Transforming the Urban Waste Mountains: Lessons from Indore's Bioremediation of Legacy Waste

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ABSTRACT

Waste management in urban areas can pose manifold challenges that can threaten the goal of achieving sustainable cities. The need of the hour is to assess the existing waste management practices in our cities and explore new alternatives to develop cost-effective, non-hazardous long-term waste management plans. The Solid Waste Management Rules 2016 instructed Urban Local Bodies (ULBs) in India to investigate and analyse existing dumpsites to explore their potential for biomining and bioremediation. This paper briefly touches upon the challenges posed by poorly managed municipal solid waste and also provides a glimpse into measures adopted by the Indore Municipal Corporation (IMC) in successful implementation of Bio-remediation of process.

Keywords: *Municipal Solid Waste Management; Bioremediation; Legacy Waste; Indore.*

URBAN WASTE CHALLENGE: AN INTRODUCTION

Cities have always been a complex system of production and consumption. With this characteristic of the city comes exponential population growth, improved incomes, and therefore increased consumption, subsequently leading to the copious amounts of waste being generated. In its 2018 report titled "What A Waste 2.0: A Global Snapshot of Global Solid Waste Management to 2050", the World Bank estimates that waste generation will increase from 2.01 billion tonnes

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in 2016 to 3.40 billion tonnes in 2050. A 2014 Planning Commission report stated that urban Indian generates 62 million tonnes of municipal solid waste (MSW) annually. It also predicted that the volume will increase to 165 million tonnes by 2030. In 2016, The Centre for Science and Environment (CSE) published Not In My Backyard: Solid Waste Management in Indian Cities report, highlighting the concerns of overflowing landfills in Indian cities. It recommended avoiding the use of scarce and valuable land for disposing waste and to treat waste as a resource. In recent years, the Urban Local Bodies (ULBs) in India have attempted to explore new methods of waste disposal and re-invent waste management in the country largely due to the Swach Bharat mission launched in 2014. In the second phase launched in September 2021, the focus was on making cities garbage-free with efficient source segregation, 100 per cent door-to-door collection and complete remedial treatment of the waste.

This paper highlights various urban solid waste challenges in India and elucidates the meticulous planning, rigorous efforts, coordination, collaboration and cooperation involved in the bioremediation process and its cuccessful implementation.

Proper management of urban solid waste has posed a serious challenge for ULBs and citizens globally, especially in developing countries. MSW Management System involves activities associated with the generation, storage, collection, transfer and transport, processing, and disposal of solid wastes however, in most cities, it comprises only of four activities, i.e., waste generation, collection, transportation, and disposal (Bundela, Gautam, et al. 2010). Improper management of waste can directly or indirectly affect many aspects of a city and its citizens, leaving ULBs with a manifold of unforeseen challenges to tackle, such as – Spatial challenges, Societal Challenges, Health Challenges, and Environmental Challenges.

Spatial Challenges

In Indian cities, land is a scarce and expensive resource however, landfilling is a common method adopted by many ULBs to manage urban waste. In India, most of the solid waste is disposed off by landfilling in low-lying areas located in and around the urban centres (Kumar, Gaikwad et al. 2004). Almost 70–90 per cent of landfills in India are open dumpsites (Jha, Sharma, et al. 2008). Indian megacities like Delhi, Bangalore, Chennai, Kolkata and Mumbai have landfills that have amassed waste for almost two to three decades and waste dumped have reached a height of 300 feet in Bhalswa, Delhi to 78 feet in Kolkata (S. Goswami & S. Baswak, 2021). Landfills are an unpleasant sight and can damage the city's aesthetics and blanket its surroundings with an unbearable stench. Through Landfill Reclamation ULBs can avoid high costs for acquiring new land and also recover reclamation costs with sales or use of recovered materials (USEPA, 1997).

Societal Challenges (Caste and Class)

Right from the waste being collected from everyone's doorstep to its transportation, segregation, or recycling, the entire process of waste management involves people from the lowest rung of the society. These include the poor, individuals at the bottom of the caste hierarchy, women, the elderly, and at times even children. They often work in unhealthy conditions, lack social security or health insurance, lack education and training opportunities, and face strong social stigma (Kaza, Yao, et al. 2018). The kins of these workers also take over this job once they retire or die, thus this work is 'reserved' for the poor and the lower caste and they are trapped in this cycle.

