Issues and Opportunities for Moving Towards Zero Waste Cities in India: A Perspective

Arvind K Jha*, Kareena Sharma, Kavitha B.V. and Prasoon Gargava

Central Pollution Control Board, Regional Directorate, Vadodara-390023, India

Abstract

There is significant impact on all dimension of quality of life including waste management after flagging the issue in Maan Ki Baat by the Prime Minister of India. Various interventions to improve quality of life in cities are under implementation in India. These are smart city mission in 100 cities covering 7870 projects, Atal missions for rejuvenation and urban transformation (AMRUT), National Clean Air Programme (NCAP), Swachh Bharat Mission (SBM), etc. The process is continuous in nature to fulfil the objective of sustainability. The target also encompasses improvement in environmental conditions of surrounding areas. All these interventions have direct or indirect positive impacton waste management. However, waste management still remained a challenge for cities due to adoption of conventional measures to handle waste resulting in negative financial gain. Present article attempted to assess the existing situation and find ways and means through these interventions to achieve zero waste city goal by incorporating variousscientific concepts discussed in Maan Ki Baat talk by the Prime Minister of India as national commitment.

Keywords: Smart city; Zero waste city; Pollution; Waste management

1. Introduction

Waste generation is an environmental burden arising from developmental activities for human settlements and manufacturing activities. These wastes reduce the aesthetics of ambience, effectiveness of business, increases pressures on the environment and negatively impacts vitality of societies. India has taken up series of initiatives for transforming the quality of life through various projects in mission mode. Smart city mission targeted 100 cities with 7870 projects/ interventions, National Clean air Programme (NCAP) targeted 132 cities and 500 cities are targeted under AMRUT. Parallel programmes targeting energy sector [like SATAT (sustainable alternative towards affordable transportation), FAME India Scheme], water sector [Jal Shakri, Jal Jeevan mission. PM Krishi SinchayeeYojna, river rejuvenation programmes, etc.] and solid waste management sector [swachchh Bharat Abhiyan, swachchhtasarvekshan, Swachchhta Hi Seva, Programmes of Ministry of New and Renewable Energy Resources, etc] are in place. Each of the intervention has independence for customization of action for targeted sectors. Besides this, motivational elements are also added in each of these projects like competitivenessand ranking as well as financial allocation based on performance. The selection of city for financial allocation and ranking are based on performance through intra-city competition evaluated on parameters such as completion/ progress for targeted actions, targeted service levels, financial & institutional capacity, past track record and reforms [1]. The identified cities have proposed their plans for development based on the prescribed guidelines.

*Corresponding Author(Email:arvind1711@gmail.com)

According to the various guidelines of different programmes of Government of India, a city contains wish list of infrastructure and services that describes citizen level of aspiration[2]. The aspects covered in the said guidelines include solid waste management in direct or indirect manner [3]. Swachchh Bharat Abhiyan and NCAP has predefined issues related to solid waste management, construction and demolition waste management, hazardous waste management, etc. whereas other interventions of Government of India like AMRUT (service level benchmark and septage management), SATAT (social infrastructure, allied activities in agriculture), etc. The guidelines of schemes do not prescribe any model and hence all selected cities/ targeted sector has opportunity to frame action plans with customised interventions based on visualised need and aspirations. In several action plans available on government websites like Smart City Misson (smartcities.gov.in) and Central Pollution Control Board (cpcb.nic.in) has solid waste management aspect restricted to conventional approach i.e. improving the collection efficiency and land filling with some scope of reprocessing as the cities have other priority sectors for improvement resulting in lesser weightage on advanced solid waste management practices. The cities in world like Adelaide, San Francisco, New York and Masdar city have moved to zero waste city. Due to plenty of opportunities in government missions for cities and intended sectors, Indian citiesmay also move towards zero waste cities to ensure sustainability and improve quality of life. The sustainability indicators of cities in terms of solid waste management (3 core and 07 supporting indicators) are defined elsewhere [2]. Zero waste city could be a long-term goal with prevailing capacity (may be 10-15 years) as compared to smart city goal (05 years in case of India). With the development of peri-urban areas, it is likely that the landfill site planned these days will have proximity with one or the other inhabitations/ installations in future and would be a cause of nuisance for the surrounding area. The situation thus arising will again require efforts to make the place liveable or workable besides further land requirement for land filling. It is very crucial at this stage to consider increase in jurisdiction of municipalities in future while working on development of cities so that aspect of solid waste management is given due care to keep a pace with expansion[4] besides efforts to eliminate landfilling needs and increasing treatment of legacy waste. Therefore, the planners need to give appropriate focus on wise alternates of solid waste management like diversion of landfillable waste for value added product, usage of high calorific waste for waste to energy, 100% recycling of recyclable materials and complete reuse of construction & demolition waste. Prime minister of India has flagged the issue of waste management in his deliberations at various national and international forums and his direct talk with Indian citizens under Man Ki Baat programme. The present article highlights the aspects that are required to be addressed to move towards zero waste city along with the smart city mission of India.

