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Urban Municipal Solid Waste Management in the Garbage City of India: A Technical Report

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Abstract: Scientific knowledge led to the development of machinery and industries, which started industrialization. That historically resulted in urbanisation due to job opportunities created in these industries. Hence, urbanisation directed economic growth and boosted peoples' living standards that ultimately affect consumer behavior to purchase packaged food and other good. The unattended and managed trash and garbage keep on piling up and give rise to in current environmental issue called Municipal Solid Waste (MSW). MSW is an immense problem nowadays in developing countries and their cities like Patna. The waste generated needs to be addressed soon so that its pollutants will not spread to cause a health hazard. In such a scenario, a detailed analysis of the city's waste is required at most. Hence this paper represents the extensive field survey information regarding MSW and its management in Patna. Findings show proper channelized authorities to handle the MSW. But certain limitations are found at each level which causes hindrance at every stage of waste management. Public awareness and education will help to manage the per capita waste generated through per capita waste management. That will lead to the develop cleanliness as a habit or the culture of the people.

Keywords: Industrialisation; Municipal solid waste management; Municipal solid waste; Patna

1. Introduction

Environmental Protection Agency (EPA) has defined municipal solid waste (MSW) as items which are utilised by human beings and the remains of these used items that are thrown away (such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries) are more commonly called trash or garbage, and is generated in municipal notified areas (USEPA, 2012). MSW is both commercial and residential waste as they originate from different sources like houses, schools, restaurants, markets, institutions, and businesses. During the 20th century, municipal solid waste management (MSWM) has become a prominent issue in developing countries especially in their cities, which must be addressed for reducing its impact on the environment and for promoting public health (Shekdar, 2009). Hence, to address MSWM problem the present study considers Patna, the capital of Bihar. The current scenario of MSWM in Patna is neither integrated nor sustainable and this situation places environment and health of people at potential risk (Kumari et al., 2011; Bhanu and Kumar, 2014). This paper presents findings from extensive fieldwork and data collected. This study focuses on the MSW and its management in Patna.

2. Detailed analysis and discussion

In Patna these preventive measures can be comprehended by the detailed study of MSWM governing structure; Patna MSWM formal sector and actor's hierarchy; MSW generation and composition; MSW collection and transportation; MSW treatment and disposal: through Public Private Participation; and MSWM through informal Recycling. This helps in developing a city specific management of waste.

3. Methodology

The data on the MSW and MSWM has been primarily collected via purposive sampling technique, from twenty-four stakeholders of MSWM. For the collection of desired information through survey two different techniques can be implemented that are structured questionnaire and personal interview.

4. Governance structure of MSWM in Patna

The state municipalities are responsible for the management of MSW (MoEFCC, 2016). The central government prescribes set of rules and regulations whereas local government defines the configuration, procedure and implications of MSWM. The stakeholder A, chief engineer at Patna Municipal Corporation (PMC) and his personal assistant at PMC office in the interview explained briefly about the spread of working boundaries of PMC. Patna is divided into six circles that have been a divided into total seventy-two administrative wards. The four circles named New Capital, Kankarbagh, Bankipore and Patliputra, includes most of the administrative wards, i.e., fifty-two administrative wards. The two circles called as Patna city and Azimabad cover the remaining twenty administrative wards.

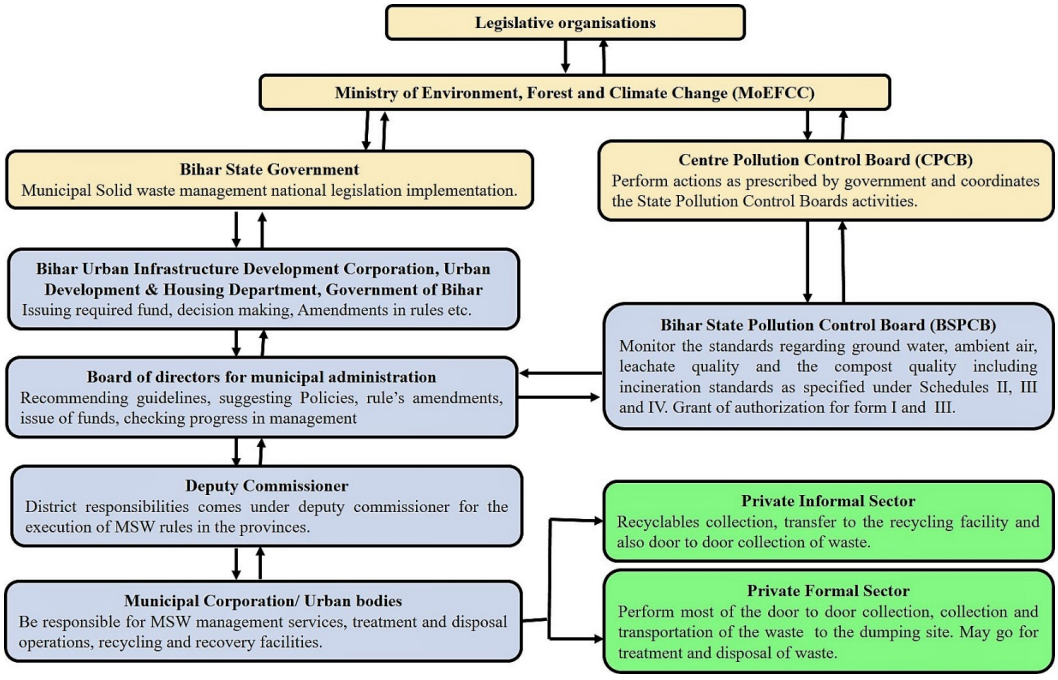

Figure 1. egulatory configuration of central and local authorities (Source: Drawn from fieldwork information in 2017).

