Assessment of municipal plastic waste in the Yangtze River Delta, China

Marta Sibhat[1], Jianfu Zhao[2], Sha Lu[3], Huanzheng Du[1,3], Tao Wang[*,2,4]

1. Tongji University, UNEP-Tongji Institute of Environment for Sustainable Development (IESD), Shanghai 200092, P.R. China
2. College of Environmental Science and Engineering, Tongji University, Shanghai
3. Circular Economy Research Institute, Marxism Faculty, Tongji University, Shanghai
4. Institute for Advanced Study, Tongji University, Shanghai

* Corresponding author

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Abstract-With rapid urbanization and the rising standard of living, more plastic materials are used in cities in China, leading to an increasing quantity of municipal plastic waste (MPW). However, robust information about details for waste plastic management, including plastic composition, plastic waste sources, waste generation, and material recycling, are limited. Using cross-sectional data, this study estimated MPW generation in the Yangtze River Delta (YRD) in China from 2000 to 2018 by employing the environmental logistics regression model. The historical analysis showed that MPW per cap had increased from 11.96 kg/(cap. a) in 2000 to 27.3 kg/(cap. a) in 2018. Extrapolating the total mass-produced across YRD (including 41 cities and 4 provinces), approximately 33.54 million tonnes (Mt) of MPW were produced between 2000 and 2018 with an annual average growth of 10.1%. The spatial distribution of the result showed that the MPW generation mainly concentrated in certain economically developed and populous cities. Comparably in the same period, the total municipal solid waste (MSW) generation was 481.7 Mt, but its annual average growth rate was 8.1%.

Keywords: Municipal Solid Waste (MSW), Municipal Plastic Waste (MPW), Yangtze River Delta (YRD), Environmental Logistic Curve

I. INTRODUCTION

Urbanization creates an ever-growing of municipal solid waste (MSW) flow. When nations and cities become more populous and affluent and provide people with more goods and services, they face corresponding quantities of waste to be handled through treatment and disposal. One of the increasingly large fractions of urban solid waste is plastics. The plastic waste fractions in municipal solid waste (MSW) grew from less than 1% to over 10% in middle-income and high-income countries in 1960 and 2005 respectively [1]. As the production and usage of plastics have increased, the importance of plastics in material waste has grown over the years. The Chinese plastic industry has witnessed rapid growth in the last 8 years, now representing 25% of global plastic products followed by European Union Countries, North America, Middle East, and Africa, as well as Latin America accounts for 22.9%, 20%, 7.3%, and 4.8% respectively [2]. This wide-ranging production and usage of plastics have produced more than 30 million tons a year of plastic waste in recent years in China [3, 4]. Plastic packaging is the leading application of plastics production, powered by the widespread consumer usage of single-use containers for immediate disposal, representing a nearly two-thirds generation of plastic waste [5].

The major plastic waste embodied in MSW includes plastic packaging's and food containers made of polyethylene, polypropylene, polystyrene, polyvinyl chloride (PVC), polyethylene terephthalate, etc. These products have limited lifespans and pose major environmental problems due to ecosystem accumulation when disposed of inappropriately plastic waste, due to their polymer structure, they are difficult to degrade naturally and have a risk in marine species and occupy natural land[6]. Plastics also destroy marine species. There is growing proof of the fact that a wide variety of terrestrial species ingest plastic[7]. Many features of human well-being are impacted by plastic pollution disrupting beach aesthetics [8], blocking sewage and wastewater engineering systems [9], and providing a fertile environment for vector diseases[8, 10]. Microplastics are also increasingly found in the human diet system, but it is difficult to absurd to justify their effects on human health and needs more study[11, 12].These negative aspects have received increasing attention from policy initiatives to resolve these issues, in particular plastic packaging, as this is the main application of plastics of the post-consumer plastic waste stream. The emphasis is on the consumption side of these steps, such as reductions or restrictions on lightweight plastic carrier shopping bags and waste[13, 14]. The Chinese government implemented a "plastic limit order" to curb plastic shopping bag use in 2008. This order helped halve plastic packaging's annual growth rate from 10% to 4% between the 2000s to 2010s respectively. This initiative, however, was partly offset by the booming e-commerce and food distribution services, both using high quantities of plastic packaging[15]. Even though plastic waste is a growing concern, there is no sufficient information about details for waste plastic management, including plastic composition, plastic waste sources, plastic waste generation, and the recycling rates in China.

Most studies are at a national level [5, 16, 17]and relatively limited research has been investigated at the City level[18]. The correlation between the overall economy and the growth of MSW is a major issue for researchers and governments. Jambeck, Geyer, et al. 2015 studied that the characteristic rising urbanization in coastal areas of China is as is part of the cause to generate the world's main source of plastic waste to the sea, in 2010. Currently, Megacities in China cities produce between 1,000 and 20,000 tons of MSW daily, with fractions of plastic waste as high as 13.6%, being the second-largest component of MSW[19]. To better reduce China's generation of plastic waste and improve the management, concentrating on key regions that contribute a considerable quantity of plastic waste should be adopted. However, due to a lack of details on diverted recyclable waste, total plastic waste generation in prefectural towns is uncertain. To fill this gap, we are interested in analyzing the historical trend of per capita MPW generation and conditions under which the waste has been growing in the Yangtze river delta region of China. A quantitative regression model can contribute to filling the data gap of time-continuous at the city, regional, and national levels. Obtaining this information can become important in cases, when, for instance, intervention, turning points, or sustainable management strategies need to be devised. In this study, 41 prefectural cities are included particularly found in the four provinces (Jiangsu, Zhejiang, Anhui, and Shanghai) of the region.

II. LITRATURE REVIEW

The relationship between municipal plastic waste (MPW) generation and economic development may follow the hypothesis of the Environmental Kuznets Curve (EKC) [20]. EKC proposed a U-shaped inverted curve that appears between the overall economy and the environment, which implies that environmental pollution would first rise with economic development and decrease after a certain amount (turning point). The EKC hypothesis has been commonly used in many areas, such as environmental economics[21], health economics [22], and other macroeconomics fields. [23], using cross-sectional air pollution and deforestation data on GDP per capita for 55 high and middle-income countries, was the first one to use the terminology 'Environmental Kuznets Curve' in environmental economics studies when exploring the relationship of environmental pollution and economics. Since then, scientific findings explored the role of GDP on decreasing environmental pollution depending on the curve of Kuznets has increased using various countries or territories, study periods, pollutants, data sets, and methodologies[24-27].

