

**Technology and Work Opportunities for the Poor: An  
Analysis of Challenges in Developing a Sustainable  
Urban Solid Waste Management System in China**

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# Technology and Work Opportunities for the Poor: An Analysis of Challenges in Developing a Sustainable Urban Solid Waste Management System in China

## *Abstract*

*This study is an attempt to understand the impact of China's efforts at modernizing its urban waste management practices on its large network of informal waste pickers and waste collectors. Placed in the background of China's growing environmental challenges associated with the issues of waste management, this study explores various aspects of formal as well as informal channels of waste management in China's urban areas. It analyses how China's massive urbanization and economic growth have created a large community of waste pickers and waste collectors at the bottom layer of its labour force, and how they became a major challenge to its efforts at modernizing urban waste management in recent years. It identifies the emergence of a large network of informal waste pickers and waste collectors in China's urban areas as a failure of its model of economic development. However, this study is not an attempt to quantify the significance of informal channels in China's urban waste management system and it does not try to suggest any method for integrating the informal army of waste pickers and waste collectors into the formal channel of waste management. This study upholds the view that China cannot develop a sustainable system of waste management without reducing the uncontrolled operations of the informal sector in the channel of waste collection.*

**Keywords:** *Waste Management, Urban Solid Waste, China, Sustainability*

Technology has always been in a complex relationship with labour. On the one hand, it creates various new avenues of opportunity and accommodates a large share of the ever-growing labour force. On the other hand, it continuously challenges labour productivity in many sectors of employment that have traditionally been providing opportunities for non-skilled and semi-skilled workers and helps employers find a better non-human replacement for the same job. It is quite evident that, in the short run, such technological replacement of human labour can be a threat to the very survival of people in the lower level of the labour force. However, a positive outcome is expected in the long run, as this transformation is necessary for the efficient growth of labour productivity which is considered an inevitable requirement for achieving sustainable development. It is widely assumed that technological replacement of unskilled/semi-skilled human labour will help make human labour more productive and innovative in the future. Urban solid waste (USW) management is one of the major sectors of employment where the tension between labour productivity and technology has begun to be highly explicit in recent years. As the second largest employment sector after agriculture, the field of waste management provides economic opportunities for a large share of semi-skilled and non-skilled workers in most of the developing countries. In China, the second largest consumer market and the largest producer of waste in the world<sup>1</sup>, the waste management sector is the one of the largest

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<sup>1</sup>China had overtaken the US in 2004 to become the world's largest producer of waste. However, in terms of per capita waste generation, China remains far behind the developed countries and developing island states such as the Maldives. See, World Bank, 2005 and World Bank, 2018.

providers of employment opportunity to hundreds of thousands of semi-skilled and unskilled workers, especially migrant workers, camped in every urban periphery. In terms of a World Bank study titled, *What A Waste 2.0*, published in 2018, more than 200,000 people work as waste pickers in Beijing alone. Some assume that the total number of people who work as waste collectors and waste pickers in China will fall somewhere near 2.5 million (Comaru and Werna 2013), and some believe that the number could be as high as 5 million (Landsberger 2019). The waste picking and waste collecting community constitute a large share of China's about 10 million strong informal labour force which is currently involved in all aspects of recycling, reuse, and remanufacturing sectors<sup>2</sup>. In addition to this, over 1.5 million people are currently employed in China's formal channel of waste collection (ILO 2010).

The massive dependence of China's lower-level labour force on the waste management sector for making a living clearly reveals the failure of China in adopting scientific USW management practices in the context of its rapid economic growth and urbanization in recent decades. As it failed to have an effective waste management strategy, the size of garbage collecting and recycling community expanded significantly in its urban peripheries when the massive urbanization and prosperity induced dramatic changes in people's consumption patterns leveraged the growth of waste generation in urban China. In another sense, it can be argued that China's urbanization efforts have also created many peripheries that depend on waste disposed of by its urban residents. These peripheries, where most of the controlled landfills are located, not only occupy a large share of China's immensely valuable urban land but also create various kinds of challenges for its developmental efforts. As it began to focus on more sustainable ways of development, China is now increasingly being forced to adopt more efficient and technologically advanced methods for managing its urban solid wastes. It can no longer bet on the currently dominant unscientific waste management practices which create enormous health and ecological damages as its cities are already highly affected by the environmental problems. Precisely, growing economic, environmental, and health related concerns demand modernization of China's USW management practices, even though it may create a serious threat to the survival of a large share of workers in China's lower level of the labour force. Placed in this larger background of social, economic and environmental issues, the present study attempts to understand the emerging USW management practices in China and its potential impacts on the lives of a large army of China's informal workers who are highly depended on garbage disposed of by the urban residents.

