladesh Taka (BDT)/day) of the total budget for landfilling operation and management. Land required for disposal of MSW in Dhaka is estimated to be 110 ha per year.

2. **Vilas Mane Ashish, (2015),** Studied on “A Critical Overview of Legal Profile on SWM in India”. This paper showed that the legal profile and policies available on solid waste management in India, responsibilities of the concerned departments and future need to enhance legal regime for better management of Indian environment. It was seen that the current laws are unable to ensure environmentally sound and sustainable ways of dealing with waste generation to disposal practices. The laws are not well understood and efficaciously implemented.

3. **Rana *et. al.*, (2015),** Studied on “An Assessment of Solid Waste Management System in Chandigarh City, India”, In this paper investigator found that 370 tons/day of solid waste is generated in Chandigarh municipal corporation area. The budget allocated for the financial year 2013-2014 to the Chandigarh municipal corporation for management of so solid waste generated was INR 5737.49 crores. 80% of total SWM budget was allocated for salary of sweepers and rag pickers and only about 7-8% was allocated for collection purposes, the collection efficiency was about 70% from registered households and 20% from the slums and surrounding villages. Lid waste generated was INR 5737.49 crores which was insufficient.

4. **Njoroge *et. al.*, (2014),** investigated on “Review of Municipal Solid Waste Management: A Case Study of Nairobi, Kenya”. Study indicated that the Nairobi’s solid waste situation, which could be taken to generally represent Kenya’s status, was largely characterized by low coverage of solid waste collection, pollution from uncontrolled dumping of waste, inefficient public services, unregulated and uncoordinated private sector and lack of key solid waste management infrastructure. Solid waste generated on daily basis is 4,016 tonnes. The collection rate was as low as 33% which leaves about 2,690 tonnes uncollected.

5. **Mundhe Nitin, (2014),** studied on "Assessment of Municipal Solid Waste Management of Pune City using Geospatial Tools". This paper found that the per capita waste generation rate in India has increased from 0.44 kg per day in 2001 to 0.5 kg per day in 2011; such a steep increase in waste generation within a decade has severed the stress on all infrastructural, natural and budgetary resources. Pune is one of the fastest developing city, it generates total quantity of waste is about 1300 to 1400 metric tons per day. The study demonstrated the capacity to use GIS, GPS and remote sensing technology for the effective assessment of solid waste management system will minimize the environmental risk and human health problems.

6. **Fathi *et. al.*, (2014),** investigated on Municipal solid waste characterization and it's assessment for potential compost production: A case study in Zanjan city, Iran. MSWM practices in Zanjan, a city with population of about 350,000 persons, are generating about 300 tons of MSW daily, Compost production can be chosen as a proper management method utilizing about 60% of MSW generated, and substantially reducing the amount of waste landfilled. Composting organic materials requires special conditions, particularly of temperature, moisture, aeration, pH, particle size and C/N ratio. 61.38% of the total MSW produced in Zanjan (184.2 tons per day) was biodegradable and can be used for compost production. Average C/N ratio of the MSW was low (17.6) and must be adjusted to an optimum level by adding cow or poultry manure. Average pH values of MSW were 5.4 which were almost close to optimum values for composting. Mean relative humidity was high (69.2%) and may be reduced by aeration during the process of composting.

7. **Dalal (2017),** investigated on "Characterization and management of municipal solid waste: a case study of Ujjain city, India". The objective of the paper was to study the amount of solid waste generated during one year (2012-2013) of study period at four different places in Ujjain. Characterization of municipal solid waste shows Ujjain waste comprise maximum food waste (31.9 %) followed by plastic (22%), textile (10.6%), paper (9.6%), glass (6.7%), cardboard (6.2%), ash (5.3%), leather (5.7%) and minimum metals waste (2.8). Surveys showed that per capita MSW waste generation rate is 800 MT per day, 0.217kg/person/day. Sample from old bazar showed the highest amount of energy content according to Modified Dulong Formula with a value of 254524.46 KJ/Kg.

