QUBAHAN ACADEMIC JOURNAL
**Publication Date:** 29 Jan 2024
https://doi.org/10.58429/qaj.v4n1a200

# Integrated Recycling and The Impact of Plastic Waste from Industry and Agriculture on The Environment

**Anar Zhumadilova [1]*, Saule Zhigitova [2], Maira Turalina [2], Kuralay Aitekova [3]**
[1] Department of Ecology, M.Kh. Dulaty Taraz Regional University, 080000, 7 Suleymenov Str., Taraz, Republic of Kazakhstan;
[2] Institute of Water Management, Ecology and Construction, M.Kh. Dulaty Taraz Regional University, 080000, 7 Suleymenov Str., Taraz, Republic of Kazakhstan;
[3] Department of Biology and Agricultural Specialties, International Taraz Innovative Institute named after Sh. Murtaza, 080000, 69B Zheltoksan Str., Taraz, Republic of Kazakhstan;

**Corresponding author:** (e-mail: anarzhumadilova9@gmail.com).

**ABSTRACT** The production, use, and waste generation of plastic products is steadily increasing worldwide, and therefore it is necessary to minimize their impact on the environment, as they are a considerable source of pollution and have a substantial impact on climate change. Plastic waste prevention and control is a vital component of China's national strategy. The purpose of this study is to analyse various scenarios for predicting the impact of plastic waste from industry and agriculture on the environment in the period from 2019 to 2030. Three scenarios have been developed (the scenario of following the national policy of plastic waste management – NP, the scenario of increasing the recycling rate by 20% – RR, and the scenario of banning the incineration of plastic waste suitable for secondary use – IB). The analysis was carried out using a plastic waste management flow model, which calculates environmental indicators for each scenario. The main indicator used in the model was greenhouse gas emissions. It is established that due to the implementation of existing and proposed targets, greenhouse gas emissions will be reduced compared to the BAU scenario by 6.274 Mt CO2e for NP, by 11.523 Mt CO2e for RR and by 12.498 Mt CO2e for IB. A comparative analysis of scenarios with a discussion of their strengths and weaknesses was conducted, existing problems were considered and recommendations for possible solutions were provided. The preference for the RR scenario was reasoned. The results obtained can not only serve as an information source for scientific research, but also help practitioners solve the problem of plastic waste management in an environmentally safe and economical way.

**Keywords:** Climate Change, Waste Management Policy, Pollution, Greenhouse Gases, Environmentally Safe.

## I. INTRODUCTION

Plastic is a unique material with many advantages: it is cheap, versatile, lightweight, and durable. This makes it a valuable material not only for industries and agriculture, but also for use in everyday life. However, despite the numerous advantages of plastic, its production and use cause many environmental problems. Traditionally, plastics production is based on fossil fuels and uses crude oil and natural gas as raw materials, and a biological-based alternative has only recently been used for commercial purposes [1]. Fossil-based resources are limited and adversely affect the environment in all processes of extraction, production, and use [2]. Moreover, improper waste management methods that cannot prevent plastic from leaking into the environment usually lead to the dispersion of the material in the form of rubbish. Plastic waste is slowly but surely damaging the environment in many ways, from leaching toxic chemicals into soil and groundwater, to directly asphyxiating or poisoning animals that unwittingly ingest it [3; 4]. On the other hand, plastics can be recycled repeatedly, while maintaining their value and functional properties, which means that by increasing the level of plastics processing, a considerable share of adverse environmental impacts can be avoided. Since 1950, over than 8 billion tonnes of plastic have been produced in the world, most of which ends up directly in landfills and only about 9% is recycled [5]. According to the Organization for Economic Cooperation and Development, 69% of plastic waste is incinerated or disposed of, and 22% does not enter the waste management system (Figure 1).

