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Sustainable Solid Waste Management in India

Sabeet
Assistant Professor, Department of Geography, Indira Gandhi University, Meerpur, Haryana, India

ABSTRACT

The present study represents that the waste generation rate in Indian cities ranges between 200 - 870 grams/day, depending upon the region's lifestyle and the size of the city. The study also shows that the per capita waste generation is increasing by about 1.3% per year in India. Cities in Western India were found to be generating the least amount of waste per person, only 440 grams/day, followed by East India (500 g/day), North India (520 g/day), and South India. Southern Indian cities generate 560 grams/day, the maximum waste generation per person. States with minimum and maximum per capita waste generation rates are Manipur (220 grams/day) and Goa (620 grams/day).

Keywords : Sustainable, Solid Waste, Management, GDP, Per Capita

I. INTRODUCTION

Solid Waste Management in India

Some countries have achieved considerable success in solid waste management. But the rest of the world is grappling to deal with its wastes. In these places, improper management of solid waste continues to impact public health of entire communities and cities; pollute local water, air and land resources; contribute to climate change and ocean plastic pollution; hinder climate change adaptation; and accelerate depletion of forests and mines.

Compared to solid waste management, we can consider that the world has achieved significant success in providing other basic necessities like food, drinking water, energy and economic opportunities. Managing solid wastes properly can help improve the above services further. Composting organic waste can help nurture crops and result in a better agricultural yield. Reducing landfilling and building sanitary landfills will reduce ground and surface water pollution which can help provide cleaner drinking water. Energy recovery from non-recyclable wastes can satiate significant portion of a city's energy requirement.

Inclusive waste management where informal waste recyclers are involved can provide an enormous economic opportunity to the marginalized urban poor. Additionally, a good solid waste management plan with cost recovery mechanisms can free tax payers money for other issues. In the case of India, sustainable solid waste management in 2011 would have provided 9.6 million tons of compost that could have resulted in a better agricultural yield energy equivalent to 58 million barrels of oil from non-recyclable wastes 6.7 million tons of secondary raw materials to industries in the form of recyclable materials and livelihood to the urban poor Solid waste management until now has only been a social responsibility of the corporate world or one of the services to be provided by the municipality and a non-priority for national governments. However, in Mumbai, the improperly managed wastes generate 22,000 tons of toxic pollutants like particulate matter, carbon monoxide, nitrous and sulfur oxides in addition to 10,000 grams of carcinogenic dioxins and furans every year. These numbers are only for the city of Mumbai. This is the case in cities all across the developing world. There are numerous examples where groundwater is polluted by heavy metals and organic contaminants due to solid waste landfills.

Solid waste management expenditure of above $ 1 billion per year competes with education, poverty, security and other sustainable initiatives in New York City. Fossil fuels for above 500,000 truck trips covering hundreds of miles are required to transport NYC's waste to landfills outside the city and state. Similarly, New Delhi spends more than half of its entire municipal budget on solid waste management, while it is desperate for investments and maintenance of roads, buildings, and other infrastructure.

Solid waste management is not just a corporate social responsibility or a non-priority service anymore. Improper waste management is a public health and environmental crisis, economic loss, operational inefficiency and political and public awareness failure. Integrated solid waste management can be a nation building exercise for healthier and wealthier communities. Therefore, it needs global attention to arrive at solutions which span across such a wide range of issues.

Waste Management Outlook in India

Waste management crisis in India should be approached holistically; while planning for long term solutions, focus on addressing the immediate problems should be maintained. National and local governments should work with their partners to promote source separation, achieve higher percentages of recycling and produce high quality compost from organics. While this is being achieved and recycling is increased, provisions should be made to handle the non-recyclable wastes that are being generated and will continue to be generated in the future.

Recycling, composting and waste-to-energy are all integral parts of the waste disposal solution and they are complementary to each other; none of them can solve India’s waste crisis alone. Any technology should be considered as a means to address public priorities, but not as an end goal in itself. Finally, discussion on waste management should consider what technology can be used, to what extent in solving the bigger problem and within what timeframe.

Experts believe India will have more than nine waste-to-energy projects in different cities across India in the next three years, which will help alleviate the situation to a great extent. However, since waste-to-energy projects are designed to replace landfills, they also tend to displace informal settlements on the landfills. Here, governments should welcome discussions with local communities and harbor the informal recycling community by integrating it into the overall waste management system to make sure they do not lose their rights for the rest of the city’s residents.