Health and Wellbeing

Improper waste management can cause health hazards both for those who handle the waste and also for those who live near the dumping sites or Waste Management Plants. Those who are constantly exposed to the landfills are often at the risk of having musculoskeletal disorders, decreased lung functions and respiratory issues, mental health issues among several other health risks. Constant interaction with waste can also expose the workers to skin diseases, infections, depression, and intestinal problems created due to flies feeding on the waste (Garrido, Bittner, et al. 2015). Moreover, if these waste dumping sites are close to human settlements then there is probability of leachate contaminating the water supply, attract disease-spreading rodents and emit odour. One of the reasons for the Surat's Pneumonic Plague in 1994 was the mismanagement of waste and sewers. The Plague affected as many as 1200 people and claimed 63 lives. Zero-Landfill cities will not only be a step closer to achieving sustainable cities but also developing healthy cities.

Environmental Challenges

Improper waste management can affect the environment at various levels: soil, air, and groundwater. It can even contribute to climate change due to organic waste generating Green House Gases like carbon dioxide and methane. If the waste is directly disposed off onto the surface of the land, without a protective layer as a barrier, the toxic and harmful substances found in Municipal Solid Waste can penetrate the soil thereby depleting its qualityand also affect the ground water. It can alter the physical, physico-chemical, and chemical properties of soil. This would also reduce overall soil strength and consequently its usefulness as a foundation material (Pillai, Peter, et al. 2014).

Burning of waste, either intentional or unintentional, can pose risk to the environment. Open burning of waste generates dangerous carcinogens like dioxins, furans and black carbon which is a short-lived climate pollutant that contributes to climate change. The organic compound found mostly in domestic waste produces methane, a significant contributor to global warming (Mor, Suman, et al. 2006). This methane can also cause fires in landfills that can rage over for hours and at times, even days. The Delhi Fire Services (DFS) data brings to light the alarming rate of these landfill fires as the Bhalswa site had 69 major fire incidents, Okhla 35 and Ghazipur 27 in 2018 (The Times of India, 2019).

MUNICIPAL WASTE MANAGEMENT IN INDIA

Discerning the quantity, quality, and characteristics of waste is crucial to devise a cost-effective and efficient waste management approach that would not only address the current issues but also foresee and prevent future crises. Central Pollution Control Board's data on solid waste generation in 46 metropolitan cities revealed that for the year 2015-16 Mumbai (11,000TPD), Delhi (8,000TPD), Chennai (5,000TPD), Bangalore (3700TPD), Kolkata (4000TPD), Hyderabad (4000TPD) and Ahmedabad (2500TPD) generated the most waste. However, sufficient data regarding the composition of waste in India is severely lacking due to segregation of waste not being a prevalent practice. In 2011, High Powered Expert Committee's report titled 'Indian Urban Infrastructure and Services' stated that due to poor enforcement of The Municipal Solid Waste (Management and Handling) Rules, 2000, neither Households nor Municipalities practice segregation of biodegradable waste from the rest. These rules, framed by Ministry of Environment and Forest (MoEF), defined Municipal Solid Waste (MSW) as "commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes". The Solid Waste Management Rules, 2016 extended its jurisdiction beyond municipal area and also emphasized the need for source segregation of waste by the generators and assigned responsibility to Resident Welfare and Market Associations, gated communities, institution and SEZ. It is believed of MSW that the major components include food waste, plastic, rags, metal and glass, and small quantities of hazardous waste like electric bulbs, batteries, automotive parts, discarded medicines, and chemicals, etc.