In this study, the term USW refers to all intentionally discarded solid materials in an urban area, both from individual households and commercial and non-commercial establishments such as marketplaces, restaurants, schools and public parks. The discarded materials will include both organic materials with the potential to cause pollution and non-biodegradable materials such as plastic and glass. Therefore, the USW management is the process that involves all the activities dealing with such discarded materials that hold no primary value for its owners in its current form. Essentially, all activities pertaining to collection, transfer, sorting, treatment, disposal, and recycling of USW are included in the process of

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<sup>2</sup>Due to its high demand for cheap raw materials, China imports millions of tonnes of scrap materials from different parts of the world. Arguably, by helping the run of its massive recycling industry, the import of scrap materials also plays a significant role in maintaining employment opportunities in China's recycling sector. However, in recent years, China imposed many restrictions on scrap material imports, due its growing environmental concerns. See, Minter 2013.

USW management.

The present study is broadly divided into three major sections. The first section examines China's post-reform urbanization process and the changes it created in its USW generation. The second section analyses currently dominant USW management practices in Chinese cities and their problems and challenges. The third section assesses China's efforts towards developing technologically advanced USW management practices in the face of growing economic, environmental and health related challenges. This study upholds the view that there is no scope for protecting the high rate of unskilled and semi-skilled employment in the waste management sector of China at the expense of ecological and health related damages as it will remain a hindrance to China's sustainable development efforts.

### **Cities, Peripheries and the Waste**

According to data from the National Bureau of Statistics of China, 172.4 million people or 17.92 percentage of China's population were urban residents in 1978 when it began the reform and opening up which aimed to create what it is called 'socialism with Chinese characteristics'. Some sources project this number as low as 13.2 percentage or 129 million (Jowett 1984). The variation is mainly due to differences in defining the 'urban area'. However, with both the figures, it is clear that the rate of urbanization in China was far below the global average, which was 38.5 as per the World Bank data, during the pre-reform period. Until the early 1980s, China had strictly regulated its internal migration, from rural to urban areas, through various channels to control its labour market. It wanted to ensure an undisturbed labour supply to its agricultural production led by rural people's communes. As a result of this policy, between 1949 and 1979, the agricultural population of China expanded from 447.26 million to 813.56 million, or 82.6 percentage to 83.8 percentage of the total population (Jowett 1984). Though there were few instances of forced migration to urban areas during this period, its overall impact on the rate of urbanization was minimal when considered in a larger time frame. From 1958 to 1961, China had sent about 21 million people to urban areas to work in the non-agricultural sector because of Mao's Great Leap Forward which aimed to make China an industrial society (Sun 2019).

China's migration policy which used People's Communes and Household Registration System or *hukou* as the major tools for restricting the movement of people from rural to urban areas had effectively limited the expansion of Chinese cities until the late 1970s. The People's Commune that was constituted as a unit of farmers working together under the coordination of local leadership had played a significant role in controlling the mobility of rural workers. This institution of labour management, with nearly total control over rural economic activities, had enjoyed immense power of rural residents. The *hukou* system, which categorized people as 'agricultural' and 'non-agricultural', had directed that, for migrating to a city, farmers had to get an exit permit from their local residence department and an entry permit from their destination city unless they have secured a work permit from the city's labour agencies or an admission letter from a college or university (Sun 2019). Since the reform and opening-up, China relaxed such restrictions, and its cities and towns have begun to transform in a way that has no historical parallel in any part of the world.

In the initial years of its reform, between 1978 and 1995, along with the rapid



growth of medium and small industries in urban areas, the urban population of China increased from 172.45 million to 351.74 million with a steady increase of average 10.28 million people per year. In other words, between these periods, China's urban population rose from 17.92 percentage to 29.04 percentage of its total population with a 0.64 average annual growth rate. The change in the urban population definitely came along with an explicit change in the number and size of cities and towns in China (Wei 2019). In the early years of reform, China's per capita annual disposable income of urban households had increased from 343.4 Yuan in 1978 to 4283 Yuan in 1995. With the explicit change in these numbers, China's USW generation also began to increase rapidly. The use of plastics and paper started to grow steadily as large-scale grocery stores and shopping malls mushroomed in major cities. In the early years of economic growth and urbanization, the waste reduction was not a major concern in any Chinese city. Some estimates show that the waste generation in urban China increased from 31.3 million tons in 1980 to 113 million tons in 1998 (Wang and Nie 2001). This figure does not include the waste which never ended up in the formal channel of waste management and recyclable materials that were collected by informal garbage collectors. There is no credible data revealing the exact level of change in China's waste generation during its initial years of reform and opening up. However, because of the rapid increase in its urban population and the drastic changes in urban economic activities, waste management began to be a serious problem in many Chinese cities during this period (Ward and Li 1993).