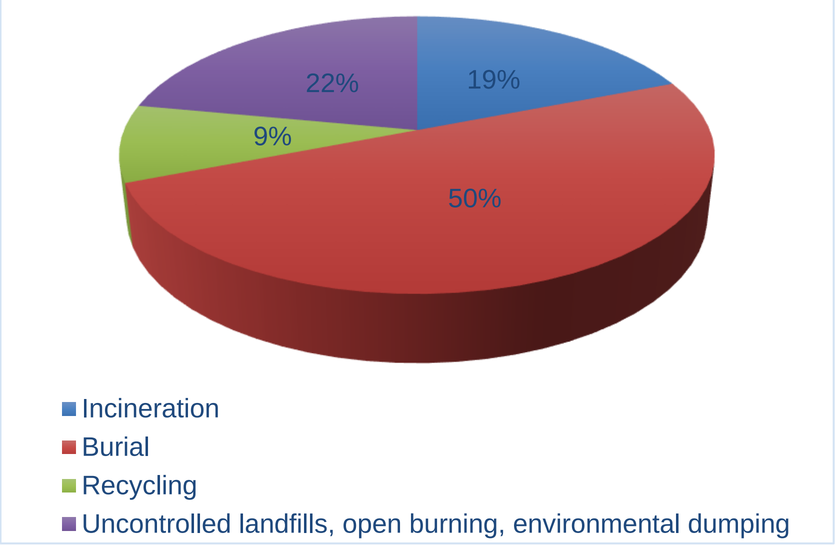


FIGURE 1. Recycling of plastic waste in the world.
Source: compiled by the authors based on [6].

From 2000 to 2019, global plastics production doubled and reached 460 million tonnes. The COVID-19 crisis led to a 2.2% reduction in plastic use in 2020 as economic activity slowed, but an increase in the amount of rubbish, takeaway food packaging and plastic medical equipment, such as masks, led to an increase in the amount of waste. With the resumption of economic activity in 2021, plastic consumption has also recovered [7; 8].

The purpose of this study was to analyse and evaluate various scenarios for predicting the impact of plastic waste from industry and agriculture on the environment in the future.

## II. LITERATURE REVIEW

Currently, China is the largest plastic producer in the world. In 2019, the production of plastic products amounted to about 80 million tonnes. However, massive consumption also leads to a massive amount of plastic waste. Since 2017, the country has stopped importing plastic waste, which began in the early 1980s to develop the processing industry to produce valuable raw materials for Chinese manufacturers. For almost 40 years, China has accounted for over 60% of the global trade in plastic waste. In 2018, a ban on the import of waste ("Ban on Waste") and aid in reforming the solid waste import management system were put into effect [7]. Thus, if before 2017 China imported a total of 170 million tonnes of plastic waste, then after the ban, imports decreased to 5.8291 million tonnes in 2017, to 70 thousand tonnes in 2018 and to zero in 2019 [9].

Although China no longer imports plastic, the amount of plastic waste in 2019 amounted to over 60 million tonnes, some of which are subject to burial, incineration, and recycling, and some (about 7%) is released into the environment [10]. The amount of recycled plastic waste was 18.9 million tonnes, which is about twice as much as in the EU or seven times more than in the USA. However, despite the impressive amount, the recycling rate is only 30%. Therefore, considering that currently the market demand for recycled plastic particles made from plastic waste is growing worldwide, China imports about 3.5 million tonnes of recycled plastic particles [9]. Recently, China has issued and implemented some policies and regulations to combat plastic pollution [11, 12]. They are primarily characterized by orderly management of plastic pollution by region, time intervals, and industries. These documents mark a new phase of stricter plastic pollution control in China, followed by supportive particular policies and programs.

Most current research on China's potential to reduce plastic waste production focuses on the impact of the country's import ban on international trade in plastic waste [13-15]. Some studies are aimed at analysing the current issues in the field of waste management, forecasting future emissions of plastic waste, assessing the impact of recycling methods [16, 17]. Studies aimed at assessing the impact of industrial and/or agricultural plastic waste on the environment are rare [18, 19].