Stakeholder A, explained the administrative hierarchy of the office that is shown in Figure 1. The figure 1 explains about the authorities or organizations handling the responsibility, and the channelized pathway from higher authorities to ground level workers of MSWM in Patna. In the diagrammatic representation of PMC, given below, the orange boxes symbolize the national authorities whereas blue boxes are the state governing bodies, and green boxes are private sector associated with the MSWM. Indian Supreme Court (Gupta, 2010) after finding casualties due to lack of MSWM structured laws, and rules for its regulation. These rules were formulated which demonstrate the definitions related to MSW needed to be known prior its management.

These guidelines also highlight the duties and responsibilities for MSW generators, authorities engaged in and responsible for execution of management plans, ministry of urban development, secretary-in-charge of urban and housing development, state pollution control board, state level advisory body- which consists of commissioner of municipalities, deputy commissioner of municipalities. The guidelines also specifically point the inclusion better management practices being followed which include waste to energy production processes. These processes, guideline explains as production of Refuse Drive Fuel (RFD). The guidelines also prerequisites the formulation of permissible pollution control limits, MSW treatment and disposal methods, overall monitoring and assessment and publication of annual reports. The Ministry of Environment, Forestry and Climate Change (MoEFCC), however prescribes different guidelines for MSWM in hilly region.

The Ministry of Environment, Forestry and Climate Change (MoEFCC) is apex body for administering the nationwide execution of these MSW laws. The primary concern of MoEFCC is to implement the set of rules and programmes connecting MSW and lack of MSWM, for prevention and control of pollution and its hazardous impact on ecosystem (UD and HD, 2012). The Central Pollution Control Board (CPCB) acts as a technical wing of MoEFCC which is a countrywide environmental pollution control body, which oversees the activities of respective state pollution control boards by aiding technological support, guidance, and resolving local disagreement between different municipalities. For example, stakeholder A, chief engineer at PMC said that these disagreements are mainly due to paucity of technologies of MSWM or disposal grounds for MSW. He recalled that during 2011 there was some dispute of recycling of MSW at Muzaffarpur municipal body as it has this facility of recycling. But, the Muzaffarpur municipal body did not agree to extend the facility for the same, citing the overload and overwork of machines, despite efforts from Bihar State Pollution Control Board. The state governing bodies are authorized to adopt the most suitable methods for MSW collection, transportation, treatment and disposal under the guidelines of national legislation. The governing bodies are also authorized to generate funds for these activities. The decision making of MSWM, its technical and financial support requires appropriate technical guidance and infrastructure development which comes from Bihar Urban Infrastructure Development Corporation (BUIDCO) and Urban Development and Housing Department (UD and HD).

During fieldwork stakeholder B, scientist at Bihar State Pollution Control Board (BSPCB) Patna provided the information about the role of BSPCB in MSWM at state level, which was also confirmed by the PMC chief engineer. Stakeholder B also emphasized that the BSPCB has to match the standards provided in the schedule II, III, and IV in MSWM rules. These rules stipulate guidelines regarding incineration, composting, landfill, leachate, groundwater quality, and ambient air quality. Furthermore, PMC is authorized for the fulfillment of its prerequisite criteria and standard consents. BSPCB also prepares an annual report and submit it to CPCB. Apart from this, stakeholder C as a part of the committee for landfill site selection project in Patna with State Environment Impact Assessment Authority (SEIAA) described that SEIAA also monitors the quality control and assesses the various sectors such as groundwater, surface water bodies, ambient air quality, permissible leachate quality, incineration standards and allowable compost quality for developmental project. Almost all the activities, which have the potential to deteriorate the environment, are under the check of BSPCB and SEIAA in Bihar. As per the information provided by stakeholder A, municipal administration issues guidelines, procedure, policies, technical infrastructure requirements, and release funds for MSWM accordingly. All the tenders regarding collection, transportation, waste to energy process of MSW, proposed by PMC first go through administrative channel. For specific districts such as Patna total responsibilities come under Deputy Commissioner to implement MSWM rules in the provinces. Municipal Corporation/Urban Bodies such as PMC is mainly responsible for the door to door collection of MSW sweeping of streets, transportation, treatment and disposal operations, waste to energy plant, and recycling and recovery facilities. PMC chief engineer stakeholder A also suggested managing the funding issue associated with MSWM

Our commissioner has come up with the provision of payment basis collection of MSW from each house, shops, hotels, hospital, restaurants etc. Public private partnership is also an initia-

tive to maintain fund.