This is important from a utilitarian perspective too, because in case of emergency situations like those in Bengaluru, Kerala, and elsewhere, the informal recycling community might be the only existing tool to mitigate damage due to improper waste management as opposed to infrastructure projects which take more than one year for completion and public awareness programs which take decades to show significant results.

Indian policy makers and municipal officials should utilize this opportunity, created by improper waste management examples across India, to make adjustments to the existing MSW Rules 2000, and design a concrete national policy based on public needs and backed by science. If this chance passes without a strong national framework to improve waste management, the conditions in today’s Bengaluru, Thiruvananthapuram, Kolkata, Mumbai, Chennai, Coimbatore and Srinagar will arise in many more cities as various forcing factors converge. This is what will lead to a solid waste management crisis affecting large populations of urban Indians.

The Indian Judiciary proved to be the most effective platform for the public to influence government action. The majority of local and national government activity towards improving municipal solid waste management is the result of direct public action, funneled through High Courts in each state, and the Supreme Court. In a recent case (Nov 2012), a slew of PILs led the High Court of Karnataka to threaten to supersede its state capital Bengaluru’s elected municipal council, and its dissolution, if it hinders efforts to improve waste management in the city. In another case in the state of Haryana, two senior officials in its urban development board faced prosecution in its High Court for dumping waste illegally near suburbs. India’s strong and independent judiciary is expected to play an increasing role in waste management in the future, but it cannot bring about the required change without the aid of a comprehensive national policy.

II. SWM IN INDIA – ROLE OF POLICIES AND PLANNING

Out of all the measures that are necessary in addressing India's impending waste management crisis, the most efficient will be changes at the national policy and planning level. It is well known among the small but growing waste management sector that urban India will hit rock bottom due to improper waste management. Unfortunately, they think such a crisis is required to bring about policy changes, as they generally tend to happen only after the damage has been done. This attitude is unfortunate because it indicates a lack of or failed effort from the sector to change policy, and also the level of India's planning and preparedness.

Important Statistics

An average of 32,000 people will be added to urban India every day, continuously, until 2021. This number is a warning, considering how India's waste management infrastructure went berserk trying to deal with just 25,000 new urban Indians during the last decade. The scale of urbanization in India and around the world is unprecedented with planetary consequences to Earth's limited material and energy resources, and its natural balance. Rate of increase in access to sanitation infrastructure generally lags behind the rate of urbanization by 33% around the world; however, the lack of planning and impromptu piecemeal responses to waste management issues observed in India might indicate a much wider gap. This means urban Indians will have to wait longer than an average urban citizen of our world for access to proper waste management infrastructure.

The clear trend in the outbreak of epidemic and public protests around India is that they are happening in the biggest cities in their respective regions. Kolkata, Bengaluru, Thiruvananthapuram, and Srinagar are capitals of their respective states, and Coimbatore is the second largest city in Tamil Nadu. However, long term national level plans to improve waste management in India do not exist and guidance offered to urban local bodies is meager. Apart from the Jawaharlal Nehru National Urban Renewal Mission (JnNURM), there has been no national level effort required to address the problem. Even though JnNURM was phenomenal in stimulating the industry and local governments, it was not enough to address the scale and extent of the problem. This is because of JnNURM is not a long term financing program, sorts of which are required to tackle issues like solid waste management.

Role of Municipal Corporations

In the short term, municipal corporations have their hands tied and will not be able to deliver solutions immediately. They face the task of realizing waste management facilities inside or near cities while none of their citizens want them near their residences. Officials of Hyderabad's municipal corporation have been conducting interviews with locals for about eight years now for a new landfill site, to no avail. In spite of the mounting pressure, most corporations will not be able to close the dumpsites that they are currently using. This might not be the good news for which local residents could be waiting, but, it is important that bureaucrats, municipal officials and politicians be clear about it. Residents near Vellalore dump protested and blocked roads leading to the site because Coimbatore municipal officials repeatedly failed to fulfill their promises after every landfill fire incident.

Due to lack of existing alternatives, other than diverting waste fractionally by increasing informal recycling sector's role, closing existing landfills would mean finding new sites. Finding new landfills in and around cities is nearly impossible because of the track record of dumpsite operations and maintenance in India and the Not in My Backyard (NIMBY) phenomenon. However, the corporations can and should take measures to reduce landfill fires and open burning, and control pollution due to leachate and odor and vector nuisance. This will provide much needed relief to adjacent communities and give the corporations time to plan better. While navigating through an issue as sensitive this, it is of the utmost importance that they work closely with the community by increasing clarity and transparency.