The definition of an environmental logistic model which relies on the environmental Kuznets Curve(EKC) emerges in [28]. In fact, what is not explicitly laid out in the EKC literature is whether a quadratic or cubic relationship characterizes the inverted U-shape. Although both functions may reveal a propensity to reverse, the specification will have an impact on empirical modeling of environmental degradation[29]. Besides, the cubic relationship that depicts the hypothesis of the inverted-U can take the method of a logistic function and could be used to demonstrate how society functions from a primitive to a well-developed level. The theoretical basis of a logistic relationship that connects environmental pollution to per capita income. The assumption of a quadratic MED (marginal environmental deterioration) leads to a logistic EKC where the marginal environmental deterioration MED increases before a given income threshold, hits a limit at the threshold, and eventually falls below it. The proposal by Sobhee is still based on a third-degree polynomial Environmental Kuznets Curve, despite its logistic pattern. The logistic function is represented by an S-shape curve that finds applications in several areas, including demographics, genetics, economics, psychology, political science, medicine, or the environment. Focusing on this last example, it is assumed by the logistic model that the growth of environmental deterioration at the initial stage is roughly exponential; then saturation starts, growth slows and growth ends at maturity. [30] Provided a crosse sectional data of countries competing between the methods of EKC and ELC, they provide important proof of their compressive goodness of fit strength and their precision in forecasting. In China, among the prior studies focusing on water pollution, [31] used the regression model to assess the EKC for eleven provinces over the period 2001- 2016 between socio-economic growth and seawater quality; their results verified the soundness of the EKC in six provinces (Liaoning, Shandong, Guangdong, Fujian, Hainan, Guangxi). [32] studied that in Jiaxing City, China that a U-shaped inverted curve accompanied the relationship between discharged industrial wastewater and GDP per capita by the ordinary least square (OLS) method between 1995 and 2005. The EKC of economic development and water pollution was similarly verified [33] in China using panel regression; found an indication to support a U-shaped inverted curve over the period 1990-2014.

Waste Kuznets Curve (WKC) studies focused which used solid waste as an indicator of environmental degradation; such studies included municipal solid waste (MSW), hazardous waste, packaging waste, medical waste, and plastic waste. A new analysis by [34] found in the eastern region which is the largest economic zone of China the relation between MSW and economic growth of China found that there occurs a significant N-shaped inverted curve, while an inversed N-shaped curve relationship is not significant in the western region. but the inflection points indicate that the per capita MSW is far from the saturated level and it will likely increase with economic development for a long time. In several WKC (waste Kuznets curve) empirical studies, scholars generally perform model analysis based on cross-sectional data from various geographical regions or administrative divisions.

In China, most of the former publications are on WKC used MSW as an indicator. Although it is evident that another waste was also studied earlier, studies using an indicator other than MSW are still limited, and the few findings obtained are inconclusive. Plastic is typical waste that is an increasingly significant component of waste in the processing of cities' solid waste and leads to the rapid and pervasive contamination and destruction of our natural environment, which is distinct from other forms of waste.

III. METHODOLOGY AND DATA

Study area

This study focuses on one of East Asia's most populous and economically productive regions called Yangtze River Delta (YRD), situated in eastern China. This region spans the Jiangsu, Zhejiang, Anhui provinces, as well as Shanghai, a municipality that is under the central government. Although the YRD accounts for just 2.2% of the sq. km of China, it contributes 19.9% of the national GDP and is home to 11.7% of the country's population. The region's total urbanization pace has hit 60% percent and most of the region's prefecture-level cities have more than one million people[35]. The annual average MSW and per-capita rate of growth of the eastern coastal province were significantly higher than the country's western and central provinces. Throughout the past 2 decades, the generation of MSW has increased steadily, with a slight decline during the five successive years of 2004-2007, which could be due to the 2004 revision of the 'Solid Waste Statute.' Furthermore, the per capita MSW average annual growth rate was faster than the average annual growth rate for the total MSW generation in the eastern coastal provinces.

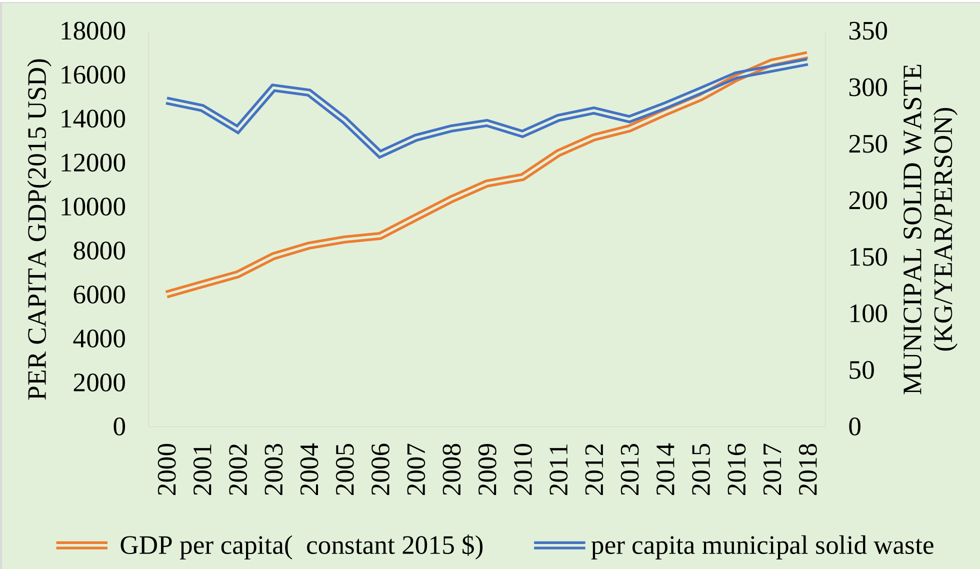


Figure1: Municipal solid waste generation and per capita GDP in Yangtze river delta, 2000–2018.

The substantially high population density following relatively high MSW generation rates resulted from the catchment Yangtze river leads to 0.33 million tonnes (range 0.31-0.48) of plastic waste discharged annually into the China East Sea. [16, 36]. The proportion of plastics increased rapidly, probably due to urbanization and rapid economic development along the delta. Pollution and changes in biodiversity have already driven endangered species such as the Yangtze starfish Right to the brink of extinction [37]. Coordinating the relationship between economic growth and the ecological environment has thus been a major concern for the region's sustainable development.