In the later years of reform, China's urban population reached 562 million in 2005, 669 million in 2010 and 813 million in 2017. During this period, crossing the 50-percentage mark in 2011, it reached 58.5 percentage of the total population of the country. Along with the growth of urban population, China's per capita annual disposable income of urban households reached 10493 Yuan in 2005, 19109 Yuan in 2010 and 36396 Yuan in 2017. The massive growth of urban population, new found prosperity and, of course, the dramatic changes in technology in recent decades, have significantly transformed the consumption behaviour of China's urban residents. The level of inorganic content in China's USW, the rate of waste collection from its urban area, and the number and the size of its urban uncontrolled landfills also increased significantly with the increase in its average urban disposable income (World Bank 2018). The usage of paper and plastics in the country saw multifold growth in this period, primarily because of the emergence of new e-commerce giants and the increase in the number of supermarkets and shopping malls. The entry of new tech giants into the food delivery business, with a large army of delivery boys, also led to an increase in the usage of single-use plastics and paper. China became the largest generator of single-use plastic waste which the United Nations considers as one of the biggest environmental challenges in the present world (UNEP 2018). It is important to note that packaging constitutes nearly half of the plastic waste generated globally today and China generated about 40 million tons of plastic packaging waste in 2014 alone. Along with this highly critical single-use plastic waste generation, the total volume of China's urban waste generation reached 220 million tons by 2016, surpassing 200 million tons mark in 2010, and it is expected to grow to 295 million tons by 2030 (World Bank 2018).

The massive growth of China's urban population since 1978, making one half of its population living in 656 cities and 23000 towns, has dramatically transformed its cities and towns (Su Lianghu et al. 2014). With the growing population, all major cities expanded to its rural peripheries in two different ways. On the one side, it

has expanded by creating new urban settlement areas that express China's economic development and growing prosperity. On the other side, its expansion has created many urban villages that help to keep the city clean and tidy by managing its growing urban waste. Most of these villages emerged on illegally occupied rural land under the land management system in China (Tong and Tao 2016). When these villages evolved as dumping sites of China's urban waste, a new army of waste picking community also emerged in these villages. Many poor local farmers who lost their traditional agrarian means of livelihood with the expansion of the city, and many semi-skilled and non-skilled rural workers who came to the urban area to find a better economic opportunity became part of this waste picking community. They survived at the bottom layer of a growing China by combing landfill sites, trash bins in residential areas and marketplaces, and waste heaps on roadsides for recyclable materials. The high demand for cheap raw materials from China's manufacturing sector, which intensified its garbage imports, has further heightened the significance of such waste villages in China's waste management and recycling sector. Under the shadow of garbage mountains and waste villages, silently thrived China's millions of dollars' worth recycling industry (Ward and Li 1993, Goldstein 2006, Cheshmehzangi and Dawodu 2019).

Since the reform and opening up, along with its massive urbanization and miraculous economic growth, China has also seen a dramatic increase in the size of its urban middle class. The growing economic prosperity has gradually increased the demands of China's urban middle class. They became highly concerned about the presence of odour-emitting dirty garbage mountains in their neighbourhood. They began being aware of impact of landfill sites on their personal health and the health of their living environment. The expansion of the city has led them to think about exploring more economically productive options for the land which is occupied by landfills and waste villages. In some places, numerous reasons like these had forced the government to demolish some of the waste villages and uncontrolled landfill sites (Tong and Tao 2016, Inverardi-Ferri 2018). However, the closing of one uncontrolled landfill site or waste village has always reinforced the expansion of the other or led to the creation of a new one at the further remote side of the city's hotspot. Without a drastic reduction in waste generation or finding an advanced solution for managing the ever growing amount of USW, there was no scope for closing down landfill sites or waste villages. As the landfill sites and waste villages became a major concern for the new urban middle class, the Chinese government also started to be serious about the issue of waste management. The increased governmental effort for managing China's waste problem has set the stage for a clash between technology and labour productivity in China's USW management sector.