Negligence and lack of stringent laws has led to around 3159 dumpsites to emerge in India over the years (Centre for Science and Environmnet, 2020). World Bank's 2018 report titled "What a Waste 2.0" revealed that 77% of waste generated in India is disposed in dumpsites, 18% is composted and only 5% is recycled However, Swach Survekshan, a competitive monitoring framework for accelerating Swachhata outcomes in Urban India, conducted annually by Government of India to assess and rank urban areas on their cleanliness, hygiene and sanitation, shows the changes in MSWM in India. Swach Survekshan 2017 which was conducted across 500 Indian cities found that 297 cities practiced door-to-door collection of waste, in 407 cities 75% of the residential areas were found to be substantially clean and in 85 cities segregation of waste was sustained at all levels of waste processing in more than 75% of the wards. In 2021, the number of cities surveyed had increased exponentialy to cover 4320 cities. The survey found that 1161 ULBs had enhanced their waste collection process, 1493 have started waste segregation process, 762 cities have constituted bulk rule /act waste generator to process waste on-site. These figures are a reflection of the positive changes that have developed in MSWM and an indictaion that ULBs across the nation are gradually moving towards achieveing the goals setup by the Swach Bharat Abhyan.

Moreover, new and innovative approaches have also emerged in Indian cities. NITI Ayog in its 2021 report titled 'Waste-Wise Cities – Best practices in municipal solid waste management' documented the best practices in MSWM in 28 Indian cities across 15 states to highlight environment friendly and financially sustained practices adopted by several ULBs to manage their MSW. The cities were identified in 10 thematic areas of MSWM. Panaji achieved 99% source segregation by segregating waste into 16 fractions, its collection on designated dates and continuous information, education and communication (IEC). Jamshedpur has become a model for material recovery by constructing 20 km of roads using non-recyclable plastic from its Dry Waste Collection Centres and popularizing eco-bricks in schools and households. Bruhat Bengaluru Mahanagara Palike utilized Information, Communication and Technology (ICT) such as Radio Frequency Identification (RFID) based attendance system, geo-tagging of collection routes and mobile app Ezetap to monitor Garbage-Vulnerable Points to ensure 100% door-to-door collection and make the city free from garbage-vulnerble points.

BIOREMEDIATION PROCESS

Bioremediation, in simple terms, uses living micro-organisms to decompose contaminants. This process stimulates the growth of certain microbes that feed on contaminants, changing them into small amounts of water or harmless gases like Carbon Dioxide and Ethene. It was first used on a large scale in 1972 to clean up Sun Oil pipeline spill in Ambler, Pennsylvania and since it has been used to remove pollutants from water bodies, groundwater, soil, etc. and restore them to their original pristine state. The success of the bioremediation process depends on the right selection criteria and performance criteria (Azubuike, Chikere & Okpokwasili, 2016).

The nature of the pollutant, the extent of pollution, type of environment, location, cost, and environmental policies for the region are some of the selection criteria that are considered when choosing any bioremediation technique (Frutos et al. 2012; Smith et al. 2015). Based on the site of application, bioremediation techniques can be categorised as ex situ or in situ. In situ technology involves treatment of the contaminated material on the same site. In situ technology might be enhanced (bioventing, biosparging, and phytoremediation) or may not need any enhancement (intrinsic bioremediation or natural attenuation). Ex-situ technique requires physical transportation of the contaminated material to another area for treatment under a controlled environment. Out of the two ex-situ is more expensive due to the cost of excavating and transporting the material and can also have risks due to improper handling. However, it is preferred due to it being faster, easier to control and applicable for a variety of contaminants as compared to in situ technique. For bioremediation to be effective, performance criteria, i.e. the right conditions like the soil structure, moisture level, pH level, oxygen level, temperature and microbial diversity are also vital (Vidali, 2001). Right conditions allow the microbes to grow, multiply and eat more contaminants and in the absence of favourable conditions and contaminants, these microbes die (EPA, 2012).

Bioremediation does have certain limitations. For instance, only a few fungi or bacteria can act on the organic compound and it can be very difficult to destroy a large percentage of chemicals. It is also a very long process that takes time to show visible effects. However, it offers great benefits thereby making it a viable option that ULBs can adopt to reduce the volume of waste in their respective jurisdictions. It is a natural process that poses no threat to the health and well being of those near the site nor to the environment.