2. Existing situation of waste management in India

2.1 Municipal solid waste (MSW) management

According to Central Pollution Control Board (CPCB), 160038.9 tonnes per day (TPD) municipal solid waste was generated in IndiaOf the total waste generated, approximately 152749.5 TPD (95.4%) was collected and about 50% of collected waste is treated and about 18.4% is landfilled.

As per this data, about 31.7% of solid waste remained unaccounted[5].

Conventionally, rag pickers are key player of recycling for municipal solid wastes and spontaneous burning of municipal solid waste remained a way for waste reduction in landfills.

2.2 Plastic waste management

Merico Foundation in Association with Indian Institute of Science reported that about 3.4 Million ton of plastic waste generated in India during 2019-2020 of which about 30% is recycled whereas CPCB reported 34.69 million ton for the same period with about 50% recyling [6]. This implies that plastic waste generation is fairly estimated but the recycling percentage still needs improvement. Improving the recycling percentage in organised manner and value enrichment or complete use of waste plastic is major challenges in transforming a city to zero waste city.

There exists high cost of MSW management and lower level of services in almost all cities selected for smart city development due to factors like non-segregation at source, poor performance and management of transportation vehicles, traffic issues, insufficient facilities for disposal etc. Hence, the Indian cities are lacking in adoption of principles of sustainable and integrated solid waste management and evaluation of waste management based on criteria indicators of solid waste management and sustainability indicators for cities outlined elsewhere [7,8,9]. India has regulation for the solid waste management (Solid Waste Management Rules, 2016). However, most of the towns/ cities are still in need of proper action plan for implementation of regulation[7]**.** Door to doorsegregated collection of solid waste is yet to be fully covered in any census or statutory city. The reason of noncompliance of the Indian legal provision is discussed elsewhere[9]. Based on the technological advancements, there is need to implement concept of circular economy for better improvement in solid waste management.Source segregation, material balance, resource recovery, composting, waste to energy is key sequence of interventions to move towards zero waste cities.

2.3 Construction and demolition (C&D) waste management

According to NitiAyog India generates about 150 million ton of C&D waste per year[10].The collection, treatment and proper reuse of these waste remain challenge in almost all the cities. Very few cities have C&D waste treatment plant which results in less than 10% of C&D waste being managed properly. The benefits of C&D waste recycling are detailed elsewhere[10]. The C&D waste management rule exists in India since the year 2016 but implementation is still a challenge due to poor collection efficiency, non-incorporation of conditions related to C&D waste management in building permission, land availability for intermediate collection and storage, reuse of processed waste and economic viability. The opportunity exists for sustainable lifestyle through C&D waste management. About 10% of natural resources invested in construction activities can be saved in form of sand and aggregate[11].

2.4 Electronic (e) waste management

Electronic waste generation in India is not precisely understood. CPCB has estimated that about 1.71 million ton of E waste is generated in India whereas Global E waste monitor reports that India generates about 3.2 million Ton of e waste for the same period. By and large more that 80% of generated e-waste is managed through informal sector for recovery of key metals. Centre of Science and Environment projected that India will generate about 14 million ton of e waste by the year 2030. Besides this, large number of solar energy plants (photovoltaics) are under implementation in India making India as fourth largest solar photovoltaic energy generatorwhich will add to these estimates. In next 30 years, the photovoltaic waste in India could reach to the tune of 7.5 million ton[12].