Data

we develop a large dataset using cross-sectional data of different megacities and countries to analyze and estimate the municipal plastic waste generation across the YRD cities. Per capita data are commonly used to compare the strength of MSW generation among different countries and cities. The goal of the current study is to explore the possibility of improving the granularity of data on the development of plastic waste at the prefectural city level, using realistic assumptions based on the relationship between plastic waste and GDP per capita. Detailed data on plastic waste generation for various countries and cities are not available. We modeled both per capita MSW and share plastic % in MSW on per capita GDP to calculate MPW generation from 2000-2018 in the region. Finally, from the perspectives of spatial analysis, we discuss some policy implications and propose recommendation can be helpful for policy and decision making. The data sources are;

1. A primary data source of the MSW generation of YRD cities particularly 41 cities and 4 provinces (Shanghai, Zhejiang, Jiangsu, and Anhui) from 2000 to 2018 were obtained in *China Statistical Yearbook* from the provincial collection and treatment of MSW data; data on the urban population and Urban GDP (national currency) of the YRD were derived from the provincial urban population in the *China Statistical Yearbook*; the GDP per capita (constant US $) in these cities was calculated using the conversion factor of GDP(constant 2015) which is distributed by UN.
2. Data on MSW per capita in other regions of the world were acquired from a database developed by the Organization for Economic Cooperation and Development. These data were mainly gathered throughout the period from 2000 to2018.
3. Share of plastic percentage in MSW of different cities of China and developed countries are gathered from different works of literature.

Model Formulation

We developed a logistic regression model to estimate the percentage of plastic waste produced in YRD cities based on the available data of total MSW and plastic % in MSW of different counties and cities with GDP. The logistic function is a sigmoidal curve representing the solution to the differential equation and expresses the relationship of per capita waste generation y_i and time.

$$\frac{dy}{dt} = ry\left(1 - \frac{y}{K}\right) \qquad \text{eq 1}$$

where y represents the per capita waste generation, r denotes the growth rate, and K is the carrying capacity (saturation point), which is the maximum average number of waste generation per person.

$$Y_i = Y_o + \frac{K}{e^{-(ri+C)} + 1} \qquad \text{eq2}$$

Where $C = \ln\left[\left(\frac{y_0}{K-y_o}\right]\right.$ (y_o -refers to the initial waste generation in reference time 0, and i is the time passed. The per capita waste generation y and is defined by using the following equation:

$$y_{i=}\frac{MS_i}{Q_i} \qquad \text{eq3}$$

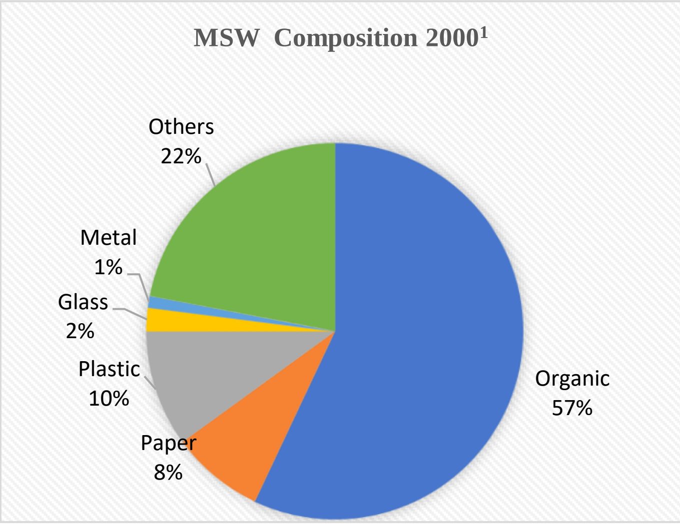
where MSi is the total waste generation Qi is the population.

There are two parameters in the logistic model, which are the carrying capacity (saturation point) and growth rate of the 'S.' In principle, the logistic function could fit the per capita to determine the growth rate and height (carrying capacity) constants r, and K, respectively empirically. The inflation and differences in living standards between countries have also been taken into account. The logistic model is calculated in two-stage in an econometric analysis, which uses Verhulst's method followed by a nonlinear least square (NLS) technique. More specifically, assuming a logistic model the first stage–following Verhulst's method-considers three observations Y_b, Y_m, and Y_u respectively located at the beginning, the middle, and the termination of the data, of the cross-sectional data providing the following estimation for the parameters of the best fitting curve result: The non-linear least squares estimation were then estimated using the Levenberg-Marquardt algorithm variant, and Assuming the preceding estimates of the parameters as initial values.

IV. RESULT AND DISCUSSION

The municipal plastic generation and economic development

In MSW, all plastics (packaging, plastic toys, furniture, etc.) are found commingled with other types of waste (organic material, metal, paper, etc.). Packaging plastics have typically short life span and thus dominate municipal plastic waste. Its short lifetime means that packaging's share in the production of plastic waste is much higher than its share in the use of plastic. HDPE (high-density polyethylene) and PET (Polyethylene terephthalate) and bottles are primarily retrieved from MSW. The large proportion of packaging in a plastic waste can have major consequences for the recycling industry of plastics, impacting collection systems and efficiency (due to contamination and use of mixed plastics). The plastics fraction in MSW varies among regions, cities, and season due to due to variations in climate, culture, living standards, and consumption, etc., In China, a high organic and moisture content dominates the composition of MSW, as organic waste is accounted for the highest proportion, which gradually decreasing as illustrated in figure 2. Plastic waste is the second-largest component in MSW which showed an increasing trend from 1990 to 2017[19].



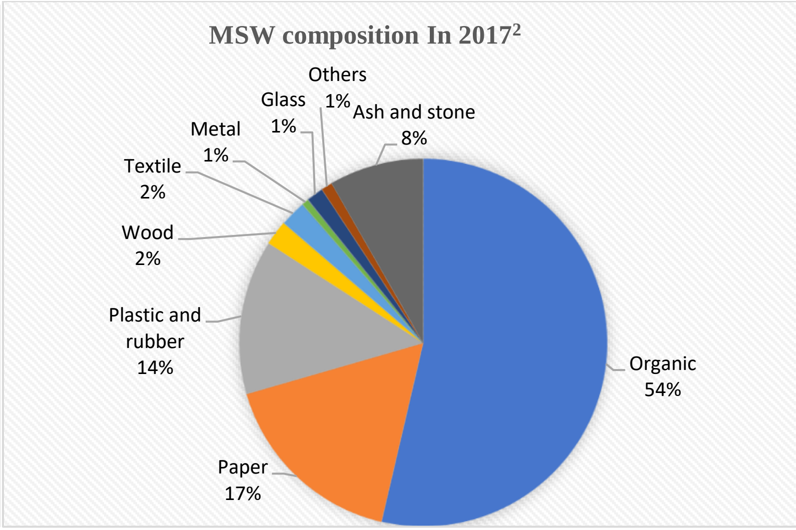


Figure 2: MSW composition in China. Source: 1.[38] 2.[19]