### **Urban Waste, Management and Problems**

China has a long history of urban waste management and recycling. Even before the establishment of communist China, a growing community of dislocated and impoverished people who collected discarded recyclable materials from rich urban residents to create handicraft materials was active in some of the Chinese cities. Mao's China was one of the first countries in the world which made recycling a part of its industrial sector. It encouraged the reuse and recycling practices to resist the challenge of shortages in production (Steuer 2017). It created a new culture of recycling since the 1950s by collectivizing recycling and reuse trades, and creating a public perception that participating in the process of recycling is a small but glorious contribution to the nation building (Goldstein 2006). However, the quality



and quantity of waste in pre-reform China was totally different from what it is in contemporary China. During this period, food waste was accounted for a large share of USW, and recyclable materials such as plastics, paper, and metals were relatively low. The quantity of highly critical e-waste was negligible. With economic prosperity and dramatic change in people's consumption behaviour, the share of non-biodegradable content began to account for a large share of China's USW. Nevertheless, neither pre-reform China nor for that matter any country in the world, ever had to deal with such a massive amount of USW as present-day China does (Wang and Nie 2001, Zhang et al. 2010).

The USW management sector in China operates through two major channels. One is the formal channel of waste collection, mostly managed by the local level administration, and the other is the informal channel of waste collection which helps to run China's recycling industry and provides economic opportunities to a large number of semi-skilled and non-skilled rural migrant workers. The performance of the formal channel of waste collection differs from city to city, and region to region. While it performs relatively well in large metropolitan cities, many small cities and towns are yet to develop an efficient formal waste collection system. The development of China's formal waste management system failed to keep pace with the rate of economic development and population growth of its cities and towns. Until 1990, China had only very few environmentally sound waste management facilities. During this period, many parts of China's urban area, including some parts of metropolitan cities such as Beijing, had no authority responsible for collecting and transporting USW. Due to the inefficiency of the formal waste management system, more than 97 percentage of collected USW were being simply dumped in the suburban area without any treatment. Since the 1990s, the situation began to transform as the central authority started paying attention to the issues of waste management in its cities, which was until then considered as the sole responsibility of municipal authorities. Thereafter, with a huge amount of investment, environmentally sound treatment and disposal of USW began to increase significantly. The environmental concerns, which became dominant by this period because of growing urban pollution, had begun to force many large cities to adopt sanitary landfilling as their main USW disposal option and China's first sanitary landfill, Hangzhou Tianziling Solid Waste Landfill, became operational in 1991(Wang and Nie 2001, Zhang et al. 2010, Tong and Tao 2016, Mian et al. 2017).

Since national concern over USW management began to increase because of growing environmental challenges, most Chinese cities have started developing proper mechanisms for collecting and transporting household waste. Advanced trucks have replaced the odour-emitting open tractors that were dominant in the past for transporting China's USW to dumping sites. Slowly but rightly, authorities have started accepting the significance of private actors in improving the efficiency of the formal channels of waste management. At present, the first stage operation of the formal channel of waste collection, which is collection and transportation of household waste to a local collection point, is carried out by both the municipal authority and the private collection companies. As the efficiency of the first stage of operation of formal waste collection system improved, most large Chinese cities now manage to collect a significant part of its growing household wastes. However, waste separation continues to remain a major challenge in Chinese cities, even though various mechanisms were adopted in recent years for this purpose. Waste separation refers to a process which categorises mixed form USW as organic, non-recyclable inorganic and recyclable waste materials. Due to

the inefficiency of the waste separation process in the formal channel, a large share of recyclable materials in the collected USW ends up in uncontrolled landfills in the suburban areas. Waste pickers find opportunity in the inefficiency of the waste separation process in the formal channel and they regularly comb both at source and landfill sites for recyclable materials.

The second stage operation of formal waste management channel, which is the storage of USW at local collection points and transportation of it to treatment centres and disposal sites, carried out primarily by municipal authorities, also saw significant improvement in recent years because of huge investments. The second stage operation includes three dominant methods of treatment and disposal of USW: landfills, incineration and composting. According to official data on treatments units, China has 1013 treatment units which include 654 landfills with a daily treatment capacity of 360524 tons, 286 incineration units with a daily capacity of 298062 tons and 73 other facilities with a daily capacity of 21303 tons (China Statistical Yearbook 2018). It further shows that these treatment facilities China have managed to treat 97.7 percentage of its collected wastes in 2017, with 55.9 percentage disposal at landfills, 39.3 percentage disposal at incineration units and 2.47 percentage disposal at other treatment/disposal facilities. As per this data, the treatment rate was 100 percentage in five major cities/regions, which are Shanghai, Jiangsu, Zhejiang, Shandong, and Hainan. Beyond the concerns on China's official data, it can be understood that it is due to the national intervention and huge amount of investments that the rate of USW treatment has significantly improved in most of the Chinese cities in the recent years (Xu et al. 2016, Mian et al. 2017).