Municipal officials at the meeting repeatedly stressed the issue of scarcity of land for waste disposal, which led to overflowing dumpsites and waste treatment facilities receiving more waste than what they were designed for. Most municipal officials are of the sense that a magic solution is right around the corner which will turn all of their city's waste into fuel oil or gas, or into recycled products. While such conversion is technologically possible with infinite energy and financial sources, that is not the reality. Despite their inability to properly manage wastes, the majority of municipal officials consider waste as "wealth" when approached by private partners. Therefore, a significant portion of officials expect royalty from private investments without sharing business risk.

Good News on the Horizon

While the situation across India is grim and official action has to be demanded through courts or public protests, there are a handful of local governments which are planning ahead and leading the way. The steps taken to solve New Delhi's waste management problem is laudable. If it was not for the kind of leadership and determination showcased in Delhi, India would not have had its only operating WTE plant. This plant was built in 2011, at a time when the need for WTE plants was being felt all over India. 1300 tons of Delhi's waste goes into this facility every day to generate electricity. The successful operation of this facility reinvigorated dormant projects across the nation.

After living with heaps of garbage for months, Thiruvananthapuram Municipal Corporation started penalizing institutions which dump their waste openly. It has also increased the subsidy on the cost of small scale biogas units to 75% and aerobic composting units to 90% to encourage decentralized waste management. The corporation is optimistic with the increase in number of applications for the subsidy from 10 in an entire year to 18 in just a few months after the announcement.
In Bengaluru, improper waste management led to the change of the city's municipal commissioner. The new commissioner was handed over the job to particularly improve waste management in the city. As a response to the dengue outbreak in Kolkata, the state's Chief Minister went door to door to create awareness about waste management, and also included the topic in her public speeches. For good or bad, many cities in India have started or initiated steps for banning plastics without performing life cycle analyses.

PER CAPITA WASTE GENERATION IN INDIA

The per capita waste generation rate is strongly correlated to the gross domestic product (GDP) of a country. Per capita waste generation is the amount of waste generated by one person in one day in a country or region. The waste generation rate generally increases with increase in GDP. High income countries generate more waste per person compared to low income countries due to reasons discussed in further sections. The average per capita waste generation in India is 370 grams/day as compared to 2,200 grams in Denmark, 2,000 grams in US and 700 grams in China (12) (13) (14).

The Census of India classifies cities and towns into 4 classes, Class 1, Class 2, Class 3, and Class 4, depending upon their population. Most of the cities studied during this research fell under Class 1. For the purpose of this study, these Class 1 cities were further categorized as Metropolitan, Class A, Class B, etc, until Class H depending upon the population of these cities. This finer classification allowed the author to observe the change in waste generation closer. However, the waste generation rates did not vary significantly between Class A, B, C, D, E, F, G & H cities. They fell in a narrow range of 0.43-0.49 kg/person/day. They generated significantly less MSW per person compared to the six metropolitan cities (0.6 kg/day). The per capita waste generation values of Class 2, 3 and 4 towns calculated in this report are not expected to represent respective classes due to the extremely small data set available. Data for only 6 out of 345 Class 2 cities, 4 out of 947 Class 3 cities and 1 out of 1,167 class 4 towns was available. Despite the lack of data in Class 2, 3, and 4 towns, the 366 cities and towns represent 70% of India's urban population and provide a fair estimation of the average per capita waste generation in Urban India (0.5 kg/day).

III. AGRICULTURAL WASTE MANAGEMENT

India with its varied agro climatic zones is amenable to grow a wide variety of food crops and horticultural products. These crops form a significant part of the total agricultural produce in the country comprising of cereals, pulses, cotton, fruits, vegetables, root and tuber crops, flowers, ornamental plants, medicinal and aromatic plants, spices, condiments, plantation crops and mushroom. After attaining independence in 1947, major emphasis was laid on achieving self sufficiency in food production. Development of high yielding wheat varieties and high production technologies and their adoption in areas of assured irrigation paved the way towards food security ushering in green revolution in the sixties. It, however, gradually became clear that horticultural crops for which the Indian topography and agro climates are well suited are an ideal option of achieving sustainability of small holdings, increasing employment, improving environment, providing an enormous export potential and above all achieving nutritional security. As a result, emphasis on diversification to horticultural crops was given since last one decade or so.