Generally, it is assumed that the faster an economy grows, the more goods and services are consumed, and thus, more solid waste is produced. Different studies investigated that MSW generation quantities and wasted plastics were demonstrated to have a good correlation with the economy ($R2 > 0.6$) in China[39, 40]. In 2008, MSW accounted for approximately 40-50% of waste plastic generation in western European countries[41]. Once economic growth has reached a certain level, economic development is correlated with decreased MSW [42]. The historical evidence on waste generation shows that the relationship of these variables is at the core of the EKC hypothesis. Waste generation has typically been shown to increase incremental tax improvements at lower income levels at a faster pace than at high-income levels[43]. This is attributable, to the lack of more comprehensive policy guidelines, to both the robust continued growth of total waste generation and the slow rise in sustainable treatment facilities.
According to [46]In the US the MSW increased by 188%, while MPW grew by 8.238% over the period from 1990 to 2013, coinciding with a decline in other components of the MSW stream. Similarly, the MPW % showed an increment from 1960 (0.4%) through 2017(13.2%)[47], in a decreasing annual growth rate, and shows saturation after 2015 seems to follow a logistic function. A similar trend is occurring in Western Europe, Japan/Australia/Netherlands (figure 3). However, the developing regions are further behind the saturation level in per cap waste generation. The regions which produce the most plastic are not necessarily the largest consumers. For instance, Japan is a region with the lowest plastic production rates; however, it is one of the biggest consumers. On the other side, China is the largest producer, but the consumption rate is lower compared with other regions (almost four times smaller than North America or Europe)[48].

Statistical fitting result

The statistical fitting show that both per capita MSW ($R2 > 0.6$) and share of plastic % fraction ($R2 = 0.51$) showed a statistically good correlation with per capita GDP. The correlation was supposed to be positive for MPW indicating the higher intake levels at the prefectural cities. The amount of MPW for countries and cities provided by different works of literature indicates distributed evenly when compared relative to per capita GDP with an average value of 6.9% and a standard deviation (SD) of 2.4% ($n = 188$). The difference in information across the reporting countries on the plastic % of MSW needs to be under consideration. In some countries, there is a large fluctuation in reporting the % of plastics, it might be because of seasonal variation. Thus, data where substantial uncertainty was present concerning plastic generation increasing simultaneously. Thus, we use country data which shows increasing over years and available. The data for the US showed a logistic function increasing trend for years which we use as a saturation level for fitted relationship.

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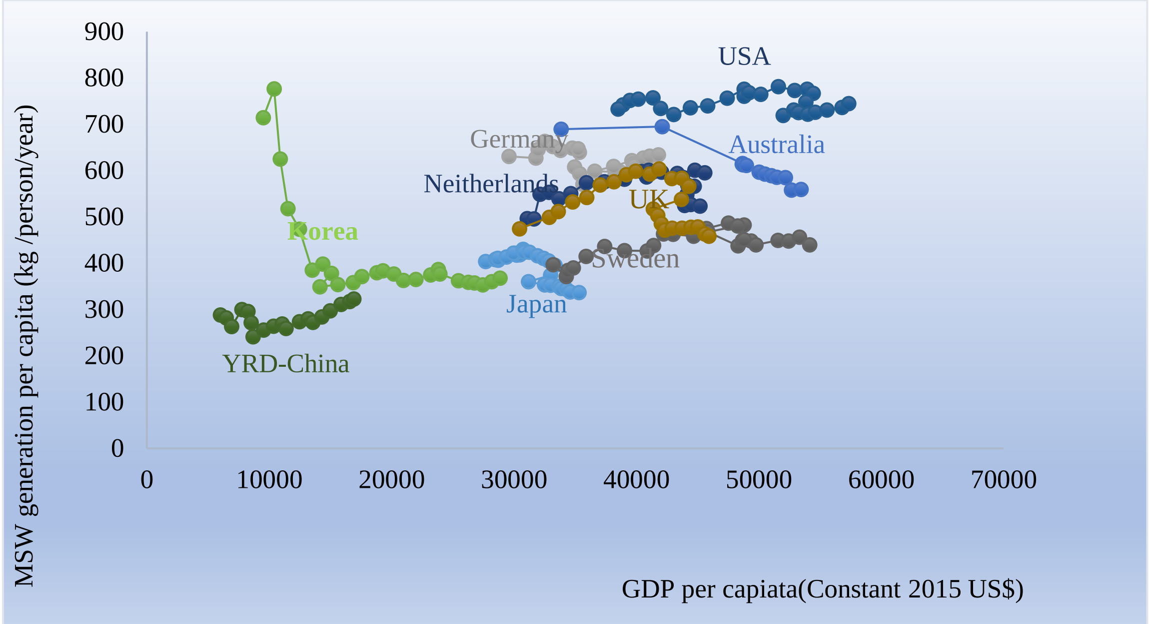
a)



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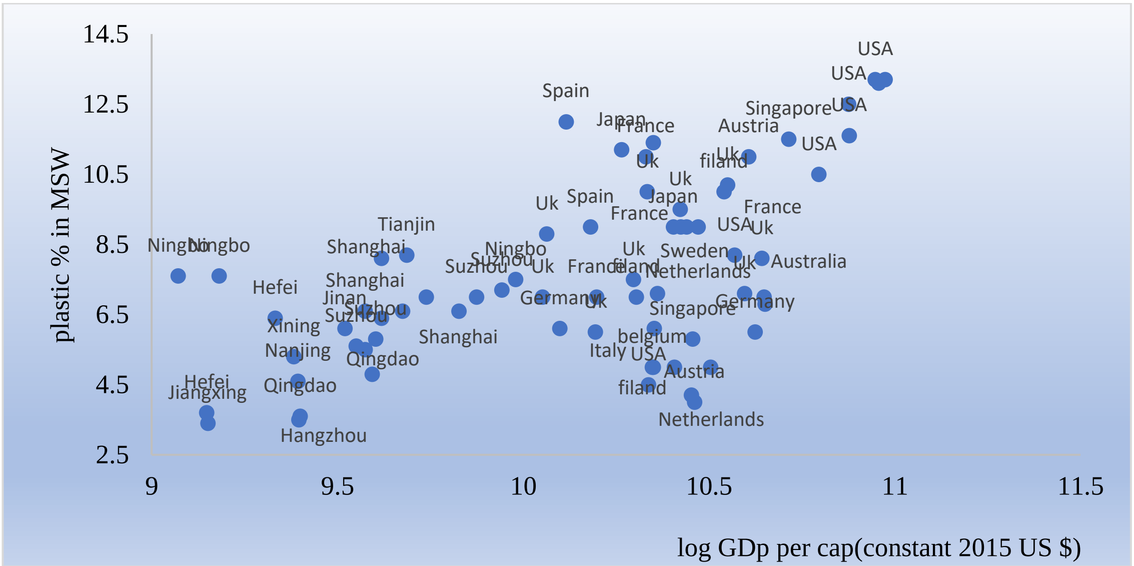

Figure3: (a) The relation between per capita municipal solid waste (MSW) generation and per capita GDP. Source for per capita MSW[44], data for per capita GDP[45] (b) % of Plastic waste in MSW, and per capita GDP in countries and cities of China.