Landfill disposal remains the most attractive USW treatment option in China because of its cost-effectiveness and capacity to hold large amounts of collected waste. However, as source separation is not widely in practice, the USW which reaches in China's landfills are mostly in a mixed state and creates serious environmental and health related challenges. Though China has been carrying out many pilot programs since the late 1990s to implement source separation of waste, which is the most effective method for waste separation, it couldn't successfully develop yet an effective source separated collecting system (Pinghui 2018, Chen et al. 2017, Ma et al. 2017, Zhang et al. 2016). Moreover, as recycling is not part of the formal channel of waste management, China's municipal authorities are less inclined to develop any adequate system for separation of waste which is collected in a mixed state (Mian et al. 2017). Beyond this question of waste separation, a large share of China's landfills does not have any facilities to control toxic emissions that pollute ground water, soil and air. Most of its landfills discharge leachate to soil and water bodies, and create serious environmental damages. The majority of its landfills are built in the 1990s with low construction and operation costs and they are generally administered by construction departments under the supervision of environmental protection departments (Zhang et al. 2010, Mian et al. 2017). The number of controlled and well-maintained sanitary landfills is very low in China because of its high cost for construction and operation. The presence of a large number of uncontrolled landfills increases China's threat of landfill accidents such as landslides of waste dumps and fires (Xiaoyong et al. 2016, Wang and Nie 2001a). However, in recent years, with the growing investment in USW management, signs of improvement are clearly visible in China's sanitary landfill disposal system. Recently, China opened some advanced sanitary landfills with facilities to recover and utilize landfill gas. Some of its cities have already started landfill gas utilization projects which aim to generate electricity by using landfill

gas collected from sanitary landfills. Nevertheless, it is yet to see whether China will widely implement this project without considering its high cost for construction and operation (Xin-gang et al. 2015, Mian et al. 2017).

Though it is building more and more advanced sanitary landfill facilities, the rate of landfill disposal in China has started slightly declining in recent years. The decline in China's landfill disposal can be considered as a good development in its waste management practices, as its landfills are already overfilled and they occupy a large share of its valuable urban land which can be used for more economically productive purposes. It is widely assumed that more than 7 billion tons of USW already exists in China's uncontrolled suburban landfills (Koty 2016). Since the late 1990s, considering various challenges with regard to the use of landfill treatment as the primary disposal option, China has been exploring alternative waste management options to reduce the amount of its landfill disposal. It sees the widespread adoption of incineration technology as a viable option for significantly reducing the volume of landfill disposal in the country. Developing incineration as an alternative for uncontrolled landfill disposal, China could save a large area of immensely valuable urban/suburban land which is currently occupied by garbage mountains and waste villages. In addition to that, incineration could help China generate electricity by recovering energy from waste in a sustainable way. Definitely, it also involves certain environmental challenges, though lesser in degree compared to the uncontrolled landfill disposal. It has the potential to create severe problems of air pollution with fly ash and toxic emissions. However, if effectively implemented with advanced technology and anti-pollution measures, the threat of secondary pollution from incineration units can be managed efficiently (Xin-gang et al. 2015, Zhang et al. 2015, Mian et al. 2017).

Approaching incineration as a sustainable waste management strategy, over the years China has significantly increased the use of incineration for its USW treatment. With massive investment in waste-to-energy technology (WTE), China became the largest producer of electricity from USW in recent years. In terms of International Energy Agency data, at the end of 2017, China has 7.3 GW installed WTE capacity with 339 plants in operation. It intends to expand the capacity to 13 GW by 2023 (IEA 2019). In China, the incinerated volume of USW increased from 3.7 million tons in 2003 to 84.6 million tons in 2017. Providing various tax incentives to the WTE industry, China highly encourages the participation of private actors in its efforts for establishing a sustainable waste management system (Nie 2010). However, private actors' drive for profit often leads to ignoring essential measures for controlling environmental pollution and thereby creates a serious problem of secondary pollution. The requirement of a large amount of investment for installing advanced technology as well as high operating costs of WTE plants also significantly affects the quality of China's incineration units. Because of the low quality of incineration units, the Chinese public has begun to be highly concerned about the potential toxic emissions from WTE plants. Following this, strong anti-incineration sentiments have emerged in various parts of China. In recent years, public protests erupted in many sites of the proposed incineration units with a slogan "not in my backyard" (Xin-gang et al. 2015, Zhang et al. 2015, Standaert 2017). Attempting to be a global leader in the fight against climate change under the leadership of President Xi Jinping, China cannot ignore such protests for a long-time.