The agriculture sector in India contributes about 17 percent of country's GDP and provides employment to approximately two third of the population. However, its potential has not been tapped due to underdevelopment of the food sector in India. The single most important challenge facing the country is providing remunerative prices to farmers for their products without incurring the additional burden of subsidy through minimum support prices or other such measures. The challenge could be addressed if cereals, fruits, vegetables, milk, fish, meat and poultry etc. are processed for consumption in the domestic and international markets. There are various issues to be dealt with in utilizing the opportunities for agribusiness industry. In post WTO scenario, Indian produce has to face competition in domestic as well as export markets. With the phasing out of quantitative restrictions, developed countries are imposing strict qualitative restrictions and are imposing barriers to trade. The Indian commodities are facing tough competition in the international market when it comes to quality, pesticide residues, varieties with more shelf life, packaging etc. This implies that Indian produce need to be more competitive to face the international competition which again demands the maintenance of quality standards 2 throughout the value chain including good agricultural practices. Whereas it has been found that 30 – 40 percent of fruits and vegetables are wasted due to post harvest losses. There is lack of basic as well as specialized infrastructure such as cold storages, refer vans, cool chains, ripening chambers etc. Also there is a missing link between production and research system and international consumers. The system lacks in capacity building market information, research and intelligence.

Some interesting facts:

- India is short by 10 million tonnes of cold storage capacity due to which over 30 percent of agricultural produce goes waste every year.
- More than 20% of produce from fields is lost to poor post-harvesting facilities and lack of cold chain infrastructure.
- Also 10% of food grain that India produces annually is eaten by rodents.
- Only 7% of food in India is processed. The United Kingdom process +65% of its food. Even a developing country like the Philippines processes as much as 45% of its food.
- India, the world's second largest fruit and vegetable producer encounters a waste of close to 25% worth of produce.

The post-harvest technologies for perishable horticulture produce serve as an effective tool for getting better return to the produce and also help in avoiding wastage both at production site and distribution centers, which will help in regulating the market infrastructure. Recycling of fruit and agricultural waste is one of the most important means of utilizing it in a number of innovative ways yielding new products and meeting the requirements of essential products required in human, animal and plant nutrition as well as in the pharmaceutical industry. Microbial technology is available for recycling and processing of fruit and vegetables waste and following products can be made out of the different processes. In the light of the above, the present study is an attempt to study the existing infrastructure for waste management and to suggest measures to utilize the bio-waste in appropriate manner.

Thus, waste management is the collection, transport, processing, recycling or disposal, and monitoring of waste materials. Concern over environment is being 3 seen a massive increase in recycling globally which has grown to be an important part of modern civilization. The consumption habits of modern consumerist lifestyles are causing a huge global waste problem. Industrialization and economic growth has produced more amounts of waste, including hazardous and toxic wastes. There is a growing realization of the negative impacts that wastes have had on the local environment (air, water, land, human health etc.).

IV. SOLID WASTES GENERATION AND THEIR ENVIRONMENTAL IMPORTANCE

Growth of population, increasing urbanisation, rising standards of living due to technological innovations have contributed to an increase both in the quantity and variety of solid wastes generated by industrial, mining, domestic and agricultural activities. Globally the estimated quantity of wastes generation was 12 billion tonnes in the year 2002 of which 11 billion tonnes were industrial wastes and 1.6 billion tonnes were municipal solid wastes (MSW). About 19 billion tonnes of solid wastes are expected to be generated annually by the year 2025. Annually, Asia alone generates 4.4 billion tonnes of solid wastes and MSW comprise 790 million tones (MT) of which about 48 (6%) MT are generated in India [4,5]. By the year 2047, MSW generation in India, is expected to reach 300 MT and land requirement for disposal of this waste would be 169.6km2 as against which only 20.2km2 were occupied in 1997 for management of 48MT. Fig. 1 shows the details on current status of solid waste (non-hazardous and hazardous waste) generation from different sources in India. As can be seen from Fig. 1 that apart from municipal wastes, the organic wastes from agricultural sources alone contribute more than 350 MT per year.