It is well known that more than 10 precious metals are used in smart phone including rare earth metals like yttrium, terbium, etc. Informal e waste recyclers mainly targets to

recover gold, silver and copper[13]. Similarly, a computer or laptop has varieties of metals and metalloids which are precious and rare in nature but informal recyclers only targets few of them. Thus there exists opportunity for material recovery including rare and precious metals.

3. Policy strategies required for waste management

3.1 Zero wastestrategy

Zero Waste concept is logical, economical, efficient, and visionary way to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are destined to become resources for others to use. As per Zero waste international Alliance website (http://zwia.org/standards/zw-definition), Zero Waste means designing and managing products and processes systematically to avoid and eliminate the volume & toxicity of waste & materials, conserve and recover all resources instead of burn or bury. Summarily, zero waste strategy eliminates discharges to land, water, or air. Thus, zero waste primarily includes 'recycling' but goes beyond recycling by adopting a system approach to the vast flow of resources and waste. Zero waste strategy reduces consumption; minimizes waste; maximizes recycling; and ensures that products are made to be reused, repaired, or recycled back into nature or the marketplace. Thus, a defined systematic approach is required to be integrated with city action plans for formulating a zero-waste plan. Recycling is a key strategy to address the issue of land filling, incineration, resource depletion, emissions, energy waste, used in new application to achieve sustainability in resource reuse. Same concept may be applied for generated waste. A waste can be looked into with respect to material use for various purposes. The projected demands in various literature for material needs in India is summed up, it can be said that next 10-12 years, the material elimination of toxic products etc. The zero-waste concept and its meaning vary among the targeted institutions. For example, municipalities in world that have declared themselves "zero waste" take the phrase at face value, concentrating on diverting all their garbage from landfills through recycling and composting. Manufacturing establishments seeks to eliminate all forms of waste from each stage of the manufacturing process.

The adoption of zero waste concept will not only reduce the landfill pressure but also protect the natural resource consumption in one way or the other. Studies show that achieving 90% reduction of landfill waste without using incinerator will be very close to zero waste target[14]. The management of last 10% waste requires a higher level of change than cities can usually achieve through efforts of individual housing societies and industries which, will have to use and design product with zero waste or limitations imposed by presence of non-recyclable and non-compostable matters.

3.2 Circular economy concept

One of the important decisions taken at recently concluded 27th Conference of Parties (COP27) in Egypt in November 2022 is integration of circular economy approach to tackle the global emissions resulting from production and consumption. European parliament has described circular economy as a model of production and consumption which involves sharing, leasing, reusing, refurbishing and recycling as long as possible. The basic idea in this definition is to extend the life cycle of product and recover the materials after end of life to be demand will be doubled. India has used about 7.4 billion tons of fresh material in the year 2017 and is projected to be increased to 14.2 billion ton by the year 2030 (2.7-billion-ton biomass, 6.5-billion-ton mineral, 4.2-billion-ton fossil fuel and 0.8-billion-ton metal). Roughly it may be said that the fresh material demand in India in the year

2030 will be tripped in comparison to the year 2010.

This is huge demand warranting to re-think about consumption pattern and looking into the waste management. Except fuel, all the materials used will return to environment in one or the other way. Thus linear model of manufacture, use, discard will be unsustainable and material recovery and reuse will be efficient mode of consumption or simply the material circularity or circular economy concept will be viable.

4.Opportunities for moving to zero waste cities

The opportunity for moving towards zero waste cities mainly lies in segregation and scientific handling of waste. Some of the aspects discussed here are required to be carefully considered in phased manner as beginning towards the zero-waste city. It is needless to say that even after completion of project mission (year 2020), the cities need to continue cater their needs and the steps taken will enable a city to move towards zero waste cities. The zero-waste strategy should aim at creating value out of waste to paradigm shift from waste disposable to waste reusable/ resource renewable. Following are opportunities for enhancing recycling of recyclable materials (papers, plastics, glass, metals, etc.) and reuse of organic waste by composting and waste to energy as well as reuse of inert generated[11], [12]. A conceptual model based on incentive, infrastructure and enforcement could be an effective tool to address the move towards zero waste.

