J. Indian Inst. Sci.
A Multidisciplinary Reviews Journal
ISSN: 0970-4140 Coden-JIISAD

REVIEW PAPER

Potential Hazards due to Municipal Solid Waste Open Dumping in India

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Abstract | The massive growth in the generation of municipal solid waste due to the rising food demand, population growth, industrialization, urbanization, economic growth, lifestyles, and other necessities of the global population have embraced the unscientific disposal of wastes in particular with developing countries like India, China, Brazil, etc. Nearly 2 billion metric tonnages of wastes are generated globally each year and nearly half of it is subjected to open burning. As evident from the physiochemical characteristics of the wastes in some of the major cities in India, more than 50% of the fresh waste contribute to organic fraction and has got high energy and nutrient value. In fact, in developing countries, the management of MSW is exacerbated by unscientific practices leading to increased environmental contamination and risk to public health. India is facing a seemingly insurmountable challenge of treating and managing the historical waste, in addition to the large accumulation of fresh daily waste. This paper attempts to enumerate the approaches that should be taken by different institutions in their various capacities to move from open dumps to scientific and environmentally friendly waste management systems embarking on the circular economy concepts. To manage the current situation, appropriate knowledge about waste generation and its treatment are necessary. The current study reveals the data regarding waste generation in different states, highlights the issues with open dumping, and a few methods which can be effectively used to treat solid waste are enumerated.

Keywords: *Municipal solid waste, Waste management, Hazards, Urbanization, Recycling, Remediation*

1 Introduction

Open dumpsites have become a huge menace and a looming hotspot for combined pollution of air, water and soil. The practice of open dumping or disposal on land in an unsecured way is still practiced in developing countries, causing significant hazards to the environment and health of surrounding biota[1]. Rapid population growth and urbanization have led to a huge quantity of municipal solid waste (MSW) generation which demands a scientific and engineered way of disposal. India is the second highly populated country in the world with a population of 1.38 billion contributing to 17.7% of the total world population according to the United Nations data assessed in mid-2020, where again 35% of the population is in urban areas. According to the recent report by United Nations, the largest increase in population is between 2019 and 2050 having maximum growth in nine countries, led by India and it is projected that India would overtake China as the world's populous country in 2027. The population growth, urbanization, and economic developments in the country have led to an increased waste generation rate. The Municipal Solid Waste (MSW) generation rate in India has increased from 0.1 to 0.45 kg/capita/day from the mid-twentieth century[2]. The per capita waste

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generation in India increased from 1 to 1.33% per year[3–6]. Dumping of MSW in an uncontrolled manner results in problems to the surrounding environment like contamination of soil, ground and surface water, air, loss of biodiversity, emission of greenhouse gases, etc.

Despite the significant development in various sectors of social, economic, and environmental areas, MSW systems management in India remains unchanged and thus faces major environmental challenges associated with waste generation, collection, transport, treatment, and disposal. The prevailing management systems are inadequate to cope up with the rapid waste generation due to increasing population, industrialization, urbanization, and illegal waste collection from developed countries. The country is shifting from an agriculture-based country to an industrial and service-oriented country. In the coming years, it is expected that India's MSW amount will increase significantly due to the migration of people from the village to towns and cities due to industrialization.

The main visual issues concerned with the open dumping are open burning of waste fractions in uncontrolled sites, mismanagement of the leachate produced in the final disposal sites, and the greenhouse gas (GHG) emissions from these sites[7]. This also has a visibly negative impact on inhabitants and tourists visiting the country.

2 MSW Statistics in India: Open Dumping

Open land disposal of MSW poses a great threat to the environment as there is leakage of CO_2, CH_4, and leachate production or greenhouse house gas (about 14% of global GHG is emitted from landfills). Thus, it is important to know about the generation, composition, and management of solid waste. Since India has many different climatic regions, the consumption and generation of solid waste also vary. Several studies indicate that recycling, reusing, reduction of solid waste are not only better options for solid waste management but also they are acceptable socially, economically, and environmentally. But in India, it is disposed of unscientifically in open and low-lying areas, causing adverse impacts on all components of the environment and human health. The MSW generation in some of the major Indian cities, 2016[8] is depicted in Fig. 1 below:

As it is evident from Fig. 1, of the major cities in India, Delhi (9620 MT/day) contributes to the maximum MSW generation followed by Mumbai, Kolkata and Chennai. According to Hoornweg et al.[9], the current urban MSW generation will increase from 109,598 tons per day (0.34 kpcd) to 376,639 tons per day (0.7 kpcd) by 2025. During 2013–2014, according to CPCB 1,43,449 TPD of MSW was generated from 29 states and union territories and the average per capita generation of waste is 0.11 kpcd. Of this total waste generated, about 1,17,644 TPD (82%) of MSW is collected and 32,871 TPD (22.9%) is processed or treated. Some studies and observations from various reports indicated that the MSW generation rate is between 0.2 and 0.6 kpcd in towns and cities and varies for the population size of the city as depicted in Table 1.