## III. MATERIAL AND METHOD

A quantitative assessment of the environmental impact of plastic waste was carried out using a model of plastic waste management flows [20]. The model describes various parameters and criteria that affect the amount of recycled plastic waste, as well as the associated costs and labour required for various specific scenarios. The construction of the model was simple, without excessive complication, factoring in the specifics of the distribution of plastic waste streams in China. The export and import of plastic waste were not considered. The assessment was conducted along the entire recycling chain, the scheme of which is presented in Figure 2.

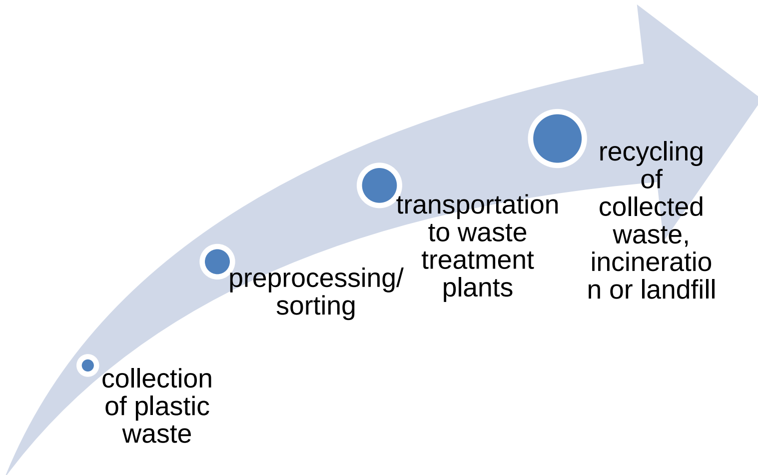


FIGURE 2. Stages of plastic waste disposal

The simulation results allow estimating the environmental impact, but they should be considered with caution, since the quality and reliability of the results linearly depend on the quality of the data sources. Some direct statistical data are either missing altogether or vary substantially depending on the source [9; 21, 22]. Given this fact, some data in the model had a certain correlation, which leads to a certain decrease in the reliability of the results. Furthermore, due to problems with the confidentiality of companies, as well as due to some difficulties associated with obtaining timely responses from the subjects with whom they communicated, some data were not received, and statistical averages taken from the reports of The Plastic Recycling Association of the CRRA [23] were used for the model. Some initial assumptions are related to forecasts for the future, which means that there is a certain degree of uncertainty and unpredictability. The model is filled with key data, including the amount of incoming waste, its distribution by streams and data on greenhouse gas emissions. Data for use in the model were collected from online literature sources, as well as from interviews with experts through telephone calls and emails sent to the relevant waste management authorities and organizations. Four main sectors were selected as modelled flows: the agricultural sector (AC), which occupies 1%; the sector of end-of-life vehicles (ELV, 5%), the sector of waste from electrical and electronic equipment (so-called e-waste, WEEE, 7%), as well as the manufacturing sector, which includes manufacturers from various industries, including construction, textile, chemical, and other industries (63%). The description of plastic waste from these sectors is presented in Figure3.