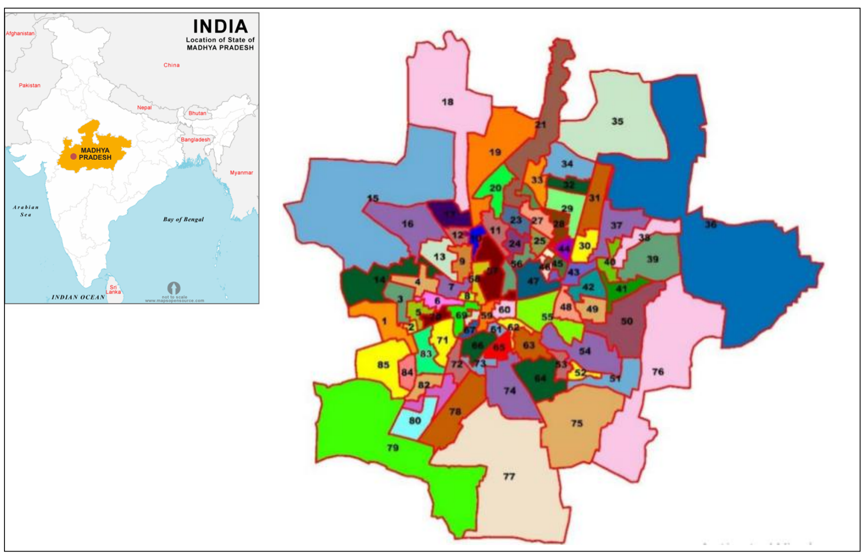
The ULBs were now pressured to undertake long-term solutions instead of merely adopting a band-aid approach to address the immediate needs.

CASE STUDY : INDORE MUNICIPAL CORPORATION

Indore: City Profile

Indore, located in the western region of Madhya Pradesh (M.P.), lies within the tributaries of Shipra River (Fig. 1). With an elevation of 553 meters above sea level, Indore has two main rivers, Chamba (west) and Kshipra. The City had a population of approx. 3,272,335 (according to Census 2011) with a population density of 839 persons per square kilometre and had decadal growth rate of about 33%. The sex ratio was 924 and the literacy rate was 82%. Indore has Marathi as the main language spoken by the majority of the population. Other languages spoken in the city are Hindi, Gujarati, Sindhi and English.

Fig. 1: Location Map of Indore Municipal Corporation (IMC)



Source: Indore Municipal Corporation.

Indore is the major hub for commercial activities but it also includes traditional agro-industries, modern corporate and IT companies making it one of the busiest cities in M.P. It also has numerous engineering and management schools to cover the supply of the growing demand for professionals. Indore's markets are filled with traditional businesses of textiles, IT & automobiles and steel industries, contributing substantially to Indore's economy, making it the business capital of M.P.

Indore is not only known for its economy and traditions but for last 5 years it is also known for its cleanliness. In 2016, the annual Swachh Survekshan Survey conducted by the Ministry of Housing and

Urban Affairs ranked Indore at 25th position, which was a below-par performance. This was mainly due to performance of Indore Municipal Corporation (Fig. 1) in context of improper collection and transportation of the MSW, leading to overflowing dumpsites, Garbage Vulnerable Points (GVPs), and secondary storage bins all over the city. But 2017 marked the turn of the tide, as since then Indore has managed to secure the first rank in the Swachh Survekshan for five years consecutively. The factors that were taken into consideration for the ranking were ground confirmation, handling of waste, innovative methodologies, financial stability, recovering solid waste administration cost etc. (Singh, R. 2021)