The municipal solid waste management system includes waste generation, collection, transportation, and disposal. Due to the rapid increase in the growth rate of population and urbanization, solid waste generation is also increasing manifold. Table 2. shows the population size per capita waste generation rate and its growth over 10 years.

Planning commission report (2014) shows that 377 million people in the urban area produce 62 million tons of MSW/annum currently and by 2031, it could reach 165 million tons and by 2050, 436 million tons. By 2031, to accommodate this huge waste, 23.5×10^7 cubic meters of land is required. Due to a lack of primary information related to per capita waste generation, waste characterization, different reports give different values. Statistics of the generation of MSW in different states in India from (2000–2011) are represented in Table 3[10,12].

The composition and characteristics of Indian municipal solid waste include Biodegradable waste (40–60%), recyclable material (10–30%), inert waste matter (30–50%), composite waste, domestic hazardous waste, and toxic waste. These include food waste, paper, plastic, wood, metals, electrical items, ashes, glass, steel, sludge, dust, agricultural waste, pesticides, etc., municipal waste contains chemicals like nitrogen, phosphorus, potassium, etc.

Table 4 illustrates the status of the management of solid waste in India[13]. From the table, it is evident that segregation of waste is done only in 5 states out of 29 states and house to house collection in 18 states that to not a complete collection. As we can see unsanitary dumping of waste accounts for the highest percentage compared to other methods of disposal of waste.

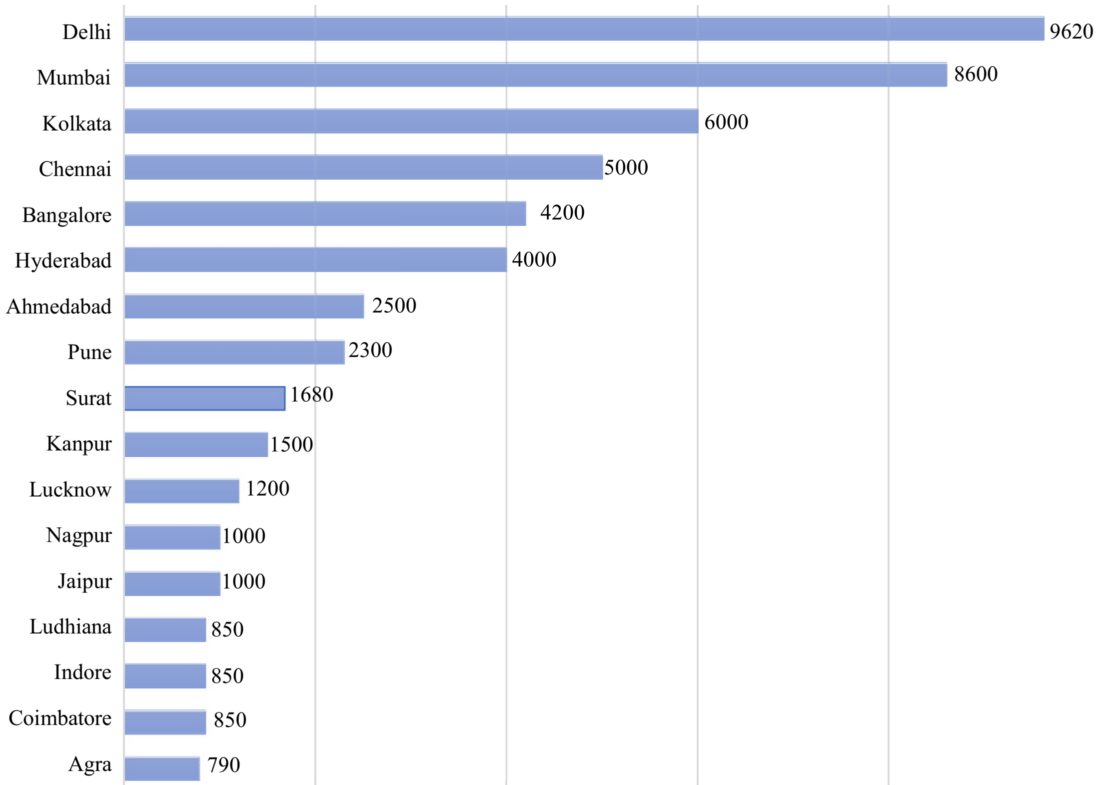

Figure 1: The daily municipal solid waste generations in metric tones in major Indian cities, 2016.

Table 1: Municipal solid waste generation rate for various population size of the city.

Population size of town/city	MSW generation per capita per day
< 200,000	0.2–0.3
200,000–500,000	0.3–0.35
500,000–1,000,000	0.35–0.4
> 1,000,000	0.4–0.6

Table 2: Waste generation per capita rate.