Nevertheless, municipal cooperation remains under insufficient financial limitations and therefore PMC in 2009 started inviting contracts from private sector for hiring MSWM services (BUIDCO, UD and HD, 2014). During the fieldwork the interviewed administrators said that the success of this PPP for door to door collection and treatment was questionable till 2014. But, stakeholder A in his interview also said that now all 72 wards are working in Public-Private-Partnership (PPP) for the door-to-door collection and transportation of MSW. However, some of them also said that now this door to door collection method was gaining some success. Stakeholder B in his interview pointed out that the management of MSW was problematic more due to the attitudinal problems of people and not the awareness. The Private Formal Division, within the administrative hierarchy of PMC, is responsible for the execution and monitoring of performance and processes of most of the door-to-door collection, their transportation to the dumping site, which may go for treatment, and disposal of MSW. Stakeholder D of Nidan Swachdhara Private Limited (NSPL) confirmed this information during the field visit to his office. He also provided information about Private Informal Division which collects recyclables, transfer to the recycling facility and also door-to-door collection of MSW. The Private Informal Division MSW collectors both from the government sector and private sector usually belong to the deprived economic and social conditions (Madhav, 2010),

5. Patna MSWM formal sector and actor's hierarchy

This section discusses the working structure of the MSWM and the Private Formal Division. As shown in figure 2 box (1) the permanent administrated sector has been represented consists of PMC commissioner who heads the corporation, operating as a chief executive. He is preceded by one additional Municipal Commissioner (for sanitation) who is the overall in-charge of MSW operations. One deputy municipal commissioner position is provided by administration to assist additional municipal commissioner. Patna district is divided into six circles where each circle is headed by an executive officer. Besides, each executive officer has an assistant called as city manager. The Municipal Corporation also has elected representative called the Mayor, followed by deputy mayor who works as an assistant to the Mayor. These people's representatives Mayor and Ward members are elected every five years. The corporates or elected ward members on a ward level represent their respective wards. The MSWM of respective wards come under the ward member's supervision so that they can select any private organization for MSWM. The elected ward members, stakeholder A said that, they have the authority to engage private sector MSW managers in their own ward.

At public, circle level, one assistant health officer is appointed, but Patna has only three assistant health officers in place of six. Also, at circle level sanitary inspectors are assigned by the administration for public MSWM services benefits. Sanitary supervisors from all 72 wards cooperate with them. According to the information of stakeholder A there are currently twenty-one position for sanitary inspector and for sanitary supervisors there are two hundred and twenty-one positions. Still administration of Patna is unable to handle the MSWM. To curb this situation therefore, in 2009 the PMC commissioner opened up this MSWM project for the private sectors, to come into MSW handling. The private sector is shown in the figure 2 box (4). Private contractors which include private companies and NGOs, collect, transport and treat the MSW produced in Patna for the respective amount of money. While stakeholder E, stakeholder F and stakeholder D show their interest lies with PMC private contracts, but they also say that few clause of private tender need to be revised. These private sector MSW stakeholders want the complete privatization of the process. Since, private contractors involve their manual power such as drivers and numerous sanitary workers in different wards separately. So, these stakeholders want such provisions, because they understand that the mechanism needs to function independent of PMC. Stakeholder F argued that the funds thus created will be used for strengthening the private informal division workers. He also said that the PMC should at least give them a year of time gap to generate these funds, and that he was also open to share profits with the PMC after that. He added that this would not only streamline the proper collection and recycling of

MSW but also for procuring and upgrading old machines, still used by the PMC.