Apart from the issues related to financing and technology, the quality of its USW also affects China's efforts for adopting incineration as a sustainable waste

management strategy. The moisture content in China's USW is relatively higher when compared to developed countries. In other words, like in most of the developing countries, the heating value of China's incineration material is relatively lower because of the large presence of food remnants in its mixed form of USW (Zhou et al 2017). The low heating value of China's USW essentially causes an increase in the operating costs of its incineration units, as it forces to adopt coal as an auxiliary fuel in most of the incinerators (Xu et al. 2016, Havukainen, et al. 2017). To meet this challenge, China needs to develop an efficient system of waste separation with the help of a technology that could classify different types of solid wastes. It could also use advanced technology to effectively incinerate the USW with low heating value.

In comparison to landfill disposal and incineration, the third method of USW treatment, which is composting, is the least used method of waste treatment everywhere in the world. The term composting refers to a controlled bioprocess that allows "transformation of organic waste into a stabilized product" (Karak et al. 2012). In 2017, China treated only less than 3 percentage of its USW by employing the composting method. As in the case of landfill disposal and incineration, a mixed collection of waste remains the most important challenge for employing composting as a USW treatment option in China. Through composting, low quality waste could create only low-quality products with less fertilizer value. Such products could be used only as a soil stabilizer. Moreover, compared with the other dominant methods, the large-scale application of composting involves a high cost of operation. Composting, thus, remains as the least attractive method of treatment of USW in China (Nie 2010).

China's formal channel of waste management which primarily employs these three methods of treatment is yet to develop an effective strategy for collecting, treating and safely disposing of the entire amount of USW generated in China's cities. It is the inefficiency of China's formal channel which helps the development of its huge informal waste management sector. The informal channel of waste management in China includes three major groups of players as connected to its recycling industry and accommodates the largest share of workers employed in the field of waste management. The first group is waste pickers who roam around the city to comb residential areas, marketplaces, public places and landfill sites for recyclable materials. This group, composed largely of non-skilled and semi-skilled rural migrant workers, is the most underprivileged community who work in China's urban area. The second group is Waste Merchants, who specialise in doorstep collection of recyclable materials. They generally buy recyclable materials from households, restaurants, shops, etc, and transport them by using tricycles or trucks to transfer stations mostly located in suburban areas. This group is also comprised mostly of rural migrant workers. The third group is called Middle Men who act as representatives of the recycling industry and purchase recyclables from Waste Pickers and Waste Merchants. They pre-process recyclables at their storage centres and sell them to the recycling industry. Many people have found their fortune from this position and became really rich when the demand for cheap raw materials was very high in China's manufacturing sector (Steuer et al. 2017, Goldstein 2006).

The informal channel of waste management in China, including the recycling industry, is the second largest employment sector after agriculture in the country (Koty 2016). The labour-intensive informal waste management sector accommodates a large share of non-skilled and semi-skilled rural migrant workers seeking economic opportunity in China's urban area. It is a sector that provides



economic opportunities for those rejected by society and those struggling to find other ways for survival (Landsberger 2019). As it is the socially marginalized, economically struggling individuals who constitute the community of informal waste collectors, their only motive is to find a living by collecting recyclable from what others discarded as garbage. Considering the economic value of recyclable materials, they generally seek only those materials which hold high economic value in the recycling sector. The recyclable materials with less economic value, along with other non-biodegradable materials, are mostly left behind in the landfills even after the combing by informal waste collectors.

Though the informal waste collection does not completely fill the gap left by the formal channel of waste management, the contribution of informal waste collectors is highly important for China's USW management sector. It is the informal waste collectors who provide a substantial share of recyclable materials for China's recycling industry (Steuer 2017). However, there is no official data to understand the exact amount of USW which goes through the informal channel of waste management. Considering the approximate number of waste collectors in Chinese cities and the average quantity of their collection of recyclables, some assume that China's army of informal waste collectors might be collecting as high as about 200 million tons of recyclable materials every year (Linzner and Salhofer 2014). In fact, a large share of China's informal collection comes as a transaction between waste generators and waste collectors. Finding an additional way to make some extra income in selling recyclable materials to informal waste collectors, China's waste generators somehow encourage the existence of informal channels of waste management (Steuer 2017). They are not concerned about the fact that it is those working in the bottom layer of China's informal waste management system who are highly affected by the negative impacts of China's poorly managed system of waste management. Working in an unsafe condition, it is the waste picking community who generally becomes the first victim of toxic emissions of China's uncontrolled landfills. It is also they who suffer mostly because of frequent landfill accidents such as fire and landslides of waste dumps. As the damage it creates on workers, public health and the environment is much larger than its benefits, China cannot sustain its unsafe informal channel of waste collection if it intends to modernize its USW management practices.