Population size	Waste generation (kg/capita/day)[10]	Waste generation (kg/capita/day)[11]
> 20,00,000	0.43	0.55
10,00,000–20,00,000	0.39	0.46
5,00,000–10,00,000	0.38	0.48
1,00,000–5,00,000	0.39	0.46
< 1,00,000	0.36	–

According to the recent study carried out by the Centre for Science and Environment (CSE), it was understood that around 3000 dumpsites in India need to be closed permanently or reclaimed as all of these dumpsites are unscientifically constructed and operated creating irreversible damage to the environment. The natural water bodies and drains that are emptying into mighty rivers and lakes carry an unimaginable amount of waste.

The type of treatment to be adopted for the MSW handling is greatly influenced by the physical and chemical composition of the waste mass, meteorological conditions of the region, and the economic viability of the project. Table 5 represents the physical composition of the waste characteristics at some of the major cities in India[14].

A better understanding of the physico-chemical characteristics of the waste will help in framing the waste management strategies and policies. In all these cities, more than 50% of the MSW waste composition is biodegradable and subsequent measures have to be taken to handle the biodegradable part, as it has energy and nutrients and also a significant contributor to the GHG emissions.

Table 3: Statistics of municipal solid waste generated in different states in India.

Sl. no.	States	Municipal solid waste (TPD) 2000	Municipal Solid Waste (TPD) (2009–2011)	Collected (TPD) (2009–2011)	Treated (TPD) (2009–2011)	Growth (%)
1	Andhra Pradesh	4376	11,500	10,655	3656	163
2	Assam	285	1146	807	73	302
3	Delhi	4000	7384	6796	1927	85
4	Gujarat	NA	7379	6744	873	–
5	Karnataka	3277	6500	2100	2100	98
6	Kerala	1298	8338	1739	4	542
7	Madhya Pradesh	2684	4500	2700	975	68
8	Maharashtra	9099	19,204	19,204	2080	111
9	Manipur	40	113	93	3	182
10	Meghalaya	35	285	238	100	713
11	Orissa	655	2239	1837	33	242
12	Punjab	1266	2794	NA	Nil	121
13	Puducherry	69	380	NA	Nil	451
14	Rajasthan	1966	5037	NA	Nil	156
15	Tamil Nadu	5403	12,504	11,626	603	131
16	Tripura	33	360	246	40	991
17	Uttar Pradesh	5968	11,585	10,563	Nil	94
18	West Bengal	4621	122,557	5054	607	172

Table 4: Current status of municipal solid waste management in India.

Parameter	Status
House-to-house collection of waste	18 states (of 29)
Segregation of waste at the source	5 states (of 29)
Number of unsanitary landfill sites identified	1285
Number of sanitary landfill sites constructed	95
Number of ULBs operating compost/vermicompost facilities	553
Number of UBLs under construction compost/ vermicompost facilities	173
Number of operating pipe composting facilities	7000
Number of operating RDF facilities	12
Number of operating biogas plants	645
Number of energy generation plants	11(6 operational)
Waste generation	143,449 Mt/day
Waste collection	117,644 Mt/day (82%)
Waste treated	32,871 Mt/day (28%)

3 Potential Hazards of Open Dumping of MSW

Open dumping of MSW is a huge menace to developing countries as it caused very much ill effects on human health and also deteriorated the environmental condition leading to air, water, and soil contamination. Although we have different systems for various classifications of wastes, most of these systems fail in practice and as a result, the un-segregated waste that ends up in

Table 5: Percentage composition of MSW generated in some major cities[14].

Composition %	Delhi	Guwahati	Mumbai	Kochi	Nagpur
Paper	5.9	16.41	27	4.9	8.6
Bio-resistant	13.3	2.4	–	1.5	–
Glass	1.4	4.1	5	1.1	–
Plastic	6.15	17.4	4	5.1	11.6
Metals	0.47	0.37	3	0.35	0
Food waste	42.7	37.4	40	79.8	77.2
Wood	–	2.45	–	–	–
Textiles	–	4.94	6	–	1.0
Yard wastes	–	5.25	–	–	–
Dirt/ash	30.0	9.2	15	7.33	1.6

Table 6: Comparison of the result of different parameters with the Bureau of Indian standards.

Parameter	Unit	Results from Ghazipur landfill site	Results from Boragaon site	Bureau of India Standards
pH	–	7.5–7.8	6.7–8.2	6.5–8.5
Conductivity	mS/cm	220–274	54.8–76.5	–
TDS	mg/l	771–1440	35–49	500
Total hardness	mg/l	256–306	140–160	300
Alkalinity	mg/l	215–270	160–200	200
Chloride	mg/l	183–243	10–34	250
Residual chlorine	mg/l	0.26	NIL	0.2

landfill consists of toxic materials emanated from various industries, pharmaceuticals, hospitals, e-waste, etc., which abrupt the environment and also pose a greater risk to human life.