https://doi.org/10.58429/qaj.v4n1a200

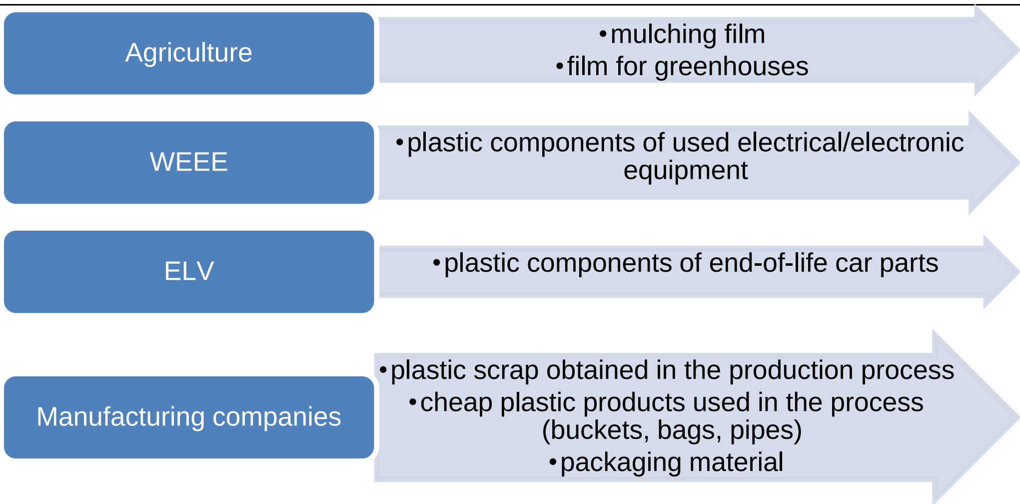


FIGURE 3. Identification of the main plastic waste by sectors

The remaining 24% of the total amount of waste falls on the municipal and household sector, but they were not considered in the model, since the purpose of this study was to assess the impact of industrial and agricultural waste. For the baseline scenario, data for 2019 were taken [24]. To calculate the future formation of plastic waste and build scenarios, the forecast was made based on the current situation with certain assumptions based on a literature review and consultations with specialists. The annual increase in waste production for the period up to 2030 is set at 5.01% [22]. WEEE growth is set at 4.5%, given that in 2019 it was 3.17% [18], and this sector is developing rapidly. No significant increase in the amount of agricultural plastic waste is expected in the future, but the volume of waste collected will certainly increase. The growth rate of 1.5% is set for calculations. For the remaining categories, the annual growth estimate is set at 3.5%. The annual growth rates of all waste streams used in the model are quite conservative and demonstrate slower growth compared to a rather optimistic approach in the development of the Chinese plastic recycling market. The growth forecasts in the model factor in the consequences of the recent economic downturn caused by the COVID-19 outbreak, which ultimately affected the development of a closed-loop economy, and which will affect all sectors of industry and agriculture in the medium term [25]. The distribution of the amount of plastic waste by sector is presented in Table 1.

**Table 1.** Amount of plastic waste by sector (in million tonnes)

| The sector producing plastic waste | Amount of plastic waste (2019) | Annual growth | Amount of plastic waste (2030) |
|---|---|---|---|
| AC | 0.189 | 1.5 | 0.222 |
| WEEE | 1.323 | 4.5 | 2.147 |
| ELV | 0.945 | 3.5 | 1.38 |
| Manufacturing companies | 11.91 | 3.5 | 17.388 |
| Total | 14.367* | - | 21.137 |

Note: * – the total amount of plastic waste from industry and agriculture, excluding the municipal sector.

## IV. DATA ANALYSIS

This section presents the results obtained from the analysis of various scenarios for the processing of plastic waste, examines their potential impact on the environment, conducts a comparative analysis to identify existing problems and provides recommendations for possible solutions to these problems. Three target scenarios have been developed to estimate the potential impact of integrated recycling of plastic waste on the environment. The business-as-usual (BAU) scenario will not be analysed, since there are no substantial changes, except for the amount of plastic waste generated, but it will be used to compare the corresponding benefits of the other three scenarios. Scenario analysis does not predict the future, it is simply a tool for investigating and comparing various future possible solutions for the existing problem [26]. Furthermore, it helps reduce the potential overestimation and underestimation of future developments. The target scenarios are as follows:

1. The scenario of following the national policy (NP) of plastic waste management. This scenario represents the minimum necessary efforts of all stakeholders involved in waste management and plastic recycling operations to meet the legally binding goals set out in government directives and regulations by 2030 [27, 28]. In the absence of a mandatory recycling goal, the scenario defines minimum goals based on industry voluntary agreements and/or best practices, which makes these goals feasible and acceptable.
2. The scenario of increasing the recycling rate (RR) of plastic waste. This scenario assumes the performance of all the conditions of the NP scenario, with more actions to increase the collection and recycling of plastic waste by 20% compared to the baseline scenario. The Renewable Resource Recovery System is the main recycling route for plastic waste and includes plastic waste recycling and processing systems. Presently, small companies are being replaced by large ones, and the entire industry is growing in size and becoming increasingly standardized [9]. Local plastic waste disposal and management systems are still imperfect, which does not allow large recycling enterprises to receive sufficient amounts of plastic waste. An increase in the supply of plastic waste to processors will eventually lead to savings due to an increase in the volume of their processing. An increase in the amount of recycled plastic, combined with an improvement in quality, will help stimulate demand for the recycled product, which will further contribute to stable supplies and uniformity of input raw materials.
3. The scenario of incineration ban (IB) of recyclable plastic waste. In addition to the conditions of the NP scenario, a ban on the incineration of plastic waste suitable for recycling is assumed. Similar to the RR scenario, this option aims to increase the supply of plastic waste to processors and, thus, to improve their activities and increase productivity. The scenario assumes that plastic waste that is suitable for recycling is not allowed to be sent to incinerators. Only plastic waste that has been discarded from sorting and/or recycling operations can be sent for incineration.

Plastic waste recycling is a strategic developing industry with great development potential. In recent years, the construction of plastic waste recycling systems has been actively promoted in China. Relying on China's three main industry associations, namely the Plastics Recycling Association, the China Synthetic Resin Manufacturing Association and the China Materials Recycling Association, many large retail markets and recycling centres for recycled plastics have been established, and 25 industrial parks for the renewable resource-circular economy have been established, including 21 plastic waste recycling parks [16].

Statistics show that in 2019, the recycling volume of household plastic waste was 1.89*107 tonnes. The recycling rate was close to 30%, and the total economic value of recycling was over 100 billion yuan. There are over 3000 registered enterprises in China recycling plastic waste, of which 300 enterprises have a processing capacity of more than 1*104 t/year and 50 enterprises have a processing capacity of more than 5*104 t/year [29]. It is assumed that the significantly increased amount of plastic waste as a result of the incineration ban will provoke a high interest in the construction of infrastructure within the country. The rejection of imported plastic waste has led to a shortage in the domestic market, and the average price of most plastic waste has increased by 6-16% compared to 2017 [30]. In this regard, the consumption of primary plastic has increased. This scenario is being considered in connection with the strategic vision of the Chinese government to minimize CO2 emissions by 2060 [31]. In July 2021, a nationwide program was launched, which replaced previous regional pilot programs and is expected to provide about half of the reduction of CO2 emissions in China by 2060. This goal is part of the policy of "ecological civilization" [32].

Developing an effective global strategy requires understanding the potential of various mitigation solutions and the scale of global efforts needed to significantly reduce plastic pollution. The scenarios presented in the literature are mainly aimed at predicting the amount of expected plastic waste. For instance, the paper predicts the trends in the formation and costs of plastic waste management in China from 2020 to 2035 under three different scenarios in which China is divided into three regions for particular political consequences [33]. To estimate the effectiveness of actions to reduce plastic pollution, flows of solid household waste and four sources of microplastics were modelled for five scenarios in the period from 2016 to 2040 [34]. Several ways of recycling plastic household waste and their environmental impact are compared in [35]. Scenarios for changing plastic waste treatment schemes have been developed to predict their impact on the environment in the future. Furthermore, alternative improvement scenarios were proposed to analyse the potential reduction of the environmental impact due to energy conservation, emission reduction and a ban on the import of plastic waste for mechanical processing.

The analysis of the literature conducted during this study did not reveal scenarios that would consider the impact of the integrated processing of plastic waste from industry and agriculture on the environment in China. At the same time, theoretical analysis, and practices of using plastic waste management flow models allowed creating the above scenarios for quantifying the impact of plastic waste on the environment [20]. Recycling is considered the most profitable waste management option after preparation for reuse and prevention of waste generation [36]. The environmental benefits of plastics recycling compared to alternative management options have been extensively investigated in numerous papers and include, among others, reduction of energy consumption, greenhouse gas emissions, depletion of land resources and land use, and particulate emissions.