TREATMENT METHOD OF SOLID WASTE

Types of Solid Waste and its Generation Rate in Different Indian Cities:

- Domestic waste or Household waste or Municipal waste:
- Biomedical waste or Hospital waste
- Hazardous wastes or Industrial waste:
- Agricultural waste
- Radioactive waste:

Treatment Methods:

- Landfilling
- Sanitary Landfilling
- Composting
- Vermicomposting
- Biomineralization
- Thermal treatment techniques

Incineration: In an Integrated Waste Management approach, incineration occupies the next to last priority, after waste prevention, reuse, recycling and composting have been undertaken. Incineration is the burning of wastes under controlled conditions, usually carried out in an enclosed structure. Incineration may include energy recovery. Wastes generated in developing countries, however, usually do not allow energy recovery, due to their high moisture and high content of organic matter. Experience with incineration in developing countries has been mostly negative. Incinerators built in Africa, Asia and Latin America did not function as promised. In Lagos, Nigeria, incinerators were built at a cost of U.S. $ 10 million. The moisture content of wastes was so high that fuel had to be added to maintain combustion, which increased costs significantly. The incinerators never operated normally, one was abandoned and the other turned into a community center. Similar experiences have been observed in India, Mexico, the Philippines, Indonesia, and Turkey. Therefore, incineration of MSW is likely to fail in many Third World cities [Sridevi *et. al.,* 2012].

MODELLING OF THE INCINERATOR

Proposal for On-site Cleaning Techniques –

The Bio-medical waste is a heterogeneous mixture of various wastes and if mixed with Solid Waste Management it is practically near to impossible to separate and manage that's why it's been transported separately (Dalal P 2017). We in this paper are proposing the Incineration techniques in detail and this proposal can also be used in small hospitals and nursing homes.

The incinerator can work from a load of 50 Kg/Hr to 400 Kg/Hr of Bio-medical waste. Generally, the diesel fired incinerators are used nowadays but here we propose a LPG or a Natural gas incinerator so that the smoke pollution also do not cross limit of 1 Ringelmann scale.

Construction of the body – As in diesel fired incinerators there are two chambers

Primary Combustion Chamber (PCC) and

Secondary Combustion Chamber (SCC)

Here in this proposal if we combine the two chambers it will help us in lapse time and also energy conservation. Here the brass frame of 10 mm diameter can be used. This will not initiate any heat loss through this chamber. The casting refractory bricks should have a proper thermal insulation cover suitable for a temperature of about 1500 °c. Also it should bear an outer surface temperature of 55 °c – 60 °c. The door fitted should have a quick release clamp and should get fit with approx no energy loss when closed. The door can be made up of mild steel refractory lined thermal insulation also in the door a viewing glasses to be hinged with protection flap and this glass should be heat resistant.

Burners – the burners in the chamber should be auto ignited temperature controlled which can bear the temperature of 1500 °c. The burners are either LPG packed or natural gas fired burners with a control box censor, thermometer as it gets auto ignited if the temperature falls below 1000 °c, electrodes, combustion head, flame failure, checker device, direct drive fan. All these equipments should be easy for maintenance.

Air Supply – The air jet should be injected in a low speed so that it do not affect the burner and inside temperature directly. This air supply should be present on both sides of the chamber so that the availability of air is maintained.

Energy Generator – The flue gases with steam coming out of incinerator is at a very high temperature so this heat can be utilized to generate electricity. This can be done by See-back generator also known as Thermoelectric generator. This device converts heat flux directly to electricity which can be used directly.

Flue–Gas Scrubber – Gases eliminating from the see-back generator are low in temperature so these can get pass through a washer system. This sprinkles the water to gases and then this mixture pass through filter which removes particulate matter from hot gases and water can be used again. The gases are liberated to atmosphere by stack.

Stack or Chimney – The stack should be of aluminum steel mixture with a minimum height of 120 meters from ground level. This stack should be internally lined with insulation and externally it should be painted in bright heat resistant colors visible to air vehicles from a long distance. A carbon settler can also be fixed at endpoint of stack which collects soot. This soot now days are used as a pigment as it contains various heavy metals and carcinogens. This pigment produces ink known as Air Ink thus giving us the second useful by product of our proposal. Despite of all these efforts and pollution control techniques we cannot achieve Zero discharge system some amount of pollution liberated from LPG or natural gas incinerator is in Table-3.

Table-3: Polluter with their concentration in Incinerator

S. No.	Polluter	Concentration in mg/Nm^3
1.	Particulate Matter	30
2.	Carbon-Mono-Oxide	90
3.	Sulphur Oxides	230
4.	Hydro Chloric Acid	40
5.	Nitrogen Oxides	340
6.	Dioxins	0.50
7.	Furness	0.50
Inside a 100 Kg/m^3 incinerator, we need		
1.	Water	15L/Hr
2.	LPG	250 PSI
3.	Resistant Time	2-3Sec

RESULTS AND DISCUSSIONS

Fly ash Bricks - Fly ash brick (FAB) is a building material, specifically masonry units, containing class C or class F fly ash and water. Compressed at 28 MPa (272 atm) and cured for 24 hours in a 66 °C steam bath, then toughened with an air entrainment agent, the bricks last for more than 100 freeze-thaw cycles. Owing to the high concentration of calcium oxide in class C fly ash, the brick is described as "self-cementing". The manufacturing method saves energy, reduces mercury pollution, and costs 20% less than traditional clay brick manufacturing.