An increase in GDP per capita improves the standard of living, income levels, and existing infrastructure. The developing world like YRD cities is far from hitting its asymptotic height (caring capacity), posing a challenge to the model's reasonable statistical fitting. Statistical fits only the plastic % may not give a reasonable result. A significant model assumption here is that MSW output scales with GDP within a country per capita. Because Modeling the total per capita MSW can give information to the MPW generation. We computed the two datasets to quantify the per capita MPW derived. The GDP dataset of all urban countries and cities allows the estimation of GDP per capita at the city /prefectural cities of China. The mass of plastic wastes (in tonnes per year) is calculated as follows

Municipal plastic waste=per capita MPW generated * plastic %* population

Estimate of historic Municipal plastic waste generation (2000-2018) in YRD

It is estimated that the municipal plastic waste per cap in YRD has increased from 12.0 kg/(cap. a) in 2000 to 27.3 kg/(cap. a) in 2018. Across the region (population of 1.192 million in 41 cities and 4 provinces), approximately 33.54 Mt MPW were produced between 2000 and 2018. The MSW generated in the region was estimated to be 481.7 Mt. The plastic waste increased by nearly 5.7% times from 2000 to 2018 while overall MSW has only increased by 3.9% times. Figure 4 shows the changes in per capita MPW generated and per capita GDP in the YRD economic zone, which indicates that plastic waste has steadily increased from 2000 to 2018.

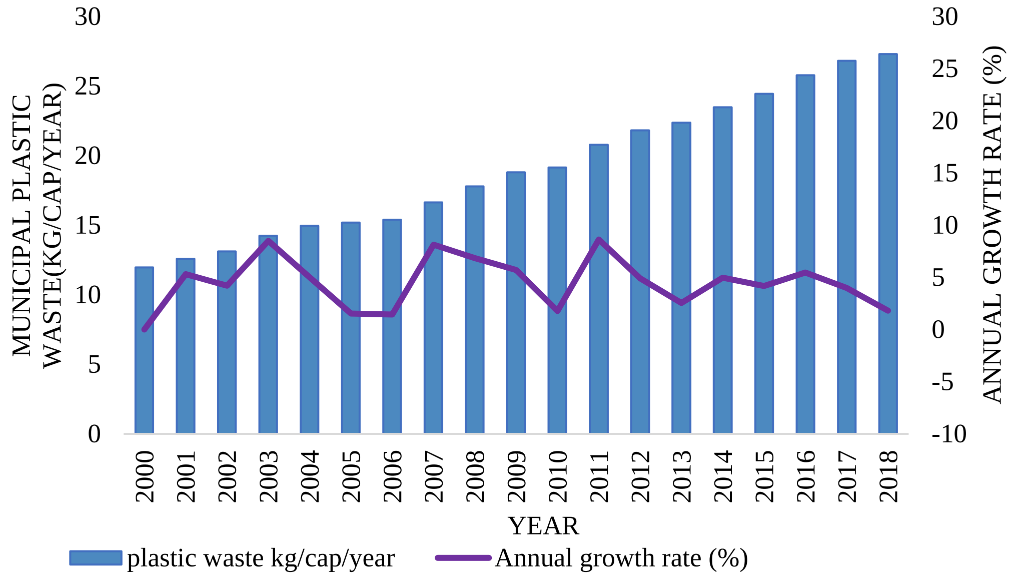

Figure 4: The estimated amount and growth rate of YRD Municipal plastic waste per capita generation, 2000-2018.

Many industrialized and prosperous nations have developed programs for resource recovery (e.g. recycling) to attempt to detach their continued rise in living standards with a related increase in the generation of MSW. Notably, in YRD, the annual growth rate (AGR) of MPW was 23.2% in 2000, the fastest growth rate in recent years, but the growth rate in 2018 dropped to 4.3%. The Chinese government has formulated many policies and practices to encourage the implementation of the MSW recycling system, such as the pilot program for urban waste recycling[49-51] and regulations[52, 53]. Shanghai City has recently led China into a new era of urban recycling, as on July 1, 2019, it launched China's first urban legislation on household waste sorting and recycling[54]. In such circumstances, the implementation of an appropriate recycling system plays a key role in supporting the management of municipal solid waste in the early phase of MSW recycling. Incineration is also becoming favorable due to its well-recognized properties in reducing the quantity of waste and enhance energy recovery in YRD-China (figure 9). In the eastern provinces, several prefectural towns, such as Jiangsu, Zhejiang, and Shanghai , have at least one incineration facility[55]. However, despite the large fluctuations in the growth rate of per capita plastic waste from 2000 to 2018, it has been increasing, with a compound average growth rate of 10%.

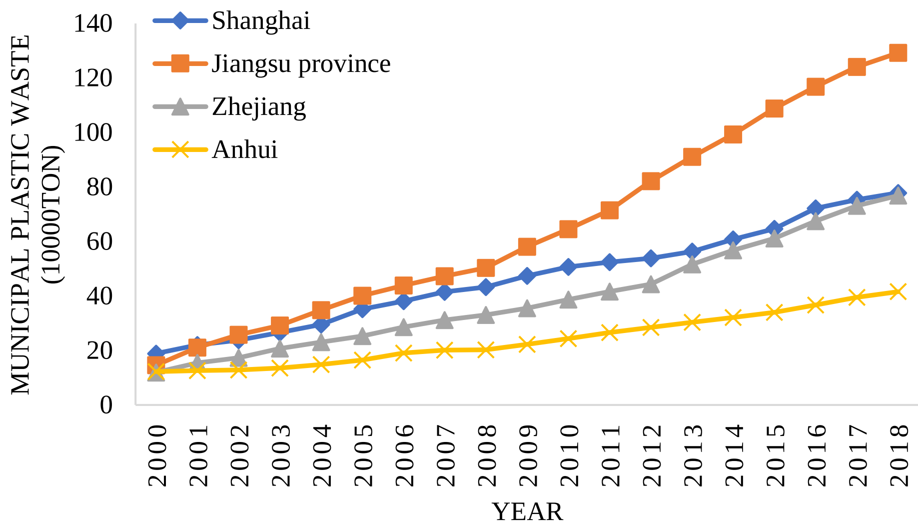

Figure 5: MPW generation in the provinces of YRD during 2000-2018.