3.1 Water

A study was conducted at the Ghazipur landfill site and Boragaon dumping site and the study showed the impact of open dumping on air, water, soil. The result showed that due to solid wastes dumping, most of the water properties like conductivity, Total Dissolved Solids, hardness; alkalinity increased significantly and are represented in Table 6. Other issues like foul smell, bacterial contamination; discoloration of water were also recorded. This has also caused leaching from the dumpsite and eventually led to an increase in heavy metal contamination like mercury, lead, etc., and also resulted in high algal blooms in rivers and streams due to the nitrogen and phosphorous presence.

The impact of leachate emanating from open dumpsite on groundwater quality in Chennai was studied by Mohan et al.[15]. From the study, it was evident that most of the physic-chemical parameters and heavy metal parameters were above the safe drinking standards and not advisable for any potable use. The Cr and Pb concentrations in the groundwater have increased manifold when compared to the past 10-year data and three times higher than the permissible limit of drinking water standards. A significant contribution to the heavy metals was attributed to the hazardous fractions within the waste like metal parts, chemical wastes, paint wastes, batteries, e-waste, etc., which are accumulated overtime at the dumpsite. The irony is that most of the informal settlements and financially deprived people depend on these sources for their day-to-day activities and their health is at a major stake.

Another study conducted at Trivandrum, Kerala on the effect of MSW leachate on the groundwater quality using the water quality index revealed that groundwater around the MSW dumpsite was found more polluted than the control site[16]. The high concentrations of chlorides and chemical oxygen demand was found in the leachate from the Bhalawsa dumpsite in Delhi disclosed the potential threat to the water resource in its vicinity[17].

One of the major unplanned landfills in India—Okhla in Delhi, located in the flood plains of the Yamuna River poses a severe potential threat to the environment as the concentration of leachate heavy metals; organics, and toxicity were very high when examined. Here, the leachate can directly into the surface water and cause severe health risks and damage[18]. The groundwater and leachate samples analysis near Semur and Vairapalayam sites of the Erode city, Tamil Nadu result in a significant level of concentrations of Cl^-, SO_4^{2-}, NO_3^- and NH_4^+ uncovering the drastic effect of the dumpsite[19].

Groundwater resource is often less vulnerable to pollution, cheaper and more convenient to extract for the public water supplies and so in most of the developing countries, a large fraction of people depend on the groundwater resource. On the contrary to this, groundwater pollution is less visible, more difficult to clean up than any of the open sources and the more source of groundwater pollution include industrial and household chemicals and garbage dumpsites, excessive fertilizers, and pesticides used in farming, waste lagoons, process water from mines, oil field brine pits, leaking underground storage tanks like oil storage and pipelines, sewage sludge and septic systems.

The most common health risk attributed is the spread of infectious diseases like diarrhea, hepatitis, etc., which is often spread by direct contact with water/waste logged in the site or from a polluted stream contaminated by clinical waste or fecal matter. These are often spread by scavengers, vectors, such as foraging animals, rats, birds, flies, and mosquitoes, etc., or unauthorized persons being on the site. The fauna in and around the dumpsite is also greatly impacted by the direct consumption or by indirect consumption of contaminated plants or animals or as a result of the leachate effect on the water bodies. The plants around the dumpsite are impacted directly by the waste, contaminated surface or groundwater, and dust and smoke due to burning. The potential of leachate contamination is greatly influenced by landfill location—landfill type (engineered/not), the concentration of leachate, the receiving source (quantity and quality) accounting for the dilution factor[20].

3.2 Air

As the quantity of biodegradable fraction present in the MSW is higher in the Indian context, a quantum of inflammable biogases will be trapped in the open dumpsites and are vulnerable hotspots for spontaneous fires. Most often, the habitants residing near the dumpsite are exposed to several hazardous pollutants emanated from these fire incidents. The burning of solid waste emits pollutants like sulfur dioxide, nitrogen oxides, hydrogen chloride, carbon monoxide, lead, mercury, arsenic, cadmium, selenium, etc., and also led to the greenhouse gas effect. The public health of the habitat around the dumpsites is at stake as the smoke is caused by burning debris and the GHG emissions from the decomposition of waste. The fires at the dumpsites occur due to the interaction between oxygen, combustible waste material (fuel), and heat formed by biotic and abiotic processes[21, 22].