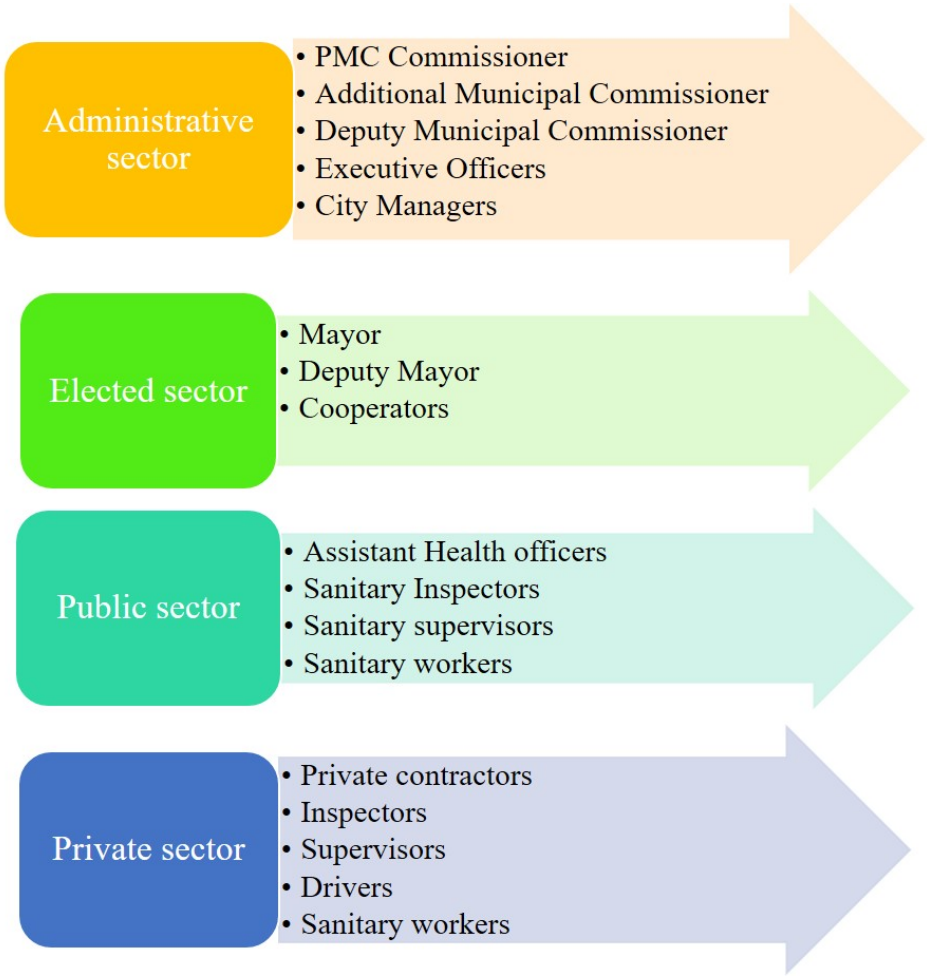

Figure 2. SWM formal sector and actor's hierarchy (Source: Developed by the field experience in 2017 Note: There actor's is defined as formal MSWM stakeholders such as for administrative sector PMC commissioner is an actor).

6. MSW generation and composition

The information in this section has been collected from questionnaire and interview conducted at the PMC office. And also from the secondary sources obtained and made available by the PMC data records. Patna produces approx. 1000-1200 tonne of MSW per day and the per capita MSW per day is 0.450-0.600 kg during 2016-17. While the field visit to BSPCB, stakeholder B said:

"Whatever the data we receive regarding MSW generation and MSWM or the number and placement of collection bins, types of collection bins, number of transportation vehicles that the PMC has, treatment process etc. is provided to us by PMC."

In the same interview he added that the landfill in Patna exists but the condition of that landfill is deplorable. He cited that the landfill at Bairiya was more of a dumping ground that has no rule regulation. And that it was necessary for the PMC to become active in imposing rules on this dumping ground. Stakeholder B being a senior scientist at BSPCB emphasised that

there was an urgent need to speed up the processes of MSW management otherwise given the condition in Patna it would be difficult in coming times. He also cited that the main reason for this was shortage of funds, proper infrastructure within the PMC.

Until 2011 the MSW produce in Patna was 225.67-800.00 tonne/day, which has been significantly lower than in developed countries cities (Pandey, 2014). But, the field information shows the raising generation rate of MSW per day. According to stakeholder F, due to rapid urbanisation, Patna is facing an exponential population growth that directly affects the amount of MSW generated per day (Vij, 2012). In 2014, BUIDCO had projected the population of Patna by 2036 and also calculated the amount of MSW generated per day with such an exponential rise in population growth till 2036. The synchronisation of rising MSW and rapid urban population growth has been explained in **Figure 3**. The figure (calculated and prepared by author) explains that during the year 2016, 2026 and 2031 the percentage increase of MSW per day would be ten percent more than the population percentage increase. The year 2021 and 2036 population growth percentage increase is 12.30% and 11.78% respectively. That is less than the percentage increase of MSW produce per day in Patna during these years, i.e., approx. 6.26% and 0.01% respectively. Raj and Raj (2015) have listed several sources, major generators and the type of MSW produced by these such as- residential localities, commercial areas, institutional and construction sites. These sources belong to families, hotels, markets, schools and construction sites. As the MSW generator's lifestyle and consuming pattern changes along with rapid urbanization it leads to the exponential increase in the amount of MSW and variation in its composition (Pandey, 2014; Raj and Raj, 2015).

The physical and chemical properties of MSW generated in Patna have been described in table 1. The physical composition constitutes larger fraction of organic MSW, which is biodegradable, 45%, in nature generated largely by households, hotels, restaurants and offices etc. The second largest portion belongs to non-biodegradable MSW which are called 'other', 35% constituted of ash, fine earth, silt and construction and demolition waste (Bhanu and Kumar 2014; Pandey, 2014, MoEFCC, 2016). The third type of MSW includes recyclable materials which contain 6% plastic; 5% textile; 4% paper; 2% leather; 2% glass and 1% metal of total MSW weight (Pandey, 2014; Gandhe and Kumar, 2016). Gandhi and Kumar (2016) further in their study experiment on the chemical properties of MSW generated in Patna. The results explicate carbon and nitrogen ratio (C/N) of 28.14:1 with very high moisture content of 35.43%. Worrell and Vesilind, (2012) Tchobanoglous et al., (2014, p.687) through multiple experimentation on MSW generated in different developing countries have calculated in their studies that the optimum values of C/N ratio and moisture content are $\geq$20:1 and $\geq$40% respectively. They establish through these experimentation, that to carry out biological treatment methods, the above C/N ratio and moisture content ae suitable for anaerobic digestion and aerobic composting for MSW. Hence, it can be concluded that the MSW generated in Patna on the basis of their physical and chemical properties, the biological treatment, recovering and recycling are the best suitable methods. However, stakeholder D (from NSPL) and stakeholder E (from Clean India, an NGO), who have been working in this sector of MSWM for more than over a decade cite that in all these times the nature and composition of the MSW has changed drastically. They cite that the share of biodegradable and recyclable MSW has increased considerably. This claim was also supported by stakeholder F during his interview, he said,