4.1 Incentive-Infrastructure-Enforcement (IIE) Model

It has always been felt that segregation at source is the key to address the MSW issue but the inclusive approach has always been missing to ascertain this key. The number of approaches & concepts evolved and applied for smart cities should necessarily have ways different from the conventionally used in old or existing cities for municipal solid waste management. The concept of zero liquid discharge was impossible and impractical few decades ago, which is not the case as on today. Similar, approach if applied for municipal solid waste in smart city, the concept of zero municipal solid waste can be very well materialized. The maximum decentralization of the waste treatment/recycle at micro level itself can prevent formation of huge dumping sites and resulting nuisance in smart city.

Three-dimensional strategic plan and broad category based well defined methodology can play crucial role in smart cities. The three-dimensional strategic plan should have following tools:

- Incentive
- Infrastructure
- Enforcement

The micro level plan for incentives to strengthen reduce, refurbish, recycle & reuse are very important. The type of incentives could be either in direct monitory terms or could be sort of area wise ranking/rating from time to time, which may indirectly appreciate the land cost/rental values. The incentive approach can also ignite performance competition among residential or commercial clusters. The incentives can also have two categories namely household based and cluster based separately.

Infrastructure development to deal with MSW aspect in smart city should compulsorily base on Public-Private-Partnership (PPP) model. Household based composting for daily kitchen waste and common decentralized society-based composting are required to be developed & promoted. Small size wet waste shredder & composting system can be very well developed & adopted. The concept of commercial compost dealers should be applied so that bulk surplus (after utilization in own green spaces) quantity generated by housing societies, complexes can be collected and marketed after enriching with

micronutrients for mutual benefits of stakeholders. Similar to the conventional system of cloth market or grain market, housing similar types of shops at one place, the smart city can have cluster of scarp vendors dealing with paper, metal, plastic & E-waste in land demarcated/allocated during planning stage itself. The cluster will give opportunity for aesthetically developed scrap market with proper parking & beautiful landscaping. The cluster can also make exchange of undesired scrap (received by them in mix) of their interest among themselves in easier & profitable manner. The cluster will give healthy competition to buyers as well as sellers of scrap. The scrap cluster can also have refurbishing facility and art crafts manufacturing from scrap items. Smart cities can be declared free from polythene bags. A common bio-digester facility with membership of all hotels/restaurants and vegetable market (which are basically source of biodegradable waste) can be developed near any large recreation garden/green space so that gas generated can be used for power generation and in-turn illumination of the recreation garden/green space including energy requirement for water application in green area and the digested material can be used as rich manure. The plastic, wooden and metal wastes from construction & demolition activity normally find route of recycling/reprocessing. The debris & concrete waste should be made compulsory for filling in deep excavation of foundation of high-rise construction and road sub-surface construction. The adequate infrastructure arrangement can make the zero-waste possible in smart city. However, to counter the small possibility of unattended/unaddressed waste plasma incineration may be provided, which require less space and generates very small residues.

The enforcement mechanism in a smart city is also necessary even after taking adequate steps with respect to incentives & infrastructure. The enforcement mechanism can involve local bodies as well as local community help groups to prevent littering as well as to prevent any deviation from practices prescribed and supported with infrastructure. Smart network of CCTVs for surveillance on potential spots of littering can be used for control & penal provisions. The penalty provisions can also help in strengthening of financial aspect of the entire mechanism of zero waste to environment from smart city.