A study conducted by Global Alliance for Incinerator Alternatives (GAIA) and Community of Environmental Monitoring (CEM) at the Kodungaiyur Open Dumpyard[23], Chennai reveals that a total of 19 chemicals were detected in the air sample. The identified chemicals include Carbon Disulphide, Carbonyl Sulfide, Propene, Chloro-methane, 1–3 Butadiene, Ethanol, Acetonitrile, Acrolein, Acetone, *n*-Hexane, Tetrahydrofuran, Benzene, *n*-Heptane, Toluene, *n*-Octane, Ethylbenzene, Styrene, *n*-Nonane and D-Limonene. Out of these 3 chemicals found were carcinogenic—1–3 Butadiene, Benzene, and Chloro-methane, and of these two chemicals were above the levels considered safe for lifetime exposure by the US Environmental Protection Agency. Benzene was 50 times above the US EPA Reference Concentration (RfC) screening level and 1–3 Butadiene was 8.5 times above the US EPA RfC screening level. RfC screening limit refers to the concentration to which an individual can be exposed to a substance for a lifetime without causing adverse effects. Again, out of these 19 chemicals—1 targets blood, heart, and bone marrow, 2 chemicals target the Cardio Vascular System and Peripheral Nervous System, 5 chemicals target the kidneys and reproductive system, 6 chemicals target the liver, 13 chemicals target the skin and eyes, 15 and 16 chemicals target the respiratory system and the Central Nervous System, respectively.

Another major identification was the presence of the chemical Acrolein and the level exceeds the California short-term (acute) "health-based standards revealing the fact that the human settlements around this region are prone to adverse health effects. Any exposure to Acrolein through inhalation, oral, and dermal exposures exerts toxic effects as a potent irritant to the mucous membranes and at higher concentrations, it can also irritate the skin. As such, its toxicity is exerted at the point of contact with tissues (Table 7).

The disposal of MSW in dumpsites or landfills has become a significant contributor to the Green House Gas Emissions globally (mainly CO_2 and CH_4) which triggers the fire and explosions in the landfill if found excess in the dumpsite.

3.3 Soil

It was reported that the soil becomes quickly acidic due to the dumping site from the Ghazipur landfill site and Boragaon solid wastes sites[24]. Plant nutrients like calcium, potassium, magnesium were fluctuating. This creates a bad odor of soil and also leads to contamination of water. Soil is unfit for agricultural or irrigational use and it also results in health hazards. Table 8 shows the effects of MSW on soil properties.

Ali et al.[24] examined the soil at the dumpsite to understand the influence of the open dumping on the soil properties and most of the heavy metals like Pb, Ni, Cr, Cu, and Zn were in high concentrations disrupting the soil quality leaving it ill-suited for any activities. Also, this poses a potential risk after a while since the adsorbed particles start leaching out of the system and ending up in any water source and the overall strength of the soil also gets reduced. This was also reported in another study carried out at Lalur dumpsite, Thrissur while investigating the effect of open dumping on the engineering and chemical properties of soil[25]. Soil properties like compressibility, swell index, and consolidation settlement showed a notable increase for the dumpsite soil compared to a virgin one[26].

Most of the heavy metals which are trapped in the soil around the dumpsite pose a long-term risk to the surrounding environs and also restrict the potential after use of the site. Direct or Indirect exposure with polluted soil or leaching from the soil especially when these recovered lands are subsequently used for cultivation for vegetables by urban dwellers leads to bioaccumulation of metals, which when consumed causes severe health risk.

3.4 Others

In the Indian context, open dumps have become the predominant environment for various vectors like mosquitoes, flies, rats, dogs, and other pets. Most of these vectors become channels for most communicable diseases like plague, murine, typhus, malaria, histoplasmosis, dengue, West Nile fever, etc.[27]. It also becomes direful for the inhabitants around the dumpsite due to the foul smell emanating from the dumpsite and reaches extreme at extreme summer (average temperature exceeding 45 °C)[28].

4 Remediation Strategies

MSW management should follow the principle of minimizing waste, recycling, resource recovery, and integrated waste disposal facility. In recent days, waste reduction and reuse are more important and methods like incineration and composting are preferred rather than landfilling. Waste that is suitable for thermal treatment is incinerated, gasified, or pyrolyzed and waste that requires biological treatment is either composted or anaerobically digested and the rest of the waste goes to landfills.

Countries like Germany, Japan, Austria, Netherlands, Singapore have removed landfilling by implanting a combination of recycling, composting. Many techniques like composting (aerobic and vermin-composting), anaerobic digestion, recycling, refuse-derived fuel, incineration; pyrolysis, gasification, engineered landfills, etc., are available. Every technique has its advantages and disadvantages. Some research shows that 40–60% of organic matter is present in MSW in India and can be used for compost or biogas production. Where waste cannot be recycled it can be converted to heat, power, or fuel. The method to select for waste management depends on population size, the quantity of waste, waste characters, the economics of waste processing, environmental condition, feasibility, country's policies, and many.