Ever since FaL-G (Fly ash-Lime-Gypsum) process is introduced in 1991, fly ash brick activity has been revolutionised in India. FaL-G technology (www.fal-g.com) developed and patented by Dr. Bhanumathidas and Kalidas has simplified the process by adding gypsum to fly ash+lime/cement, converting the calcium aluminates into calcium alumino-sulphates resulting in to achieve high early strengths. Thus FaL-G brick does not need any pressure and gets cured at ambient temperature of 20-40 °C. By avoiding both press and heating chamber, FaL-G process has brought down the multi-million plant cost to a few lakhs, within the reach of micro units. This has facilitated proliferation of over 18000 units in the country as of 2016.

The strength of fly ash brick manufactured with the above compositions is normally of the order of 7.5 N/mm2 to 10 N/mm2. Fly ash bricks are lighter and stronger than clay bricks.

Main ingredients include fly ash, water, quicklime or lime sludge, cement, aluminum powder and gypsum. The block hardness is being achieved by cement strength, and instant curing mechanism by autoclaving. Gypsum acts as a long term strength gainer. The chemical reaction due to the aluminum paste provides AAC its distinct porous structure, lightness, and insulation properties, completely different compared to other lightweight concrete materials. The finished product is a lighter Block - less than 40% the weight of conventional Bricks, while providing the similar strengths. The specific gravity stays around 0.6 to 0.65. This is one single most USP of the AAC blocks, because by using these blocks in structural buildings, the builder saves around 30 to 35% of structural steel, and concrete, as these blocks reduce the dead load on the building significantly.

Notwithstanding above, FaL-G process is practiced in two ways: lime route and cement (OPC) route where the latter is availed as source of lime. In lime route, the composition is fly ash (60%) slaked lime (30%) and anhydrite gypsum (10%) to which 3 to 4 times of stone dust, sand or any inert filler material can be added. In cement route, the composition is fly ash (76%), OPC (20%) and anhydrite (4%) to which 3 to 4 times of filler material can be added.

There are three important ingredients of fly ash which affect the strength and look of fly ash brick.

1. Loss on Ignition (LOI); fly ash loses weight when it burns at about 1000 °C due to presence of carbon and water. The weight loss happens due to carbon combustion and moisture evaporation is called "Loss on Ignition (LOI)". This is expressed as percentage. The lower the loss of Ignition, the better will be fly ash. As per BIS, it should not be more than 5%.

2. Fineness; the fine fly ash has more surface area available to react with lime, thus more will be the pozzolanic activity of fly ash. The greater pozzolanic activity contributes to the strength of fly ash brick. As per BIS, it should not be more than 320 m^2/kg.

3. Calcium (CaO) content; the pozzolanic reactivity of fly ash is more in high calcium fly ash. The greater the pozzolanic activity leads to higher the strength of fly ash brick. As per ASTM C618 fly ash is classified into two; Class C contains more than 10% lime and Class F fly ash contains less than 10% lime.

Our Strength Testing Results –

Comparison of Clay Bricks and Fly Ash Bricks

Properties	Red Bricks/Clay Bricks	Fly Ash Bricks	Remarks
Density	1600-1750 kg/m^3	1700-1850 kg/m^3	Higher load bearing
Compressive strength	30-35 kg/cm^2	90-100 kg/cm^2	Higher load bearing
Absorption	15-25%	10-14%	Less dampness
Dimensional stability	Very low tolerance	High tolerance	Saving in mortar up to 25%
Wastage during transit	Up to 10%	Less than 2%	Saving in cost up to 8%
Plastering	Thickness vary on both sides of walls	Even on both sides	Saving in plaster up to 15%.

6.2.2 Take results and make it

Testing of Brick:

Size of brick:-

Length L = 19 cm.

Width B = 9 cm.

Height h = 8.7 cm.

Area of Brick = 19 * 9

= 171 cm^2

1) Strength Test: - Reading = 33 tone

Breaking Point: - 34 tone

Strength = Reading / Area = 33000 / 171

= 192 kg / cm^2

Strength of Brick = 192 kg / cm^2

2) Water Absorption

Test for bricks:

Dry brick weight = 3.192 k gm

W_1 = 3192 gm

Wet brick weight = 3.52 k gm

W_2 = 35200 gm

Water absorption formula

= $(W_2 – W_1) / W_1$

= (35200 – 3192) / 3192

= 32008 / 3192

Water Absorption = 10.02

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