The strategy of waste management also lies in the understanding quantitative and qualitative aspects of the waste. The precise data related to solid waste generation is not available and the figures are mostly arrived either based on sample survey at source or at the disposal facility. It is important to have the uniform source of data so that the lapses can be identified. Uniform data structuresfor electronic data interchange are required with scope of refinement based on future knowledge. The waste related data lying with municipalities generally pertains to quality and quantity. However, local authorities require data for strengthening their command over municipal solid waste including data on recycling, composting, materials having potential for alternative uses, data on production and packaging houses and their wastes, impact on solid waste management after lateral expansion of cities, experience with waste reduction technologies, inventory of recyclers (both, formal and informal), compliance with regulatory requirements, number of rag pickers and their integration in main stream, etc. More emphasis is required on awareness among citizens about recyclable, compostable and inert materials with encouragement to use products which can enable the city to achieve zero status in faster way.

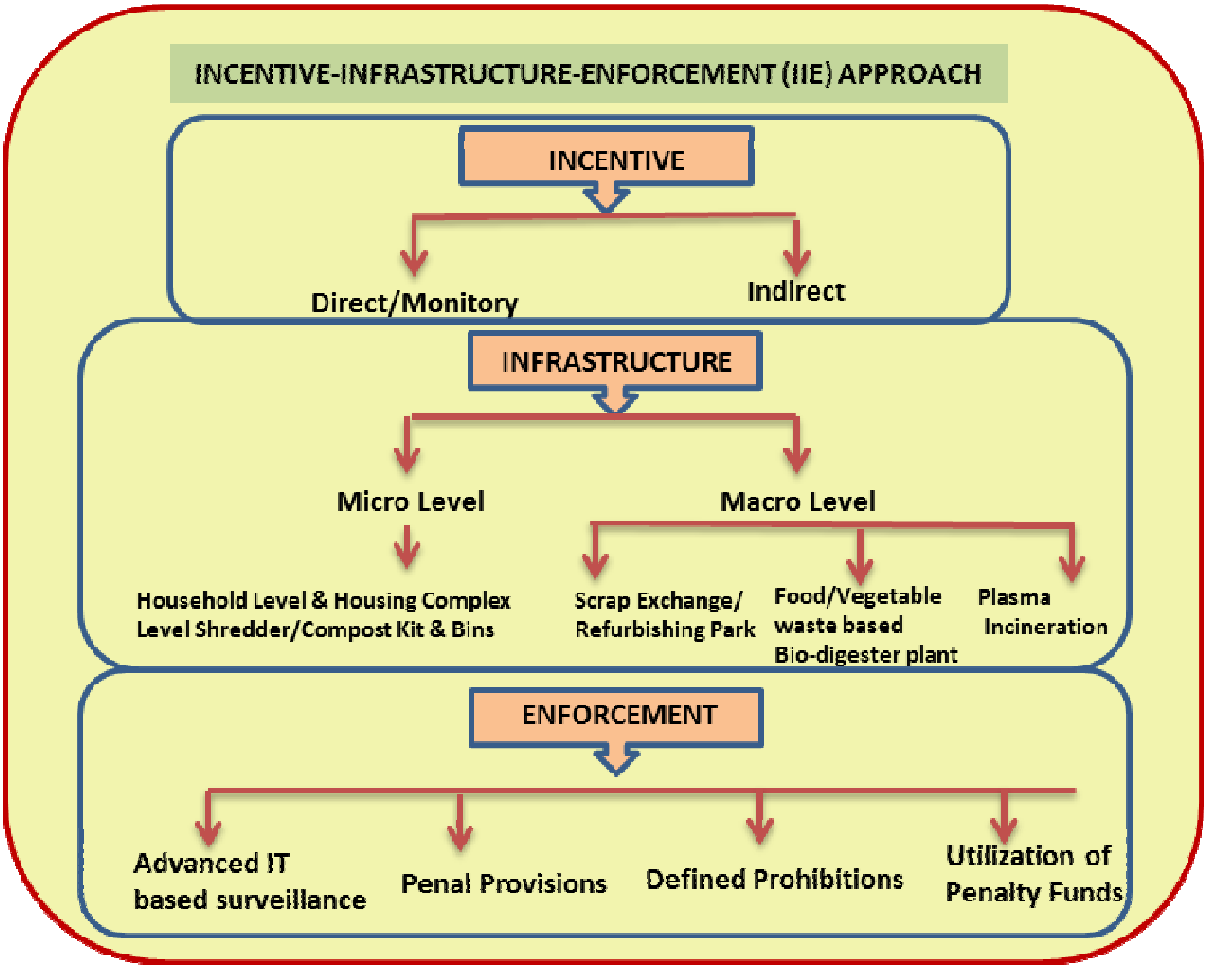

Fig.-1: Incentive-Infrastructure-Enforcement Model

The industries are required to be encouraged for adopting the zero-waste strategy in their manufacturing.The manufacturing industries near the smart cities may be motivated to adopt practices which have been adopted by leading multinational companies like Nike where zero-waste product design, using recyclable polymers, water-based solvents (which reduce both toxins and energy consumption), and fabric woven from used soda bottles are used. Several household chemical manufacturers evaluate ingredients in their product using their "green list" test, which rates raw materials based on bio degradability and toxicity.

4.2 Application of Circular economy concept

To infuse circularity in waste management, segregation of waste is of prime importance. After segregation, the waste stream can be assessed based on various models prescribed in literature which has several degrees of circularity. Several R frameworks has been proposed from 3R to 10R under circular economy concept. The some of them are reproduced in Table-1 in comparative manner.

Table-1. Different models of circularity for waste management

10R principle Cramer 2017	Ellen MacArthur Foundation 2013	Ladder of Lansink Lansink 2015	Three R principle (1970s)	Explanation (Cramer 2017)
Refuse	Maintain/ prolong	Prevention	Reduce	'Prevent raw materials use'
Reduce				'Decrease raw materials use'
Renew/ Redesign				'Redesign product in view of circularity'
Reuse	Reuse/ redistribute	Reuse	Reuse	'Use product again (second hand)'
Repair				'Maintain and repair product'
Refurbish				'Revive product'
Remanufacture	Refurbish/ Remanufacture			'Make new product from second hand'
Repurpose				'Re-use product but with other function'
Recycle	Recycle	Recycling	Recycle	'Salvage material streams with highest possible value'