4.1 Integrated Waste Management

Policy level interventions have to be brought into effect; not just the recent Solid waste Management Rules 2016 is going to solve the problem—public participation and corporation system needs to be enacted and implemented. Integrated waste management has to be adopted to handle the growing volumes of waste, consisting of waste minimization techniques, waste prevention,

Table 7: Report of the sample taken downwind of the Kodungaiyur Dumpyard.

Sl no.	Chemical found	Levels detected (μg/m^3)	Odor	Health Effects	Target Organs	Carcinogen
1	Carbon disulfide	15	A sweet ether-like odor	Dizziness, headache, poor sleep, weakness, exhaustion, anxiety, weight loss; gastritis; kidney, liver injury; eye, skin burns; dermatitis; reproductive effects	Central nervous system, peripheral nervous system, cardiovascular system, eyes, kidneys, liver, skin, reproductive system	No
2	Carbonyl sulfide	20				
3	Propene	110	–	Anesthetic effects, unconsciousness	Respiratory system and CNS	No
4	Chloro-methane	57	A faint, sweet odor that is not noticeable at dangerous levels	Dizziness, nausea, vomiting; visual disturbance, stagger, slurred speech, convulsions, coma; liver, kidney damage; reproductive damage; [potential occupational carcinogen]	Central nervous system, liver, kidneys, reproductive system Cancer site [in animals: lung, kidney and forestomach tumors]	Yes
5	1–3 Butadiene	17		Irritation eyes, nose, throat; drowsiness, dizziness; reproductive damages; [potential occupational carcinogen]	Eyes, respiratory system, central nervous system, reproductive system Cancer site [blood cancer]	Yes
6	Ethanol	170	A pungent fruity odor	Irritation eyes, skin, nose; headache, drowsiness, weakness, exhaustion, cough; liver damage; reproductive damages	Eyes, skin, respiratory system, central nervous system, liver, blood, reproductive system	No
7	Acetonitrile	16	Aromatic odor	Irritation nose, throat; nausea, vomiting; chest pain; weakness, exhaustion, convulsions; in animals: liver, kidney damage	Respiratory system, cardiovascular system, central nervous system, liver, kidneys	No
8	Acrolein	31	A piercing disagreeable odor	Irritation eyes, skin, mucous membrane; chronic respiratory disease	Eyes, skin, respiratory system, heart	No
9	Acetone	89	A fragrant, mint-like odor	Irritation eyes, nose, throat; headache, dizziness, central nervous system depression; dermatitis	Eyes, skin, respiratory system, central nervous system	No
10	*n*-Hexane	12	–	Irritation eyes, nose; nausea, headache; muscle weakness; dermatitis; dizziness; chemical pneumonitis	Eyes, skin, respiratory system, central nervous system, peripheral nervous system	No
11	Tetrahydrofuran	5.3	Ether-like odor	Irritation eyes, upper respiratory system; nausea, dizziness, headache, central nervous system depression	Eyes, respiratory system, central nervous system	No
12	Benzene	150	An aromatic odor	Irritation eyes, skin, nose, dizziness; headache, nausea, exhaustion; bone marrow depression; [potential occupational carcinogen]	Eyes, skin, respiratory system, blood, central nervous system, bone marrow Cancer site [leukemia]	Yes

Table 7: (Continued)

Sl no.	Chemical found	Levels detected (μg/m^3)	Odor	Health Effects	Target Organs	Carcinogen
13	*n*-Heptane	16	Gasoline like odor	Dizziness, stupor, incoordination; loss of appetite, nausea; dermatitis; chemical pneumonitis (aspiration liquid); unconsciousness	Skin, respiratory system, central nervous system	No
14	Toluene	48	A sweet, pungent, benzene- like odor	Irritation eyes, nose; weakness, exhaustion, confusion, euphoria, dizziness, headache; discharge of tears; anxiety, muscle fatigue, insomnia; liver, kidney damage	Eyes, skin, respiratory system, central nervous system, liver, kidneys	No
15	*n*-Octane	12	Gasoline like odor	Eyes, nose; drowsiness; dermatitis; chemical pneumonitis (aspiration liquid); in animals: narcosis	Eyes, skin, respiratory system, central nervous system	No
16	Ethylbenzene	20		Irritation eyes, skin, mucous membrane; headache; dermatitis; coma	Eyes, skin, respiratory system, central nervous system	No
17	Styrene	28	A sweet floral odor	Irritation eyes, nose, respiratory system; headache, weakness, exhaustion, dizziness, confusion, drowsiness, possible liver injury; reproductive effects	Eyes, skin, respiratory system, central nervous system, liver, reproductive system	No
18	*N*-nonane	9.4	–	–	–	–
19	D-Limonene	27	–	Irritation eyes, skin, nose, throat; headache, dizziness, convulsions; blood in the urine, kidney damage; abdominal pain, nausea, vomiting, diarrhea; chemical pneumonitis	Eyes, skin, respiratory system, central nervous system, kidneys	No

Table 8: Soil properties from different sites.