In terms of geographical distribution, the production of MPW differs among provinces. To explore the Spatial distribution of municipal plastic waste in the YRD economic region, we use ArcGIS 10.7 to classify the generation variation of the 41 prefectural cities 2000 -2018.

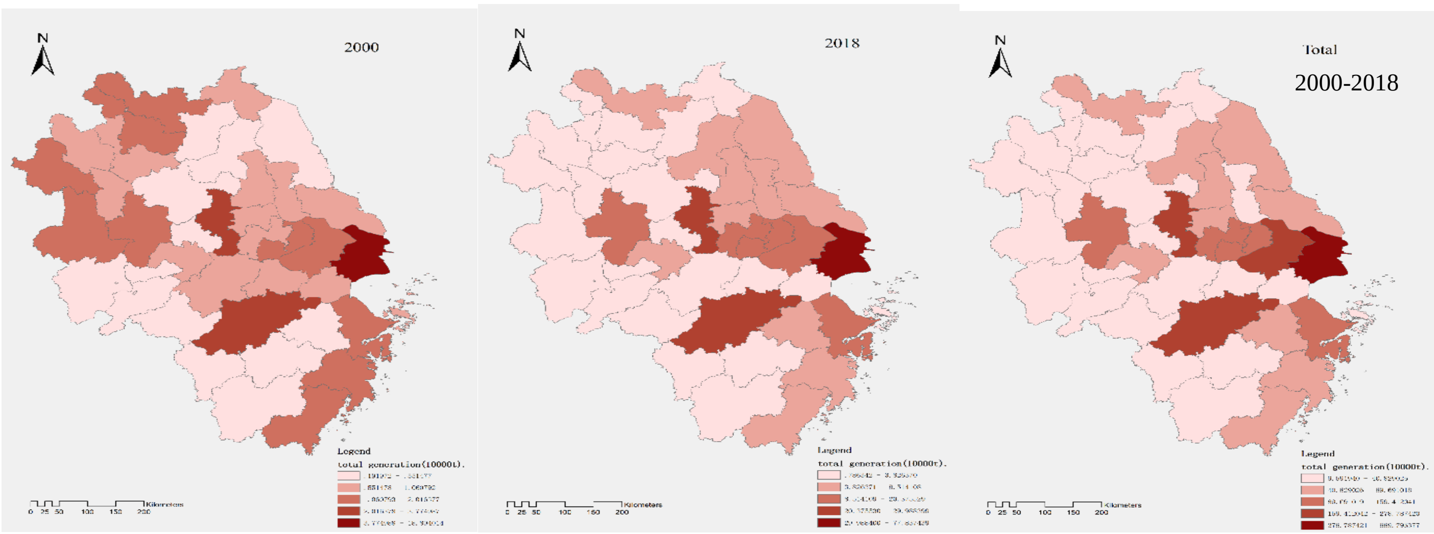

Figure 6: Spatial distribution of the total generation of municipal plastic waste in Yangtze River Delta, China.

The production of MSW in Shanghai, Jiangsu, and Zhejiang Provinces has been high. In 2010, MSW generation in Jiangsu Province became the second-largest waste generator in the country. As figure 6 and 7 illustrated, there is a major variation in the total and per capita MPW generation across the four provinces of the YRD region. The Jiangsu province generates much more MPW (12.52 Mt, 35.8%) than the other and followed by Shanghai (8.9 Mt, 25%), Zhejiang (7.54 Mt, 22%), and Anhui (4.6 Mt,17.2%) provinces. The MPW generated in all provinces mainly concentrated in certain economically developed cities. In Jiangsu province from the 13 cities included in this study, 61.6 % of the total quantity was generated from Nanjing, Wuxi, Changzhou, Suzhou cities. The plastic waste generated in Zhejiang province is dominated by Hangzhou, Ningbo, and Wenzhou cities accounting for 66.5% of the MPW of the province. On the other hand, the Anhui province which produces lower MPW comparatively than other provinces, cities like Hefei, Wuhu, Maanshan, and Fuyang produce relatively higher than the other cities. These cities discussed above in all provinces make up about 71% of the total MPW generation across the YRD