Recover	Energy recovery	Energy recovery		'Incinerate waste with energy recovery'
		Incineration		
	Landfill	Landfill		

Out of the 5 models compared in Table-1, the 10R model proposed by Cramer (2017) is most suited for making a material balance under circular economy. The average material balance of segregated waste and material balance of recovered material should be studied and gap in material can be identified and measure should be taken to properly recover the same. This will enable to recover material properly and gain the incentive in form of material gain and financial viability. But there is challenge between theoretical concept and practical implementation and hence technology supplement is required. For example, plastic waste can be easily segregated for recycling but the waste food contained plastic packages, littered plastic, etc. is difficult to sort out manually. Thus, optical sorting machines becomes important. Sorting is also a concern for C&D waste as the intermediate storage of C&D waste may be contaminated with municipal waste. In such case processing of C&D waste will require log washing to make the reprocessed building material viable. But there should be different strategies within the circular economy framework or circular economy action plan. Each sector of material waste needs different action plan. The most lucrative one in E waste. E waste has plenty of scope for technological interventions like depopulation, shredding, calcination, controlled smelting, electro-refining, etc. Each step involves innovative technological intervention so that material loss can be minimised. The combination of pyro and hydrometallurgical operations ensures better recovery of materials. The recovery of rare earth metals from spent permanent magnets of recovery of materials from lithium-ion battery has similar technological interventions leading to long term strategic asset creation. Similarly end- of-life silicon solar module should be handled by physical separation, thermal treatment, chemical method to recover material, anti- reflection layer removal, recovery of silicon, aluminium, lead, copper, silver, etc[15].

There should be organised recycling park with full fledge streams of material recovery. The recycling park can be separate for municipal waste, C&D waste and e-waste. The recycling park should be supported by nearby full fledge laboratory for the purpose, wastewater treatment plant and flue gas treatment system. Manufacturing activities should be

mandated to use certain percentage of recovered materials to replace virgin material and reduce fresh material demand. Growing e-vehicle across the country needs strong infrastructure for material recovery from battery waste and managing electronic components.

Waste management with 3 R concept will be in-efficient now a days for viability and city action plans should have scientific material recovery system for ensuring the waste reduction. If any residual waste is emerged after material recovery, it may be suitably adjusted either as compost or as construction material. However, this requires a financial model with initial support from funds allocated to cities.