To estimate the impact of integrated recycling of plastic waste on the environment, an indicator of greenhouse gas (GHG) emissions was chosen, since they are the main cause of the increase in environmental pollution. Furthermore, GHGs are the driving force behind climate change, an urgent problem that the entire world community is trying to solve today [32; 37]. The plastics industry handles 3.4% of global greenhouse gas emissions, according to the OECD. Recycling plastic instead of producing it from scratch indirectly reduces emissions of dangerous greenhouse gases. On the one hand, operations along the entire plastic waste recycling chain require energy consumption in the form of fuel, electricity from the grid and thermal energy, which contributes to GHG emissions, as well as depletion of fossil resources. On the other hand, materials recovered from recycling provide environmental benefits by avoiding virgin plastic production and associated impacts [20; 38, 39]. Figure 4 presents the results of comparing scenarios for reducing greenhouse gas emissions calculated according to the model.

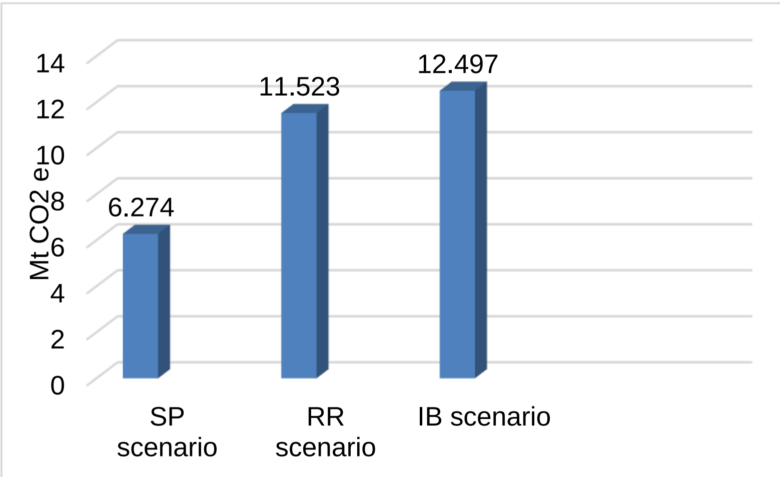


FIGURE 4. Reduction of greenhouse gas emissions according to different scenarios compared to the BAU scenario

As can be seen, the smallest reduction in GHG emissions compared to the BAU scenario is observed for the NP scenario (by 6.274 Mt (Mt CO2e)). Such a scenario illustrates rather modest environmental benefits. This is most likely because most of the laws and directives adopted by the Chinese government relate to the collection, sorting, and recycling of municipal waste, which is a considerable amount, but was not considered in this model. As for industrial and agricultural waste, part of the projected reduction in GHG emissions is related to the main goals of the government at the current legislative level, namely increasing the collection rate of agricultural plastic film to 85%, as well as holding production and sale of polyethylene agricultural film with a thickness of less than 0.01 mm, and packaging polyethylene film used to cover agricultural land [40-43]. The data obtained are fully consistent with the general trend of reducing the amount of plastic waste presented in the studies of other authors, as a result of following the national policy of plastic waste management [16; 33, 34].

More environmentally beneficial are the RR and IB scenarios, with projected emission reductions of 11.523 Mt CO2e and 12.498 Mt CO2e compared to BAU, respectively. The RR scenario reflects an increase in the level of processing by 20% compared to the base scenario of 2019 when all the conditions of the NP scenario are met. However, the implementation of such a scenario requires much more concentrated efforts, not only in terms of waste management options and policy decisions, but also in the development of technologies and logistics optimization [44, 45]. There are several issues, for instance, in the agricultural sector, where it is difficult to increase the level of processing due to the large amount of impurities in the collected waste due to the high initial investment. Any advances in the collection, sorting, and recycling processes are meaningless if there is no demand for recycled plastics [46]. It is vital to increase the demand for recycled plastics in the market and increase the number of recycled plastics that are used to produce new goods. M. Hestin et al. [20] propose to introduce certain measures (e.g., tax incentives for products with recycled content) that will create stable market conditions for recycled plastics and allow recyclers to invest in capacity and innovative technologies to increase plastics recycling. Ultimately, there needs to be a balance between the supply of plastic waste and the demand for recycled plastics to ensure a healthy and sustainable recycling sector that can make the maximum contribution to achieving elevated goals and creating a truly circular economy.