"*The lifestyle changes are highly affecting the composition of MSW. Overtime the use of plastic has increased, profoundly being used in everything like packaging and carrying purposes, which was not found in earlier days in Patna.*"

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Figure 3 MSW generation per day concerning the population growth in Patna (Source: Prepared by author from data of BUIDCO, 2014).

This argument is also supported by the study of Raj and Raj (2015) who contend that-

"*MSW generations are the result of practices of everyday life. This includes daily dietary practices including the preparation and consumption of food. They also comprise leisure activities, customs, rituals, hobbies, and other lifestyle choices. These everyday practices are co-related with our environmental practices as their manifest or latent functions effect our environment.*"

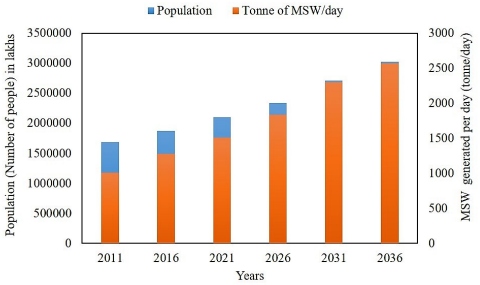

Figure 3.

Table 1. hysical and chemical properties of MSW in Patna(Source: Gandhe and Kumar, 2016).

Physical Properties		Chemical Properties	
Biodegradable	45%	C/N ratio	28.14
Others	35%	Moisture content	35.43%
Plastic	6%	Density	204 kg/m^3
Textile	5%	Energy content	14.1 MJ/kg
Paper	4%		
Leather	2%		
Glass	2%		
Metal	1%		

7. MSW collection and transportation

From the field interviews, it has also come into notice that segregation of MSW at source has not been in practice. Beside this, due to unawareness among the people the storage of MSW at source has been done in plastic buckets and carry bags. Later that is thrown in low-lying areas and road sides. Stakeholder A form PMC hence, confirms that the primary collection i.e., door-to-door collection of MSW has been initiated by PMC and UD and HD in sixteen wards of Patna during 2016 (PMC, 2013). Later during 2017 almost from 60 wards door-to-door collection of MSW has successfully been achieved via PPP approach. This door-to-door collection system under PPP has been executed on monthly charges. This functioning of door-to-door collection has been a success since implementation as claimed by stakeholder E from Clean India, which is engaged in this process in the New Capital circle region of PMC.

Stakeholder A explained the payment basis for door-to-door collection of MSW in wards as shown in table 2. He mentioned that the process excluded the houses below poverty line, and for the rest every house availing the services had to pay 60₹per month. The charges were different for commercial people such as small shopkeepers with shops within 10 feet of road have to pay 60₹per month; big shopkeepers are charged 300₹per month; restaurants/hotels/hostel need to pay 1000₹per month; five and four star hotels are charged 10,000₹per month; commercial establishments/government offices/banks/insurance companies/coaching institutions area to pay 1000₹per month; hospitals with fifty beds are to pay 3000₹per month; hospitals with more than fifty beds require to pay 10,000₹per month and other clinics and dispensaries are charged 1000₹per month.

Secondary collection system has been accomplished by PMC and under PPP model through selected NGOs/private companies. In secondary collection system, community bins and MSW collecting vehicles are used. These vehicles go for door-to-door collection of MSW or the communities themselves bring MSW to designated points. PMC has designated about 870 community bin points for secondary collection, beside this several open areas in the locality are also being used by the people as unauthorized secondary collection points as shown in **Figure 4**.

Figure 4. nauthorized dumping of MSW at different places of Patna (Source: Picture taken during the fieldwork in Patna 2017).

At all the designated points PMC has placed almost 550 community bins with the capacity of 1.1 m^3. But during the detailed interview with PMC chief engineer stakeholder. They confirmed that during 2016-17 approx. 320 more community bins have been placed. But, stakeholder E from Clean India NGO, contradicts that these bins are placed far away from the communities and near the road sides, hence it affects the idea of secondary collection points also hampering the process of carrying out door-to-door collection and simultaneous dumping of the collected MSW into PMC designated community bins. Stakeholder E also adds to his argument that,

"*The community bins are placed at each designated points, but the requirement of bins have increased among the communities. Hence, more number of community bins are required within the localities.*"

Table 2. nformation of door- to-door collection charges announced by PMC for different establishments (Source: Drawn from fieldwork information in 2017).