The Waste Scenario pre-2015

Indore, before being the cleanest city in India, was like any other Indian city in terms of its waste management. The unsegregated waste was dumped in the Devguradia trenching site and open sites in the city. Moreover, the city was characterised by a large number of Garbage Vulnerable Points (GVPs) which attracted stray animals, birds and rodents. Waste management was mainly looked after by *Jagirdaars* (traditional garabge collectors) and private operators, who had poor service quality levels and waste was dumped either in the dustbins across city's streets or in open land. In November 2013, the Madhya Pradesh Pollution Control Board submitted its report to the Madhya Pradesh High Court and suggested increasing the capacity of garbage collection and disposal. The report also noted that the unauthorized burning of the waste in the Devguradia trenching site was causing pollution in the area. It also stated that out of 875 metric tonnes of waste that was collected per day, only 250 metric tones (about 29%) was processed each day at the Devguradia trenching site (DNA, 2013). On 27th October 2015, the Madhya Pradesh High Court directed Indore Municipal Corporation (IMC) to present a comprehensive time-bound programme to manage its waste management issues before 6th November 2015. By December 2015, the IMC had swung into action by initiating door-to-door collection of waste in ward number 42 and 71 and undertaking awareness programmes to encourage segregation of waste into biodegradable and non-biodegradable waste at households. Within three years, post 2016, IMC, owing to its efficient planning, rigorous implementation, and monitoring process, was successful in remediation of 15MT legacy waste, which had been disposed off over a span of 60 years in the Devguradia trenching site. This successful venture helped the IMC reclaim around 40 acres of land which was then turned into a green belt and also helped the city earn the title of a zero-landfill, zero garbage city.

The Implementation Plan

With the advent of the Swachh Bharat Mission in 2014, ULBs were under immense pressure to take appropriate measures to address the sanitation issue in their respective jurisdictions. The IMC formulated an implementation plan that consisted of three simultaneous steps : (i) Door-to-Door colletion of waste, (ii) elimination of GVPs, landfills, and open dumpsites, and (iii) Bioremediation of Legacy Waste. These steps were designed not only to address the immediate issues at hand but to also keep possible future issues at bay.

(i) Door-to-Door Collection

Door-to-door collection of waste, one of the important steps to acheiving a zero-landfill status, as it prevents crude disposal of waste and also helps to gauge the quantity and quality of waste generated better. Hence, door-to-door collection of waste was introduced in Indore to collect household waste while semi-bulk and bulk generators of waste were covered by bulk collection system.

An identification survey was conducted to understand the volume of waste generated in each ward and accordingly a detailed route plan for collection of waste from all words and deployment of staff was designed. The pilot project launched in 2 wards was started in December 2015. The project was expanded to all the 85 wards by end of 2016. The waste, segregated at source into 3 types – dry, wet, and domestic hazardous waste, was collected from households in partitioned vehicle. Currently, waste is segregated at source into 6 fractions, namely wet, plastic, non-plastic (dry), sanitary waste, domestic hazardous waste, and e-waste.

By 2016, IMC had ensured the collection of MSW and its transportation to Garbage Transfer Stations (GTSs) and processing sites every day. The city has 10 GTSs with capacities ranging from 150-200MT and a processing site at Devguradia spread over an area of 146 acres with a waste capacity of 254MT daily. Ragpickers and scrap dealers were employed to collect the waste and around 685 vehicles were deployed to transport waste from various sources to GTSs where it's weighed through weighing bridges before being sent to the processing site. Currently, as of 2021, for door to door collection of waste, 650 vehicles of 3.2cum and for bulk waste 100 vehciles of 5cum along with 1100 workers as drives and another 1100 as helpers have been deployed.

(ii) Initiatives to become a bin free city

The IMC, simultaneous to the door to door project, made efforts to eliminate the GVPs, secondary storage bins and open landfills. A survey was conducted by IMC to estimate their numbers, and the results exposed the dismal state of waste management in the city. The city has 1380 secondary storage bins, 408 dumpsites and 4753 back lanes. The door to door system helped in curbing crude disposal of waste making the city bin-free by December 2016. M/S Eco Pro Environmental Services was hired in 2017 to conduct a survey to assess the status of these sites, and it was reported that the city was free of GVPs and dumpsites. However, the report identified 171 old dumpsites. These sites later underwent facelift. The IMC has made constant efforts to monitor and prevent them from re-emerging. In 2020, the IMC decided to conduct a quarterly survey to keep a close check and maintain the city's status as a bin free city.