Investment confidence and security is needed to enable relevant participants to invest in the downstream sector. To increase confidence and reduce investment risks, government intervention (state/regional/municipal) would ideally be required by establishing public-private partnerships and ensuring the supply of plastic waste for recycling. This is a prerequisite for the reliable functioning of recycling markets and a way to increase confidence in this sector, along with an increase in demand for recycled plastics from industrial entities [47, 48]. Analogous issues and solutions, namely, increasing the level of recycling of plastic waste to reduce their adverse environmental impact, are proposed in the studies of several authors [28; 49, 50]. However, despite the scale of these flows, the effectiveness of the measures proposed to solve the problem of plastic waste recycling, and the economic costs of their implementation, require careful analysis. The study of the data presented in the literature allows stating the absence of special studies on the economic aspects of increasing the level of processing of plastic waste from industry and agriculture in China.

Scenario IB includes a ban on the incineration of recyclable plastic waste. It demonstrates the largest environmental benefit by nearly doubling greenhouse gas emissions across the entire plastic waste recycling chain (12.498 Mt CO2e for IB vs. 6.274 Mt CO2e for SP). Admittedly, the figure will be much higher if the domestic sector is included in the model, given that in 2019, 40% of municipal waste was incinerated, and their amount was about 20 million tonnes [21]. The ban on incineration of plastic waste is a way to reduce the linearity of plastic production and is considered fundamental for the transition of the entire plastics industry to a closed-loop economy [36; 51]. Considering the results of the study by Y. Chen et al. [35], who showed that 8 out of 12 environmental indicators were adversely affected by incineration, it is expected that apart from the considerable reduction in greenhouse gas emissions calculated under the IB scenario in this paper, the ban on burning will improve other indicators, e.g., the formation of small particulate matter or human exposure (carcinogenic toxicity). Confirmation or refutation of the proposed assumption requires added research.

Plastic waste is based on fossil fuels. Recycling of plastic waste, which means reducing the production of primary plastic, can considerably reduce the consumption of crude oil [2; 52]. Oil resources in China are limited, in 2019 the country imported 50.5 million tonnes of oil, and about a third of it is used for the synthesis of plastic products [53]. Making plastic from scratch requires much more energy than making products from recycled plastic. The saved energy can be used for other important needs in the economy. Moreover, due to its petroleum origin, plastic waste itself can be effectively used for energy production, since it has a high calorific value [54]. The question of the preference for recycling or incineration of plastic waste has long been urgent and controversial, requiring a compromise. On the one hand, recycled waste that does not meet standard requirements cannot be used to replace primary plastic. This means that even with a prominent level of plastic waste recycling, the greenhouse gas reduction calculated according to scenario IB will not be realized. The ability of processors to produce high-quality materials according to demand and sell them at high prices is a key aspect in the development and sustainability of the entire plastics recycling chain [55, 56]. On the other hand, the heat generated by the incineration of plastic waste will need to be replaced by another source, which is likely to be of fossil origin.

Therefore, to materialize the benefits of a higher level of recycling, as shown in the model, and therefore contribute to reducing the impact of the plastic industry on the environment as a whole, it is important to introduce high-quality recycling technology before a possible incineration ban can effectively transfer plastic waste from incineration to recycling. As China, like other countries, gradually reclaims more and more plastic waste domestically and replaces landfill or incineration with recycling, a more favourable environmental impact will be felt in the long term [16]. Thus, considering the listed problems and factoring in the insignificant difference in the reduction of GHG emissions between the RR and IB scenarios, the scenario of an increase in the level of processing of industrial and agricultural waste by 20% is the most preferable among the proposed ones.