Type of infrastructure	Door to door collection charges (₹)
Houses below poverty line	No charges
Houses above poverty line	60₹per month
Small shopkeepers with shops within 10 feet of road	60₹per month
Big shopkeepers	300₹per month
Restaurants/hotels/hostel	1000₹per month
five and four star hotels	10,000₹per month
Commercial establishments/government offices/banks/insurance companies/coaching institutions area	1000₹per month
Hospitals with fifty beds	3000₹per month
Hospitals with more than fifty beds	10,000₹per month
Clinics and dispensaries	1000₹per month

Also, during the interview stakeholder, A, provided the information that, in June 2017 PMC introduced Bihar Municipal Act, 2007 which requires the citizens of Patna to ensure segregation of dry and wet MSW at the primary origination points i.e at homes. The Act designates wet waste are those that include the biodegradable MSW, whereas dry waste means the recyclable fraction of MSW. To advertise and sensitize the importance of segregation of waste at origin the PMC on World Environment Day 2017, set up two colour coded dustbins at Maurya Lok Complex (**Figure 5**). As picture decodes the colors representing the type of waste to be put into the dustbin- green colour dustbin for wet waste or biodegradable MSW and blue dustbin has to be used for dry waste or recyclable MSW.

PMC has been planning to place 2000 pair of colour coded community bins at the authorized destinations having a capacity of 0.12 m^3 (Nithya et al., 2013). As well as, 750 more community collection bin point are under planning to be authorized. In these points, larger capacity bins of approx. 2-5m^3 have been made up of concrete know as RC bins will be placed soon (BUIDCO, UD and HD, 2006; Nithya et al., 2013). According to PMC chief engineer stakeholder A in Patna, the frequency of MSW removal from community bins is regular in most of the areas. Daily transportation of MSW from secondary collection points to the disposal or treatment site in Patna follows the schedule of 6:00 am to 2:00 pm excluding Sundays and holidays. But, during interviews this information, of MSW collection was found to be partially true, according to stakeholder G from Rajendra Nagar and stakeholder H from Kankarbagh area. They disagreed with the information of PMC, they mentioned that the frequency of MSW collection from homes or secondary collection points by the PMC sanitary workers were very erratic, this collection generally varied between 3-4 days in their locality. They also complained during interviews that the workers were not ready to register any grievances. Stakeholder H also complained that it was very difficult to trace the sanitary inspector or supervisor of their locality.

Stakeholder H who claimed to be a freelance journalist talked at length about the problems of his locality, and Patna in general. He reasoned that,

"The facilities provided by PMC and the facilities available to PMC were insufficient, for both the institution and the citizens. Also, the removal of MSW from community bins was done through manual loading to the transportation vehicles like tractors, auto-tippers, dumper placer etc. And, these vehicles are generally uncovered when they transport the collected MSW."

The chief engineer accepted that

"There is a crunch of facilities to the manual laborers and machines to collect and transport MSW. Manual labors were deputed to collect MSW to the secondary collection points. From where the MSW are loaded in tractors or dumper placer. At times due to its large size it was difficult for this vehicle

Figure 5. MC placed a set of colour coded dustbins on World Environmental Day 2017 at Maurya Lok Complex, Patna (Source: Picture of Maurya Lok Complex, Patna taken during the fieldwork in 2017).

to access narrow areas and the collection of MSW from secondary collection points were delayed."

He also mentioned that the usage of compactors which compress collected MSW at source was a heavy vehicle and thus it becomes difficult for this machine to access places that have large amount of collected MSW near community bins or informal dumping grounds in the mohallas. Hence, he said, it was almost impossible for the workers to manage time schedules of collection and transfer of MSW eventually leading to accumulation of MSW in the locality. For these narrow localities, the chief engineer said that the auto tippers were used. Since the waste is not segregated at source hence the overall collected MSW is mostly mixed in nature. This harmful mixed MSW is loaded with the help of mechanical loaders and manual labours in tractors, dumper placer, and compactors. And then this collected MSW is transferred to its final destination at landfill Bairiya. It was observed during fieldwork that most of the vehicles used for transportation required serious maintenance or better replacement, specifically for tractors. It was only in the end of 2016 that new compactors and auto-tippers were introduced in the MSW transportation. But still older tractors were not replaced and were continued for the transportation. It was observed and revealed in the interviews at the PMC office that there was acute shortage of proper transportation machines. According to information from PMC there were only 155 tractors and 155 auto-tippers for collection form narrow areas. There were twenty dumper placers and sixteen compactors to collect MSW from broader or main roadside com-

munity bins. There were approximately 371 handcarts/tricycles for primary collection of MSW for door-to-door collection and bring it to the community bins as shown in Table 3. The MSW collected from community bins is directly transferred to land filling site at Bairiya. Hoornweg and Bhada-Tata (2012) in their study suggest that it is important to dispose of biodegradable MSW within 10 hours of collection because after that the waste starts decomposing and can create serious health problems from vector borne diseases. Stakeholder I a municipal clerk at PMC office said that

"It is taken care that the biodegradable wastes are not kept for more than 24 hours. It was taken care that the collected MSW was transferred to Bairiya every evening but at times it is difficult to follow this time frame as many times this is to be done by using tractors."