(iii) Bioremediation/ bio-mining of legacy waste

Based on the Solid Waste Management Rules 2016, the IMC sought to determine the feasibility of bioremediation of legacy waste. An action plan consisting of two phases was formulated. The first phase was rolled out to test the waters, the second phase was initiated after having empirical proof to indicate the success of the first phase, which was carried out by M/s A to Z infrastructure from July- December 2016. The second phase was carried out by E-tech projects between 2017-2019. The nine steps undertaken for the bioremediation process were:

Step 1: Identification of an area

The IMC conducted surveys to identify the areas that would be fit to carry out the bioremediation process. For the success of bioremediation, the site needs to have certain geophysical, geochemical and biological characteristics. The right conditions would allow the right microbe to thrive, multiply and eat more contaminants (Vidali, M. 2001).

The Devguradia trenching site was deemed to be fit for bioremediation. The processing facility at Devguradia site was operational since last more than 40 years. However, over the years residential areas have emerged near the site, the closest one being 200m away from the trenching site. Several residents started to raise concerns regarding the health problems that were arising due to the smoke coming from the burning garbage. In 2015, the Madhya Pradesh Pollution Control Board (MPPCB) studied the water sample collected from a tubewell near the trenching site and reported that the water quality in the area was critical and in need of immediate attention. Considering these factors and the geophysical, geochemical and biological characteristics of the site, further surveys were conducted to map out an efficient action plan.

Step 2: Conducting Surveys

Contouring and topological surveys were conducted using Total Station and Differential Geographical Positioning System (DGPS) to determine the quantity of the waste to be bio-remedied. A contour map of the Devguradia site was created and parcels of the site were labelled as location A, B, C and D (Fig. 2). The quantity of waste in each of these four parcels were estimated (Table 1). Out of the 15 lakh cum of the overall quantity of MSW, it was decided that 50,000 cum would be bio-remedied in the first phase.

Fig. 2: Contour Survey Map of Devguradia Trenching Site

Source: "Indore 2021: Remediation of all identified dumpsites no legacy waste (dumpsite)/ Zero landfill city".

TABLE 1: CONTOUR SURVEY RESULTS

Location	*Area (sq. m)*	*Average Height of waste (metre)*	*Quantity (cum)*
A	84650	4.50	3,80,925
B	49186	6.40	2,14,790
C	66493	5.10	3,39,114
D	73089	6.36	4,64,846
		Total	**14,99,675**
		Rounded-off	**15,00,000**

Source: "Indore 2021: Remediation of all identified dumpsites no legacy waste/ Zero landfill city".

The success of Door-to-Door collection and segregation of waste at source also facilitated the study of characteristics of MSW generated in the city. The characteristic of MSW in Indore indicated that most of the waste generated in the city was organic waste, while metal and glass waste constituted the minority. Sites having a large content of old decomposed waste won't be suited to undergo bioremediation.

Step 3: Excavation or bio-mining process

Before starting the bioremediation of waste, it is imperative to excavate or bio-mine legacy waste. The waste is excavated by loosening it to make windrows. Loosening the waste exposes the legacy waste to sunlight and air, causing the leachate in the legacy waste to dry up, allowing the waste to decompose without odour later when sprayed with bio-culture. Excavation is done by using JCB excavator, sieving, segregation and baling.

Step 4: Adding Bio-cultures

The dusty top layer usually consists of materials inactive biological state, therefore they were stabilised using herbal or biological culture or sanitisers. Subsequently, composting bio-cultures were introduced to the mix which created biological heat from within the waste, thereby accelerating the decomposition process. The biological heat generated through this further dried up the waste and decomposed aerated waste into carbon dioxide and water vapour, and in doing so reduced the volume of waste by 40% and released entrapped methane.

Step 5: Raking leftover recyclables

Long spike harrows operating in cross directions were used to rake the garbage and remove recyclables from it regularly.