However, it is reported that about 600 MT of wastes have been generated in India from agricultural sources alone. The major quantity of wastes generated from agricultural sources are sugarcane baggase, paddy and wheat straw and husk, wastes of vegetables, food products, tea, oil production, jute fibre, groundnut shell, wooden mill waste, coconut husk, cotton stalk etc., [2,6,8]. The major industrial non-hazardous inorganic solid wastes are coal combustion residues, bauxite red mud, tailings from aluminum, iron, copper and zinc primary extraction processes. Generation of all these inorganic industrial wastes in India is estimated to be 290 MT per annum.

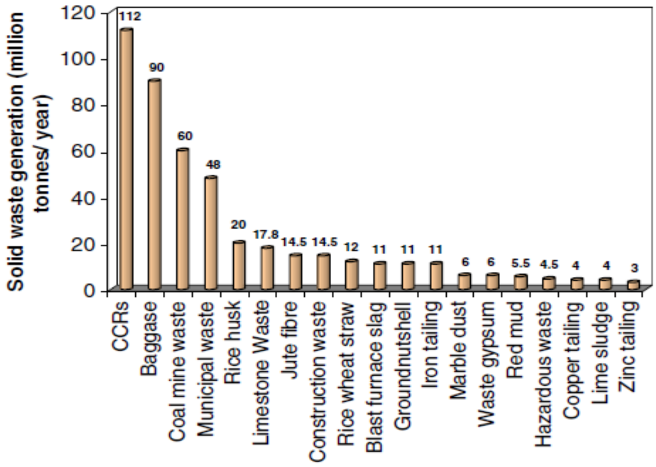

Fig. 1. Current status of solid waste generation in India. (Million tonnes/ year).

In India, 4.5 MT of hazardous wastes are being generated annually during different industrial process like electroplating, various metal extraction processes, galvanizing, refinery, petrochemical industries, pharmaceutical and pesticide industries. However, it is envisaged that the total solid wastes from municipal, agricultural, nonhazardous and hazardous wastes generated from different industrial processes in India seem to be even higher than the reported data. Already accumulated solid wastes and their increasing annual production are a major source of pollution. Due to environmental degradation, energy consumption and financial constraints, various organizations in India and abroad, apart from the regulatory frame work of United States Environmental Protection Agency (USEPA), have recommended various qualitative guidelines for generation, treatment, transport, handling, disposal and recycling of non-hazardous and hazardous wastes. Safe management of hazardous wastes is of paramount importance. It is now a global concern, to find a socio, techno-economic, environmental friendly solution to sustain a cleaner and greener environment.

The heterogeneous characteristics of the huge quantity of wastes generated lead to complexity in recycling and utilisation. The comparative physico-chemical characteristics of solid wastes generated from hazardous and non-hazardous sources over clay and cement are shown in Tables 1 and 2, respectively. The physico-chemical properties of solid wastes depend on the properties of feed raw materials, mineralogical origin, operating process and their efficiency. It is evident from the characteristics of these wastes, generated from different processes, that they have good potentials for recycling and utilization in developing various value-added building components.

Use of industrial wastes and by-products as an aggregate or raw material is of great practical significance for developing building material components as substitutes for the traditional materials and providing an alternative or supplementary materials to the housing industry in a cost effective manner. In order to effectively utilise all these solid wastes, effort have been made and mathematical models were also established universally and as a consequence considerable quantity of wastes is now being recycled and used to achieve environmentally sound management. As against the Not In My Back Yard (NIMBY) Syndrome view on the inherent imbalance in the project's cost in terms of human health and environment due to improper management of all these wastes, now, the Yes In My Back Yard (YIMBY) concept is gaining ground in most of the countries due to the benefits of newer technologies on waste recycling.

V. ORGANIC SOLID WASTES GENERATION, RECYCLING AND UTILIZATION

Solid waste generation from organic sources includes municipal and urban wastes, animal wastes, farming wastes, horticulture wastes, domestic refuses and other agro industrial wastes. A number of wide ranging agro industries have come up in India due to availability of agricultural resources, manpower and technological innovations.