5.Conclusion

Sustainability is amalgamation of critical environmental, economic, and quality of life issues. Hence, the growth of population in cities and growth of waste quantity requires identifying and sharing international best practices to collectively improve the performance of cities. Several cities in world are heading towards zero waste cities. It is high time in India to consider integrated approach to move towards zero waste cities especially in the targeted various interventions to remain environmentally sustainable in long run by adopting the strategy to handle large volume of waste by diversion of same in various uses. There is need to prepare circular economy action plan and zero waste city action plan as micro-action plan within the existing programmes to attain a zero-waste city in one hand and capacity building to cope up with growing challenge of waste management and future challenge for material availability on the other hand.

Acknowledgement

Encouragement received from Dr Prashant Gargava, Member Secretary CPCB and Shri Tanmay Kumar, Chairman CPCB is gratefully acknowledged.

Competing interests

The authors declare no conflict of financial interest or personal relationships that could affect the work presented in this paper.

References

[1] Ministry of Finance report of "Fifteenth Finance Commission of India for 2021-26" (2021) 195-221. https://fincomindia.nic.in/ShowContentOne.aspx?id=9&Section=1.

[2] ISO "Sustainable development of communities- Indicators for city services and quality of life" ISO 37120:2018, International Organisation for standardization, Geneva, Switzerland (2018).

[3] Anand Ashwathy, Sreevatsan Ajai and Taraporevala Persis Centre for Policy Research, New Delhi (2018) 1-17. https://cprindia.org/wp-content/uploads/2022/01/SCM-POLICY-BRIEF-28th-Aug.pdf

[4] Kumar, Nallapaneni Manoj, Goel Sonali, and Kumar Pradeep Mallick Technologies for Smart-City Energy Security and Power (ICSESP) (2018)1-4.

[5] CPCB Annual Report on "Implementation of Solid Waste Management Rules, 2016" (2021). https://cpcb.nic.in/uploads/MSW/MSW_Annual Report_2020-21.pdf.

[6] CPCB Annual Report on "Implementation of Plastic Waste Management Rules, 2016" (2021) https://cpcb.nic.in/uploads/plasticwaste/Annual_Report_2019-20_PWM.pdf

[7] Jha Arvind K., Singh S. K., Singh G. P. and Gupta Prabhat K Tropical Ecology 52(1) (2011) 123-131.

[8] Meena Kuldeep, Singh Mahavir, Soni Kirti and Nair Anjali S. Indian Journal of Pure & Applied Physics (IJPAP) 60(5) (2022) 422-429.

[9] Zhu Da, Asnani P. U., Zurbrügg Chris, Anapolsky Sebastian and Mani Shyamala Improving Municipal Solid Waste Management in India: A Sourcebook for Policy Makers and Practitioners, The World Bank Washington, D.C., (2008) 15.

[10] Niti Aayog report on "Waste-wise Cities, Best practices in municipal solid waste management" (2021) https://www.niti.gov.in/sites/default/files/2021-12/Waste-Wise-Cities.pdf.

[11] Jain Saurabh, Singhal Shaheen and Jain Nikunj International Journal of Construction Management 21(3) (2018) 1-10.

[12] International Renewable energy agency report on End of Life Management of PhotoVoltaic Cells (2016) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA IEAPVPS_End-of-Life_Solar_PV_Panels_2016.pdf?rev=49a75178e38c46288a 187533 46fb0b09

[13] Ghosh, B., Ghosh, M.K., Parhi, P., Mukherjee, P.S., Mishra, B.K. J. Clean. Prod. (94) (2015) 5–19. http://dx.doi.org/10.1016/j.jclepro.2015.02.024

[14] Zaman Atiq Uz, Lehmann Steffen City, Culture and Society 2(4) (2011) 177-187.

[15] Lúcia Helena Xavier, Marianna Ottoni, Leonardo Picanço Peixoto Abreu Resource Conservation and recycling 190, (2023) https://doi.org/10.1016/j.resconrec.2022.106840