Based on an unsustainable method of raw material collection, China's recycling industry creates enormous health and environmental challenges. As there is no efficient formal monitoring system, China's recycling sector generally ignores safety standards when they employ workers in the units, and create serious health and environmental damages through unsafe burning of materials and dumping of residues. However, compared with the environmental damages created by other dominant methods of USW treatment, many uphold recycling as the most sustainable waste management option (Xu et al. 2016, Yuan and Li 2017). Since it began to prioritize modernization of USW management practices, China made various efforts to reduce the significance of its informal channel of waste collection. Some of its cities have established collection booths for recyclables and waste of electrical and electronic equipment. However, such initiatives do not work effectively as the public finds informal channels more economically attractive for selling their recyclable materials (Steuer et al. 2018). With growing urbanization and the never ceasing growth of USW, it remains to be seen how effectively China could control the significance of its informal channel of waste collection.

## Sustainability, Technology and USW Management

Since the mid-1990s, China has been making laws and policies for preventing environmental pollution that occurs through its inefficient USW management system. However, it is only in recent years that China began to implement such policies with serious efforts for modernizing waste collection, transportation, storage, treatment, and disposal facilities. The conflict of interests between different ministries and different layers of administration that participate in the process of waste management has always been a major hurdle in the advancement of China's USW management system. Nevertheless, in recent years, severe environmental problems have forced China to accept that there is no way ahead for its economic development without addressing problems of growing wastes in its urban areas (Liu et al 2017). Therefore, adopting sustainable development as its fundamental concern, China has started making laws that put pressure and responsibility on municipal governments for collecting, transporting, treating and disposing of USW in a sustainable manner. In addition to this, the various other laws and policies China adopted in recent years with the aim of promoting the idea of 'circular economy', also include the provision for developing a strict framework for sustainable USW management system (Zhu et al. 2018).

Recently, China has shifted its focus from the rate of economic growth to the quality of economic development, to adopt a 'circular economy' as its new development strategy. The term 'circular economy' refers to a system which maximises the efficiency of resource-utilization by reducing waste and controlling the extraction of natural resources (Hu et al. 2018). China has already started enforcing various policies with the aim of building a "resource-conserving and environment-friendly society with features of low input and high output, low consumption and emission, and a cyclic and sustainable economic system" (Ness 2011). The idea of 'circular economy' redefines the very concept of 'waste' as it sees the waste generated by one enterprise as a resource for the other. This system prioritizes reduction, reuse, and recycling over other methods of USW treatment. It suggests strict control over the exploitation of natural resources and pollution of the environment. Adopting this economic strategy, China now encourages bringing technological advancement in its industrial sector and takes action to shut down its polluting enterprises (Cheshmehzangi and Dawodu 2019). It banned the import of recyclables, especially plastics and some other materials, to establish control over its highly polluting recycling industry (Katz 2019, Staub 2019). However, many are sceptical about China's ability to develop a socio-economic system that prioritizes reduction, reuse, and recycling of waste. They argue that the "Chinese government has little experience or capital to achieve environmental goals within a short time period" (Zhou et al. 2017, 4).

As critics note, there is a long way to go if China wants to develop an effective circular economy and establish a sustainable waste management system that dismantles its currently dominant unhealthy informal channel of waste management. It is yet to see whether China could adopt a sustainable model of development by compromising its current rate of economic growth. However, China's growing environmental concerns are quite evident today and its efforts for modernizing waste collection, treatment and disposal have already significantly transformed its formal waste management system. The most important problem for China's USW management continues to be the relationship between waste generators and the authority which is responsible for waste management. China has



been struggling to develop an effective system of source separation as the public remains mostly uncooperative towards such efforts of municipal authorities (Mingning and Qiuyu 2018). But recently, it has taken some reliable measures to improve this situation, at least in its major cities. With the growing pressure from the national government, some of its cities adopted a plan for the compulsory sorting of household waste, that directs its residents to categorise their waste and discard it into separate trash cans (Chen 2019). Those who fail to follow the rules will face hefty fines and the reduction of their social credit scores. To implement such a plan, cities like Beijing started installing high-tech trash bins with facial recognition systems. Strengthening the efforts for source separation, President Xi Jinping himself appeared on state media with a message on trash-sorting and urged the public to cultivate a good habit of garbage classification (Xiaoci 2019). Some cities have started to employ the help of AI-driven technology for ensuring successful source separation of USW. Tech giants like Alibaba have already developed smart phone application that helps people to categorise USW as biodegradable, dry, toxic and recyclable (Chen 2019a, Ng 2019). Collecting inputs from such pilot projects, China is planning to formalize a standard system and regulation for garbage sorting by 2020. With growing concern at the national level, waste sorting has now turned as a political task for local officials (Xie 2019). However, beyond the question of public participation and high-tech dustbins, China is yet to develop an effective transportation system for categorised waste. In many areas, public participation in trash sorting goes in vain when formal waste collectors load all separately categorised waste into a single bin truck for transportation (Hao 2017). The public participation in trash sorting and installation of high-tech dustbins will be meaningless if it fails to develop the appropriate transportation facilities for categorized waste. If China succeeds in developing an effective system of source separation, it can significantly reduce the volume of recyclables that end up in the suburban garbage dumps. However, it will severely affect the income of a large number of informal waste pickers who find their living by collecting recyclables from such areas.