Table 1
Comparative physical characteristic of solid wastes generated from hazardous and non-hazardous sources over sand and clay soil

Sl. No.	Characteristics	CCRs	Jarosite	Copper slag	Red mud	Marble dust	Sand	Clay (Kaolinite)
1	Particle size (μm) (D_{80})	130–260	14–23	<150	<2.0	43.9–103.1	300–600	<15
1	Bulk density (g/cc)	0.96–1.25	0.97–1.0	1.44–1.62	1.36–1.6	1.87	1.59	1.48
2	Specific gravity	2.08–2.3	2.92–3.0	2.8–3.8	2.6–3.4	2.51–2.76	2.64	2.37–2.56
3	Porosity (%)	37.45–37.5	66.5–67.7	—	49.26–54.66	39.65–49.0	68.41	36.31
4	pH	6.98–7.03	6.7–6.85	<5.70	11–12.5	8.36–9.5	8.18	7.64
5	EC (μmohs/cm)	491.65–504.24	13260–14090	500.56	495–766.48	276.94–500.	246.11	6506.67

Table 2
Comparative chemical characteristic of solid wastes generated from hazardous and non-hazardous sources over cement and clay soil

S No.	Constituents in %	CCRs	Jarosite	Red Mud	Marble waste	Copper Slag	Phosphogypsum	Cement OPC	Clay (Kaolinite)
1.	SiO_2	55.9–57.6	2.91–4.0	5–13.5	1.69–8.5	28.0–32.0	2.41	19.7–22.62	42.09–61.54
2.	Al_2O_3	16.0–24.0	0.70–4.4	10–23	1.3–6.1	2.4–6.8	<0.5	4.93–6.6	28.65–32.9
3.	Fe_2O_3	5.38–6.34	51.28	28–56	0.25–3.66	44–47.70	<0.5	3.19–3.5	11.77–12.88
4.	CaO	0.25–6.5	0.98–12.0	8–17	29.5–55.4	1.65–6.60	32–41	63.0–64.0	0.13–2.22
5.	MgO	1.01–1.34	1.81–1.94	0.35	4.04–20.6	0.75–2.54	0.10	0.7–2.38	2.04–2.63
6.	K_2O	1.62–2.13	0.71–0.75	0.39–0.50	0.01–1.9	0.61	<0.22	0.55–0.6	0.74–3.51
7.	ZnO	1–2.6	13.29	<0.5	NA	0.005–1.30	NA	NA	NA
8.	PbO	< 0.1	1.8–2.04	<0.2	NA	0.002–0.28	4–5.11	NA	NA
9.	CuO	< 0.1%	0.46–1.65	<0.2	NA	0.46–3.76	3.42–17.6	NA	NA
10	LOI	1.53–	>12.6	6–14	40.6–43.46	<1	19.20	0.3–1.75	<12.55

NA—not analysed.

The main objective of waste management system is to maximise economic benefits and at the same time protection of the environment. The urban waste mainly consists of organic matter (46%), paper (6%), glass (0.7%), rags (3.2%), plastic (1%) and the rest is moisture. Animal wastes are primarily composed of organics and moisture. Decomposition of both the animal and urban organic wastes can be done in an aerobic or anaerobic digestion. Since, huge quantity of both these organic wastes are produced annually in India, there is great potential for production of CH4 and also which will help to reduce the green house gases thereby contribute to reduction of global warming. India is one of the richest countries in agricultural resources. Agricultural wastes are the byproducts of various agricultural activities such as crop production, crop harvest, saw milling, agro-industrial processing and others. In India sugar industry alone produces about 90 MT of baggase per year and being used in manufacturing of insulation boards, wall panels, printing paper and corrugating medium. There is a growing concern for agricultural wastes, which are mostly being burnt thereby contributing considerably to global warming. Use of organic wastes such as peanut husk, mahau and linseed residues, coconut coir dust, rubber seedpod, spent cashew nut shell etc.

VI. CONCLUSION

During different industrial, mining, agricultural and domestic activities, India produces annually about 960 MT of solid wastes as by-products, which pose major environmental and ecological problems besides occupying a large area of land for their storage/disposal. Looking to such huge quantity of wastes as minerals or resources, there is a tremendous scope for setting up secondary industries for recycling and using such solid wastes in construction materials. Though many lab processes, products and technologies have been developed based on agro-industrial wastes, non-acceptability of the alternative and newly developed products among users due to lack of awareness and confidence is to be removed. However, environment friendly, energy-efficient and cost effective alternative materials developed from solid wastes will show good market potential to cater to people's needs in rural and urban areas. To effectively utilise these wastes as a raw material, filler, binder and additive in developing alternative building materials, detailed physical-chemical, engineering, thermal, mineralogical and morphological properties of these wastes are to be evaluated and accurate data made available.

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