Point	1	2	2	3	3	4
pH (1:5 water)	4.9	3.9	4.5	4.7	4.3	4.8
%C	1	1.1	0.5	1.2	0.3	1
NO_3^{2-} (mg/kg)	6	4.3	1.2	9.8	3.1	13.6
SO_4^{2-} (mg/kg)	5	3	3	3	2	3
P (mg/kg)	27	20	6	19	9	30
K (mg/kg)	1.3	1.34	0.78	1.19	0.81	1.28
Ca (meq/100 g)	2.62	3.63	4.87	2.77	1.86	3.27
Mg (meq/100 g)	0.34	0.43	0.7	0.4	0.43	0.42
Al (meq/100 g)	0.1	0.07	0	0.16	0.78	0.07
Na (meq/100 g)	0	0	0.02	0	0.03	0
Cl (mg/kg)	10	10	5	5	10	10
EC ds/m	0.04	0.03	0.05	0.04	0.02	0.04
Amm.N (mg/kg)	8	3	0	3	0	11
CEC (meq/100 g	4.37	5.48	6.36	4.53	3.9	5.04
Ca/Mg ratio	7.68	8.35	6.96	6.95	4.37	7.81
Al Sat%	2.3	1.2	0	3.4	19.9	1.3
ESP%	0	0.18	0.24	0.22	0.79	0.2

reuse, recycling, proper segregation, and disposal at the right places.

- Anticipating on the government to solve the entire waste management problem is not a viable approach rather it could be more consulted with public corporations and participation.
- Proper waste collection facilities and accounting have to be adopted to ensure that the system has an adequate number of waste collection bins and facilities and the consumers are utilizing the system properly.
- Viable metering similar to water or electricity should be in place to ensure the waste from each household/industry/occupational and public building ends up in the collection facility.
- Additionally, source segregation should be strictly followed to ensure ease of handling and treatment of waste making the system work more efficiently. At a household or institutional level, although we know the importance of segregation, often it is not followed; there is no deep core technology or knowledge required to do the segregation rather it is a psychological and behavioral syndrome that should be strictly enforced to be followed. Once the segregated waste reaches the transfer station and then to the treatment unit—any of the aerobic/anaerobic/hybrid technologies can be used to treat the organic fraction of waste and the inorganic fraction could be reused/ recycled or used as RDF or should be properly disposed in a proper landfill.
- Use of smart internet of things (IoT) systems to monitor the collection, transport, and handling of the waste management facility. One such intervention could be noticed in Chennai city, where they have considered 32 parameters for assessing the performance of the waste handling facility incorporating the IoT systems in bins and collection facilities.

4.2 Landfilling

Any landfills regardless of sanitary landfills/bioreactor landfills require a significant amount of investment as well as land for its construction. There are often political and community obstacles to its construction as no one wants to have a waste treatment facility in their neighborhood. The post-operative challenges associated with the closure of the landfill are also a major concern. Extending the life of the landfill by diverting the quantity of waste generated by prevention, reuse and recycling, and composting can economically support and this also creates jobs, improves economic competitiveness, reduces carbon emissions, less natural resources consumption, and creates an alternate economy/cash flow within the waste management streamline. Sanitary landfills

Table 9: Municipal solid waste composition from Perungudi Dumpsite, Chennai.

Composition of MSW from Perungudi Open Dumpsite, Chennai	Percentage fraction
Organics	43.19%
Paper and cardboard	5.47%
Plastics	14.16%
Rubber and leather	0.99%
Rags and clothes/textiles	2.14%
Batteries/E-board	0.08%
Aluminum	0.15%
Glass	0.59%
Wood	5.17%
Inerts	28.03%

are essential for the final disposal of wastes that cannot be reused, recycled, prevented, or composted. This would be a viable option when compared to the Open dumps which create a huge risk to human health and the environment. Other options like mass incineration, pyrolysis, etc., could be also considered after understanding the waste characteristics, calorific value, and the budget allocated to waste management.

4.3 Compositing, Bioreactor, Bio-methanation, Bio-mining and Incineration

In the South Asian region, around 70% of solid waste generated comprises biodegradable organic mass with high moisture content[29]. To better understand the waste characterization in an Indian context, a study was conducted to analyze the samples (coning and quartering process) from Perungudi open dumpsite, Chennai and the results are as shown in Table 9 below.

Considering the high percentage of organic constituents in the MSW generated in a developing country, energy recovery via. bio-reactor or bio-methanation unit or composting could be a potential option and also reduce the quantum of wastes that are disposed of in the landfills, thus extending their lifetime. In the integrated solid waste management plan, the last priority after undertaking the waste prevention, recycle, reuse, and composting is Incineration.