Step 6: Installation of machines for removal and segregation of waste

The recyclables recovered were sent to the Material Recovery facility (MRF) which is located adjacent to the Bioremediation unit. The city has two MRF sites, the one adjacent to the unit is a fully automated MRF installed by Nepra Resource Management Private Limited through the PPP model. A variety of machines were deployed to segregate the waste, all of which were brought by the appointed contractors at their own cost. The second phase made use of trommels and associated machinery. Powerful fans were attached to each trommel at the reject conveyors to blow out the plastic fractions. Machines were used to remove the dust from recovered waste, and after cleaning and washing the recovered recyclables like glass metal, cloth, plastic, etc., were sold to ragpickers and scrap dealers for recycling. Upon the successful execution of the first two phases, the IMC took up the task of bioremediation of 1,00,000 cum waste for its third phase spanning between January 2018 to August 2018. From its previous experience, the IMC concluded that 15-20 times more machinery would be required to tackle this large amount of waste in a short period, hence the IMC deployed 10 Trommels, 15 Horizontal Screens, more than 50 excavators, backhoe loaders on rent with operators with 200 plus workers to execute the work. Daily monitoring of the progress of work was done by a team headed by the Commissioner of Indore Municipal Corporation. The cost for the machines was not borne by the IMC. Apart from machines, the IMC also employed around 200 workers at the bioremediation unit. These workers included *kabaadiwalas* and rag pickers, including women. Keeping the safety and well-being of the workers, the IMC imparted them with training and personal protective equipment.

Step 7: Removal of Inert and plastic waste

After the waste was segregated and the recyclable waste was sent for recycling, inert and plastic wastes were separated from the soil. Stone, bricks and ceramics were sent to the construction and demolition waste plant where they were processed and re-used, or to the cement factory at Manawar or to low lying areas for filling and roads. The inert waste was weighed and sent to a secured scientific landfill within the disposal site. Only 10 per cent of the total waste at the site couldn't undergo bioremediation.

Step 8 & 9: Addition of soil and Construction of Green Belt and plantation

The soil that retains at the site, after the entire process is complete, is highly fertile. The microbes added to the soil during bioremediation are also commonly used in lawns and gardens, therefore do not pose a threat to the composition and fertility of the soil. This soil was spread over the site allotted for the plantation to develop a green belt. The soil recovered after segregation was transferred to existing gardens or to create new gardens in the region.

CONCLUSION : INDORE'S BIOREMEDIATION PROCESS

The Indore Municipal Corporation's laudable efforts helped transform Indore into a landfill-free city. With the Bioremediation process, Indore was able to clear around 15 lakh metric tonnes of waste in three years and transform the land into a green belt, thereby recovering 40 acres of valuable land. Also, the IMC had comprehensively planned the project. The bioremediation unit, weighbridges, MRF centres, all were located within the site to reduce unnecessary transportation and make the cleanup method easier and economical. Moreover, this ensured that life outside the site was not disrupted by the constant movement of trucks in and out of the site. (The only downside could have been the noise generated from the machinery used in the site.) The wellbeing and safety of the workers was also given consideration and they were equipped with sufficient training and safety gear.

Bioremediation is without a doubt one of the most viable Municipal Waste Management Techniques. It uses safe microbes that pose no threat to workers on-site or those who live nearby instead, it can help in increasing the soil's fertility. Regardless, it has its limitations. The process can only be successfully carried out in sites where the waste has high organic content i.e, sites that also have fresh waste along with legacy waste. Legacy waste that has been left unattended for years at landfill sites and have already reached the maximum microbial degradation cannot undergo bioremediation nor can they always be recycled, therefore they reap no commercial value. Moreover, management of legacy waste should be combined with the integrated waste management facility having adequate capacities for collecting, transporting and disposing of the MSW produced on a day-to-day basis as well as legacy waste trapped in the dumpsites. In Indore, the IMC took initiative to first ensure door to door collection and source segregation of waste to make things easier. Then they addressed the overflowing GVPs and secondary storage bins in the city before finally starting the bioremediation. Even after the bioremediation has been completed, IMC continues to practice door to door collection of waste, 6 types of waste segregation, conducts quarterly surveys to prevent re-emergence of GVPs and secondary storage bins and inculcates good waste management practices among citizens. The three steps together contributed to the success of this venture. Other ULBs who intend to reproduce the same impact in their city should bear in mind the extensive preparatory work that goes into laying the foundation for a successful bioremediation process and also the continuous monitoring that is required. Regardless, bioremediation is a first good step that ULBs all over the country can use to shrink the heaping mountains of waste.

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