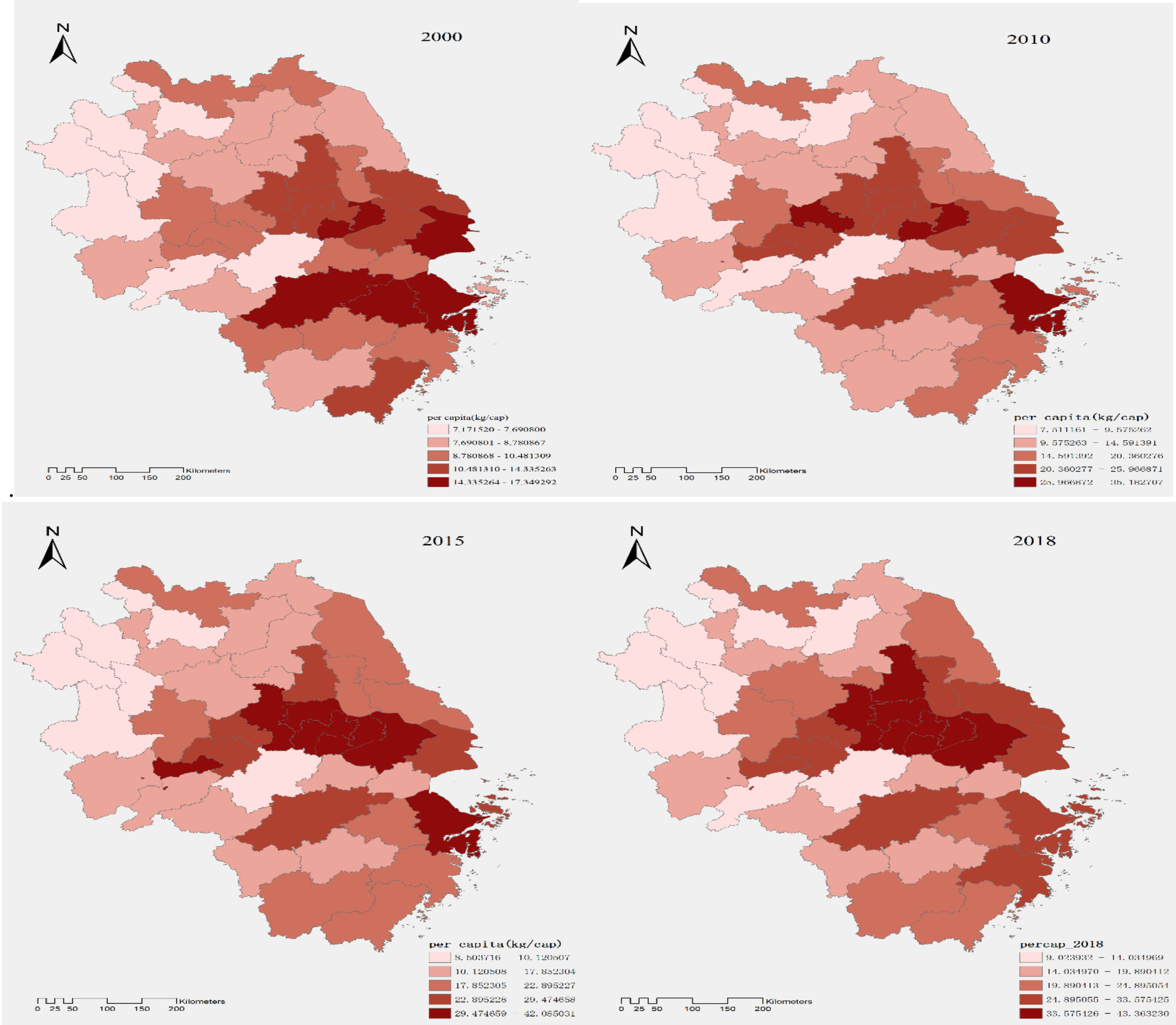

Figure 7: Spatial distribution of the per capita municipal plastic waste in Yangtze River Delta, China.

DISCUSSION

Plastic production is followed by high energy (resource) consumption and waste generation. The rise in plastic production in China has been guided by the high demand and economic growth. Starting in the late1970s, a landmark in economic change and opening-up improved the living conditions of hundreds of millions of people from China and expanded the consumption of plastic per capita. Nonetheless, the packaging industry has been the largest application in plastic use and the main source of plastic waste after use accounting for over 50% of the total waste flows. A significant proportion (70%) of MSW plastics are packaging materials, but household products (toys, recreational, and sports goods) or small electronic wastes are often discarded by households. An increase in GDP per capita improves the standard of living, income levels, and existing infrastructure, it results in more plastic waste per capita up to a certain level and then is typically followed by a decline. There are two opposing factors in the estimation of generation rates. First, it is believed that countries increase their waste generation with increasing affluence. Second, changes in technological innovations and consumption behavior (and perhaps commodity prices) are assumed to reduce the level of waste at a specific level of affluence over time. The trends are supported by observations in the UK[56] and OECD countries' waste per capita rates[57]. The WKC has evolved in the same way as the EKC identifying a trend where initial rises of GDP are directly associated with increases in pollution or environmental degradation. As sustained rises in the economy led to a decrease in environmental degradation, the transformation is gradually taking place.

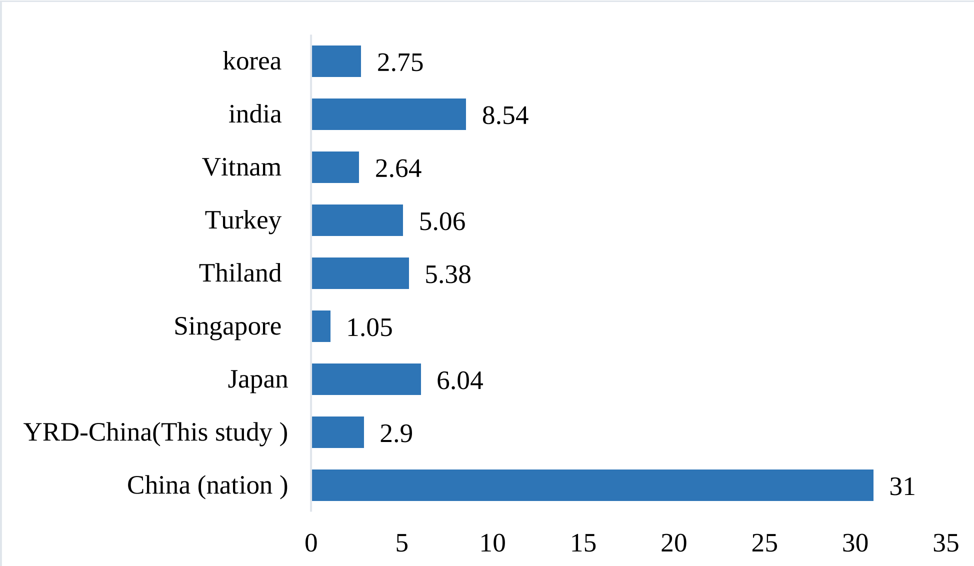

Figure 8: Municipal Plastic waste generation of different countries in (Mt) in 2016; Source[17].

The total waste generated by YRD cities in 2017 is almost 10% of the total generation of the country. Compared to other developing countries, the relatively low per capita usage of plastic waste combined with high population growth can still produce a significant quantity of plastic waste in these populated cities. China's MSW is predominantly handled in four types of waste management ways: simplified landfill, composting, sanitation, and incineration [58]. Landfill in YRD accounted for 30.3% of MSW treatment but it showed a significant decline in percentage over the past decades. The municipal plastic treatment ratio is assumed similar to the treatment ratio of MSW in different literature [59]. With more widely application of waste incineration technology, the proportion of MSW incineration has increased to 70% as of 2018. The plastic waste collection rate in China is around 33% of plastic waste, including imports and subtraction of exported plastic waste [17]. The plastic incineration climbed to 67% in YRD, which is significantly higher than in other regions of the country. Plastic waste was eventually recycled as secondary material or incinerated, consequently, the untreated plastic waste decreased. Some research studies[60] have paid attention to and have been discussed the informal method of recycling, for example, in Jakarta, Indonesia, the rate of recycled plastic was calculated by material flow analysis to be 24% [61]. In many countries, including China, the plastic waste at MSW depends largely on informal recycling methods for processing[62]. To enhance the management of plastic waste, information on the state of current plastic waste management should be obtained and innovative lifestyle improvements should be considered with economic growth. Food delivery plastic waste is expected to grow in urban areas because food delivery businesses are growing fast in major cities in China[63]. It is therefore vital that additional initiatives are introduced to complement the current emphasis on waste reduction and recycling, especially recycling measures to turn waste to a resource