He also mentioned during interview that the collection of MSW was a more challenging task as there was not much facility available for it. To overcome this challenge of excess collected MSW for transfer to dumping sites a report by BUIDCO suggests that there should be a transfer station for each circle. These transfer stations would function as proper storage for collected MSW. The same report mentions that this provision should be available for all the six circles of the PMC. However, during the interview none of the officials were able to answer satisfactorily about this provision. Stakeholder I, clerk at the PMC and the chief engineer cited that even if there was any provision it would be difficult for PMC to acquire lands for these transfer station.

Table 3. Number of transportation vehicles used by PMC and PPP's NGOs/Private firms for transportation of MSW to dumping site (Source: Field information collected from PMC in 2017).

Transportation vehicles	Number of vehicles
Tractors	155
Auto-tippers	155
Dumper placers	20
Loaders (Skid Steer)	04
Loaders (backhoe)	12
Loaders (672-mini)	01
Compactors	16
Handcarts/tricycles	371

8. MSW treatment and disposal

The UD and HD report (2010) found that in Patna, about 65% of the total MSW was being collected and the remaining 35% remained unattended, strewn beside roads, also near parks, playgrounds and vacant lands. Bhanu et al., (2014) also find in their study that in Patna there are not any proper treatment and disposal methods of MSWM. Hence, it had become normal to use open low-lying areas, and the outskirts of the city besides the existing dumping ground, at Bairiya is in practice. Such unscientific methods, Kumari et al., (2011), argue causes immense air and groundwater pollution. It was also evident from their study that the air quality and groundwater for a range of physiochemical parameters were beyond the permissible limit at two dumping sites in Patna where they conducted their experiments.

In Patna, the dumping ground is situated at Ilahibagh, Ramachak-Bairiya village with the land areas of approximately 74 acres. Patna has reserved it for development of WTE plant including sanitary landfill (BUIDCO, UD andHD, 2014). The landfill site at Bairiya is surrounded by six densely populated villages whose total population is estimated to be around 20,000. This information has also been confirmed by stakeholder B from BSPCB, but regarding Gardanibagh

dumping site he said that,

"*The public created Gardanibagh as a dumping site, according to their suitability. SEIAA only give clearance after environmental impact assessment to Bairiya landfill for WTE project and sanitary landfill.*"

Stakeholder A also agreed with the BSPCB, that they are only dumping MSW to Bairiya landfill besides going to Gardanibagh. According to stakeholder H a freelancer journalist put a light to pathetic condition of Bariya landfill. The habitants are facing environmental problems and chronic health issues such as respiratory tract inflammation, permanent respiratory problems as smoke produced due to the unsafe burning of MSW being dumped since 2010 consist of high amount of pollutants (Bhanu et al., 2014). The villagers filed a petition against the Bairiya landfill site in Patna High Court in November 2012. As per the Master Plan 2031, Ramchak Bairiya area has again been suggested as a sanitary landfill and WTE plant site. Even though it is surrounded by the habitation and offending the MSWs (Management and Handling) Rules, 2000 not showing any environmental clearance. Nevertheless, PMC considers it as MSW mismanagement and misunderstanding of MSWM project (Bhanu et al., 2014).

8.1. Public Private Participation

Stakeholder H also provided information of Public-Private-Participation (PPP) for MSW treatment. According to him, Patna during 2009, UD andHD authorities under PPP agenda heird A2Z infrastructure Pvt. Ltd. of New Delhi for nine wards door-to-door MSW collection; drainage cleaning; street sweeping mechanically, and collected MSW transportation to a designated disposal site. A2Z took forward the MSW management from January 2010 and continued till July 2011, but due to the uncooperative behaviour of PMC, the work was discontinued. Stakeholder D clearly mention the primary reason was that PMC has not been provided the bided amount of money (i.e., approx.7.62 crore ₹) to A2Z. After this, stakeholder H tell us that, in the year 2012, BUIDCO once again followed the PPP model for MSWM in Patna and Jindal ITF Urban Infrastructure Private Limited was selected, but this company refused to sign on agreement clause. PMC again floated the PPP tender agenda in 2013, but private firms showed the least interest in city waste management. To attract the attention of private contractors in 2014, few features were added to the PPP agenda. That is MSW door-to-door collection and transport to the secondary destination, or PMC provided community bins without any user charges. The PMC and BUIDCO hired a Mumbai based private company named Sunil HiTech Engineers Limited (SHEL) in 2014 for handling the MSW management of Patna. But, during the interview with PMC officials, SHEL has been failed to manage the city MSW. According to BUIDCO in spite of various warning letter, no progress was observed in SHEL services. Hence work was discontinued. But, a pilot PPP project in sixteen wards was started by PMC during 2016. According to it each house had to pay 60-70₹per month for door-to-door MSW collection. The project was initiated by Nishka private firm; Clean India NGO and, Nidan Swacchdhara Private Limited in New capital and Patliputra circle. Delhi based private firm Patheya handled the MSW at Kankarbagh and Bankipore circle. This PPP mode was able to cover 52 wards in four circles whereas tender was still open to remaining 20 wards of Patna city and Azimabad circle. But PMC sanitary workers were found working in both the circles during the different field visits. The PPP waste to energy project was still in progress; Patna Green Energy Private Limited was asked to develop the complex for the production of 10 MW of electricity from MSW during 2016. But, their work was questioned by BSPCB. PMC official told during the field interview that presently they were expecting a US-based company AG Dauters Waste Processing Private Limited to establish waste to energy plant in Patna.