4.4 Closure of an Open Dumpsite

Often when the question of closure of a dumpsite is decided, several key typical questions arise: methodology adopted, Funds/Capital Resources, and the major and most import one—How do we handle the new waste originated? Although there are potential problems associated with the closure of the dumpsite, the most common one is the difficulty in transition from old habits to new technology. Another major and significant problem is concerned with the capital cost involved in closing and invariably the funds allocated for this will be minimal. When it comes to decision-makers, especially in developing countries, they are bound to allocate funds for basic infrastructures, such as water supply, housing, and wastewater treatment, leaving the solid waste issue trivialized. However, one has to compare the cost associated with the environmental damage and public safety and health to understand the importance of closure of these sites.

On a practical aspect, it is impossible to properly close an old dumpsite; this has to be addressed by adopting certain procedures in place as follows:

a) Providing a new waste disposal facility that can accept the waste at the same time close, enable the old site to be completely closed.
b) Informing, training, and educating the waste operators, site users, and generators about the new facility and procedures.
c) Cut-off the access to the old dump and upgrade the site by re-vegetate, control and prevent drainage.
d) Post-closure management.

The three major methods available for the closure of an open dump are:

i. In-place method—closing by covering the waste.
ii. Mining/evacuation method—closing by removing the waste from the site.
iii. Upgrading method—converting the dumpsite to a controlled or secured landfill.

In recent times, one of the most notable and promising technologies gaining importance in a developing country is the concept of biomining. It refers to a process of digging out the past disposed of/dumped waste from an open dumpsite to recover the valuables, such as metals, glass, combustibles, soil, and other fine material through a series of mechanical–electrical–gravity process[29]. This has been widely practiced in different parts of the country especially in Hyderabad, Kumbhakonam, Coimbatore, Mulund—Mumbai, Kochi, and many more. Biomining will not only provide exhumation but will reclaim land and remediate existing public health and environmental quality problems associated with the existing or closed dumpsite. Although this would not solve the problem completely, rigorous efforts have to be taken to better understand and create a sustainable financial model.

5 Conclusion

This review of the impacts of open dumping reveals that there is an urgent need of reclaiming the prevailing dumpsites to ensure reuse/recycle the untapped resources, extending the current land availability, and reducing the environmental, ecological, and social damages. The MSW generation in India and the hazardous impact of water, air, and soil have become very crucial and the remedial measures should be approached holistically. Often most waste management facilities failed because of their revenue model as they are not able to convert the waste mass to its usable products for end-users in a financially viable manner and, thus at the planning phase the revenue model should be made self-sustainable for its lifetime operation.

The following are the major inferences resulted from the review on the effects of dumping sites on the environment.

- India is witnessing a rapid formation of populous megacities contributing to a larger environmental degradation and health hazard due to the non-ending piling of municipal solid wastes.
- As evident from various pieces of literature mentioned, the leachate emanating from the dumpsites poses a potential risk of contaminating water, soil, and air. The level of pollutants in all mediums around the dumpsite was found higher in most of the literature and can be concluded that dumpsites are the cause of contamination and act as an area source of contamination. The leachate emanated from the decomposition and rainfall from the dumpsite acts as a point source of contamination of surface and groundwater bodies.
- Many studies have shown that people suffered from common cough and cold, diarrhea, skin and respiratory infections, malaria, dengue, asthma, bronchitis, skin irritation, allergy, gastrointestinal diseases, etc. Various gases (GHGs, H_2S, etc.) are the main causes of odor and trigger various health issues like headaches and other respiratory problems. About 14% of global GHG is emitted from landfills and poses a great threat to the environment as there is leakage of CO_2, CH_4, and leachate production or greenhouse house gas.
- A higher concentration of various heavy metals is observed in the soil around the dumpsites which decreases the soil strength and also affects the survival of vegetation.
- Not just rehabilitation or closure of the dumpsite solves the problem, there needs to remediation carried out for the groundwater, surface water, and soil across the region. Some of the few steps to protect the contamination are by providing vertical cut-off walls around the dumpsite to contain the contamination, covers on dumpsite by HDPE or soil or locally available material to decrease the leachate generation and surface water contamination, gas collection systems to reduce the harmful gases and GHG emissions.
- The closure of the dumpsite should aspire in all situations as it shows the proactive vision and anticipation of the governing body in addressing the future risk associated the environmental contamination. The cost associated with the closure will be high and the revenue model is not so promising, one has to outweigh the damage cost associated with the environmental contamination and public health risk. As a progressive initiative of the ULBs and Corporations, the ongoing operation of open dumps should be discontinued and adequate planning and care should be taken to close and prevent future contamination from these existing sites. In most cases, often it is understood that resources are insufficient.

Publisher's Note

Received: 30 November 2020 Accepted: 17 May 2021
Published online: 2 July 2021

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