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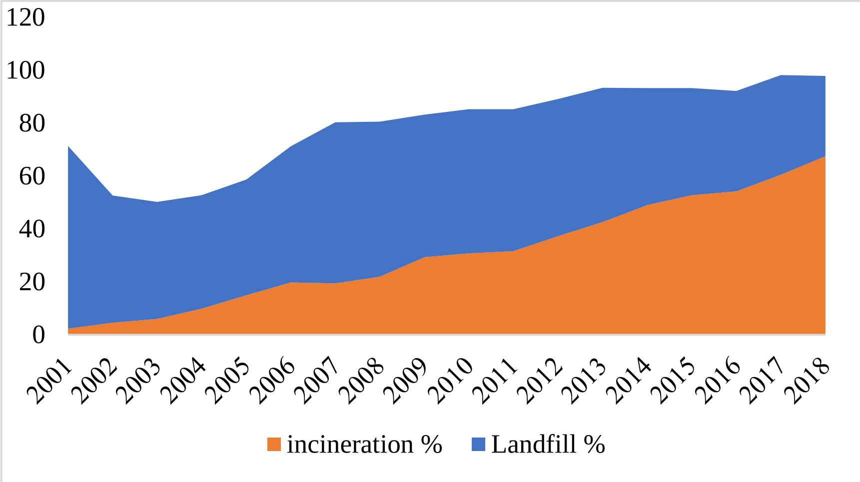

Figure 9: MSW treatment (typically landfill and incineration) in the provinces of YRD.

The EU (European Union) introduced a program that aimed at recycling all plastic packaging by 2030 and to ensure the return of plastic waste generated on ships to the ground in 2018(World Bank Group, 2018). (World Bank Group, 2018). Many cities have succeeded in managing plastic waste with enough primary MSW systems. For example, in San Francisco, the USA implemented plastic bag restrictions on the local coastline and achieved a 72% decrease in plastic waste from 2010 to 2017. Kawasaki (Japan city) has strengthened its industrial processes by adding 565,000 tonnes of waste to benefit annually which is more than half the urban waste of that city currently manages. The exchange and reuse of diversified materials within its core sector (plastics as an alternative reductant) and through the development of new enterprise units (dismantling of household items, replacement of fluorescent bulbs and plastic bags) in its environmental group company [64]. Currently, the eastern economy in China contributed economic output largest among the other regions. MSW is significantly Correlated to GDP. However, the per capita MSW in China is far below the saturation level in the developed countries which has started to decline. Thus, it will likely increase with economic growth for a long time. Thus, MSW and MPW will likely increase with economic growth for a long time. In China, the administrative units responsible for their MSW management are cities at or above the prefecture-level. By organizing the enhancement of MSW governance and driving variables such as economic growth, urbanization, technological change, and construction of the environment in each region, MSW can resolve the pressure triggered by factors like economic structure, construction of infrastructure, and public facilities and eventually realize the decoupling between urbanization and MSW generation.

V. CONCLUSIONS

Economic development is one of the main driving forces in MSW generation. plastic fraction found in municipal solid waste showed an increasing trend over the past years in China. This study estimated that the municipal plastic waste per cap in the Yangtze River Delta of China has increased from 11.96 kg/(cap. a) in 2000 to 27.3 kg/(cap. a) in 2018 with a compound average growth rate of 10%. The spatial distribution of results showed that the MPW generated in all provinces mainly concentrated in certain economically developed and populous cities. In 2017, the total municipal plastic waste generated by YRD accounted for almost 10% of the total generation of the country. The overall generation of plastic waste shows an increasing trend based on the estimation and will likely increase in the future based on searched works of literature in which the way MPW grew in developed countries. The cities of Shanghai, Nanjing, Wuxi, Changzhou, and Suzhou (Jiangsu province), Hangzhou, Ningbo, and Wenzhou (Zhejiang province) Hefei Wuhu, Maanshan, and Fuyang (Anhui province) makes up about 71% of the total MPW generation. The promotion of China's ban on packaging plastic waste and urban waste recycling pilot zone played a role in reducing the growth rate(annual) of plastic waste generation even if there is fluctuation. However, plastic waste still increases, and due to the low level of recycling technology, this waste is mainly treated by landfilling and incineration methods. The threat to the environment is still significant. To better promote the management of municipal plastic waste, according to the above research conclusions, the following suggestions are proposed. the Chinese government should formulate new policies to promote recycling and utilization of plastic waste. It is suggested to strengthen the governance and control of packaging plastic waste concentrating in key economic regions like YRD. Second, increasing investments in recycling technology and recycling methods, increasing support for related enterprises, improving the capacity for resource recycling and waste treating alleviating resource shortages, and reducing the environmental pollution caused by the accumulation of MPW and unrecycled waste.

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AUTHORS

First Author – **Marta Sibhat**, Master candidate, Tongji University, UNEP-Tongji Institute of Environment for Sustainable Development (IESD) and College of Environmental Science and Engineering; Email: martasibhat20@gmail.com; Tel.: +8613162400527 Address: 1239 Siping Road, Shanghai 200092, China.

Second Author –**Jianfu Zhao,** Mentor and supervisor, Tongji University, UNEP-Tongji Institute of Environment for Sustainable Development (IESD) and College of Environmental science and Engineering; Email: zhaojianfu@tongji.edu.cn; Tel.: +86 (21) 55054913; Address: 1239 Siping Road, Shanghai 200092, China.

Third Author – **Sha Lu,** Researcher, Tongji University, Circular Economy Research Institute, Marxism Faculty; Email: lusha_666@hotmail.com; Tel.: +86 18516608033; Address: 1239 Siping Road, Shanghai 200092, China.

Fourth Author – **Huanzheng Du,** Professor, Tongji University, UNEP-Tongji Institute of Environment for Sustainable Development (IESD); Director of the Circular Economy Research Institute, Marxism Faculty; Email: duhuanzheng@tongji.edu.cn; Tel.: +86 (21) 65981386; Address: 1239 Siping

Road, Shanghai 200092, China.
Fifth Author –**Tao Wang,** Mentor and supervisor**,** Tongji University, UNEP-Tongji Institute of Environment for Sustainable Development (IESD) and College of Environmental Science and Engineering; Email: a.t.wang@foxmail.com; Tel: +86 21 55088683; Address: 1239 Siping Road, Shanghai 200092, China.
Correspondence Author – **Tao Wang**, email address: a.t.wang@foxmail.com; Tel: +86 21 55088683; Address: 1239 Siping Road, Shanghai 200092, China.