8.2. MSWM through informal recycling

Stakeholder D from NSPL explain about the sanitary workers and ragpickers are the recyclable collectors from MSW informal recycling hierarchy as shown in Figure 6, also actively participated at each stage of informal scrap business. Sanitary workers collect the recyclables during door to door collection of MSW and during dumping the MSW in community bins. These sanitary work-

ers are also called as safai mitras, and few of them work under PMC and majority of them belong to NGOs through PPP of different NGOs with PMC. Rag pickers are roving recyclables collectors and collect the recyclables from MSW dumping grounds and community bins. The third types of recyclable collectors are Kabbdiwalla, who collect the valuable recyclables from households in return of money according to its rates. The next level of the hierarchy is the stationary dealers. The MSW collected by sanitary workers, ragpickers and kabbdiwalla is sold to small dealers. The small dealers sell a bulk amount of recyclables to medium dealers and medium dealers to recycling units, but due to the absence of recycling units in the Bihar state, the transporter used to transport the collected scrap to recycling units situated in other states like Gujarat. In India, poor economic conditions, ample labour and creativeness from waste resources have resulted in informal practices of MSW recycling. Also, approx. 92% of the people involved at the collection level of MSW recycling hierarchy are women who have pathetic economic and social situation (Gunsilius et al., 2011; Madhav, 2010). MSW collection, transportation, treatment and final disposal are performed by formal or by the partnership of formal and informal sector. But the MSW load has been reducing completely by the informal sector through recovering of recyclables to run the scrap business. Patna generates recyclables approximately 104-117 tonne per day, which has been majorly collected by informal sector (NIUA, 2015; Pandey, 2014). The collected items include plastic, textile, paper, leather and metal undergoes recycling. Also, the recovery of recyclables decreases the load on MSW final disposal stream. Field interviews and interaction with different stakeholders resulted in facts that recycling and recovery are running at good pace but entirely via informal sector.

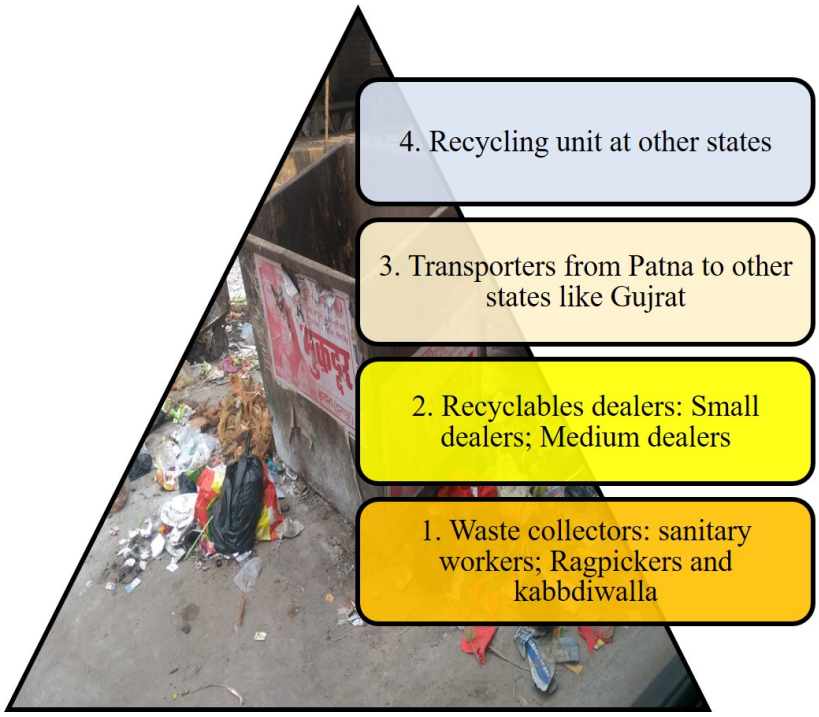

Figure 6. Recyclable MSW hierarchy (Source: Developed by field experience in 2015).

9. Conclusion

Based on the field understandings in this study, information about practices of MSW and MSWM has been derived from extensive fieldwork in Patna. This information has been used to evaluate an alternative strategy for achieving better management of MSW with integration and sustainability through multiple criteria approach. The results suggest that an integrated sustainable framework for MSW management is urgently required to reduce the environmental hazards and to promote better health for population of Patna. An effective Pedagogy for MSWM, which dealt especially with the scenario of MSW and its management and processes to aware, educate and active involvement of the citizens of Patna should be highly promoted.

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