The most important aspect of China's initiatives for modernizing its waste management system is the growing application of AI-driven technology. It is largely private actors who come with innovative ideas for using technology for solving China's USW crisis. Recently, Alipay introduced a program that enables China's city residents to sell online their recyclable materials (Zhang 2019). A recycling startup company named Xiao Huang Gou (Little Yellow Dog) installed more than 10,000 AI-powered smart trash bins in 33 major Chinese cities to collect recyclable directly from people by giving them financial incentives. Challenging the very survival of China's large army of informal waste collectors, these smart bins accept plastics, paper, textiles, metals, and glass. This startup raised 164 million US dollars through its first round of fundraising in 2018 (Chen 2018). Chinese-Norwegian joint venture INCOM TOMRA is another good example of technology driven transformation in China's waste collection and recycling sector. The company is now active in more than ten provinces of China and provides an immense contribution to its goal of developing the circular economy by establishing Reverse Vending Machines (RVM) and offering solutions for solid waste recycling. It already placed more than 5000 RVMs in Beijing itself to collect recyclable materials (Birtles 2018). Looking at the huge opportunity in China's waste management sector, many such private companies are now coming forward with innovative ideas, including the plan for developing robotic waste recycling facilities (Messenger 2016). The technology driven transformation in the channel of waste collection and the governments' efforts for controlling unsafe informal waste management has already started

affecting the lives of many poor migrant waste collectors in China's urban areas (Birtles 2018, Landsberger 2019).

Though the development of a sustainable system of waste management will severely affect the economic opportunities of workers at the lower level of China's labour force, it is expected that modernization will create many new employment opportunities in the waste management sector (ILO 2018). The new employment will be largely skill based, as the transformation from an extract-manufacture-use-discard model to a reduce-reuse-recycle model require a lot of expert knowledge and technical skills. The ultimate challenge for developing a sustainable waste management system will be on reducing the rate of consumption. Without reducing the consumption, China cannot find a long-lasting solution to its problem of USW management and all other environmental challenges associated with this issue (Landsberger 2019). The concept of waste reduction is very much part of China's idea of a circular economy that is currently shaping its economic strategy. However, it is yet to see whether China could transform the consumption behaviour of its growing middle class.

## **Conclusion**

There is no doubt that urban waste management has a broad societal impact today as the number of urban population and the quantity of USW have increased tremendously. In the present world, the method of waste management affects "the health of the environment, the livelihood and well-being of the vulnerable population, and the relationship between governments and citizens" (World Bank 2018). A system of sustainable waste management requires proper planning and monitoring from central authorities. Without having a regulatory framework designed by the central authorities, the local level administrations which generally operate waste management services cannot deal with the growing varieties of urban waste. The central level regulatory framework is essential not only for developing a sustainable system of waste collection, transportation, treatment, and disposal but also for ensuring responsible involvement of the private sector in waste management in the context of growing environmental pollution. In this sense, China is on the right track with new national level policies for sustainable waste management and recycling.

The massive growth of its urban population since the reform and opening up has created enormous challenges of USW management in China. As the development of formal waste management system in its cities and towns have failed to keep pace with the rate of economic growth and improvement in people's living standard, a large network of informal waste collectors has evolved in China's urban areas as connected to the recycling industry. In recent years, China has started efforts for modernizing its formal system of waste management as its inefficiency has been creating severe environmental and public health problems. However, its large network of informal waste management, which gives economic opportunity to millions of semi-skilled and non-skilled rural migrant workers, has become a major hindrance to the modernization efforts. China cannot successfully modernize its formal channel of waste management without limiting the level of operation of its large informal sector. It is expected that a technology driven transformation in China's waste management system will gradually reduce the possibilities of open dumping of recyclable materials. In the short run, such a change will greatly affect the means of survival of China's large network of socially excluded and economically deprived informal waste pickers. Moreover, the modernization of the

formal waste management system, by adopting AI-driven technology, will also reduce the significance of various other currently dominant labour-intensive activities, such as waste separation, in China's USW management. It will, thus, also cut down many other non-skilled and semi-skilled employment opportunities. However, China cannot delay the modernization of its waste management sector any longer as the threat of the inefficient system of waste management on public health and the environment looms large.

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