To date, the main ways of recycling plastic waste in China are incineration and burial, and only a small part gets into the recycling system. However, the quality of recycled products is variable and does not always meet the standards [9]. Proceeding from the concept of plastic waste pollution prevention and control in the comprehensive chain, plastic product waste must be reasonably and scientifically classified before processing or recycling, which can then be treated with different methods for diverse types of plastic waste. Efficient recycling can solve the problem of environmental pollution caused by improper disposal of plastic waste, as well as ensure the reuse of materials and energy from plastic waste. Building a complete plastic waste recycling production chain and increasing the recycling rate of plastic waste can effectively promote the integrated use of plastic resources [57]. According to the characteristics of production areas, sources, and differentiation of plastic waste, it is necessary to update the localization of recycling and recycling models, as well as popularize application models. For recyclable plastic waste, priority should be given to developing environmentally friendly technologies, improving the recycling of single-component and mixed plastic waste, and developing environmentally friendly equipment to achieve low emissions and energy recovery [58, 59].

Reducing plastic pollution requires active action, not only through the development of environmentally friendly alternatives, but also through innovation and product quality improvement. Efforts are also required to improve waste management and increase the degree of recycling. The fight against plastic waste is the first step towards combating plastic pollution, and this requires strong political support [60]. Policy measures are needed to ensure that a reliable solution is found to manage plastic waste and reduce its generation. They are necessary to ensure that collection, storage, transport, and final disposal or recycling are efficient, financially sustainable, technically feasible, socially and legally acceptable and environmentally sound. In general, sustainable intervention requires a combination of solutions and strategies at diverse levels of the processing chain [61]. China's legislative action on the prevention of plastic pollution is the right action that is really needed to solve the environmental problem. Chinese laws and regulations may not be a perfect model, but the country has developed its own culturally feasible solutions. As the world's largest producer and consumer of plastic, China can become a world leader in effectively controlling domestic and international plastic pollution by stepping up significant efforts to combat plastic pollution.

## V. CONCLUSION

The paper develops and analyses three different scenarios to predict the environmental impact of industrial and agricultural plastic waste recycling in China between 2019 and 2030: the scenario of following the national policy of plastic waste management (NP); scenario of increasing the plastic waste recycling rate by 20% (RR); the scenario of banning the incineration of recyclable plastic waste (IB). An indicator of greenhouse gas emissions was selected to estimate the environmental impact. It is established that due to the implementation of existing and proposed targets, greenhouse gas emissions will be reduced compared to the BAU scenario by 6.274 Mt CO2e for NP, by 11.523 Mt CO2e for RR and by 12.498 Mt CO2e for IB. It is shown that, considering the insignificant difference in the reduction of greenhouse gas emissions between scenarios RR and IB, the scenario of increasing the level of recycling of plastic waste by 20% (RR) is the most preferable. A comparative analysis of the proposed scenarios was carried out to identify existing problems and recommendations were provided for their possible solution.

The results of this study, together with the identified problems in the Chinese plastic waste market, can serve as an information source about the current situation with plastic recycling in the country, as well as become the basis for future studies of appropriate measures needed to increase waste recycling in China and assess their impact on the environment. Furthermore, the data obtained can provide producers, processors, and the government with the information needed to develop policies in the field of effective waste management, which in the long term will allow the transition to a closed-cycle economy with low greenhouse gas emissions.

During the study, new questions and problems have arisen that require further research and solutions. To better understand and increase the efficiency of the system of processing plastic waste from industry and agriculture, an in-depth analysis of the distribution of flows by industrial sectors, their detailed analysis, as well as the proportions of processing of various types of plastics are required, since the types of waste, especially in the industrial sector, are extremely diverse. In this paper, the main part of the processing data was obtained from the literature and reports. The part of the data that was received from manufacturers and processors was not always of high quality. To create more accurate forecasts, it is necessary to take this fact into account. Further studies on the environmental impact of plastic waste should also factor in socio-economic driving factors.

## REFERENCES

1. E. Palm; and E. S. Myrin. *Mapping the plastics system and its sustainability challenges*; Lund: Lund University, 2018.
2. The new plastics economy: Rethinking the future of plastics, 2016, [online]. Available: https://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf

3. Plastic pollution by country, 2023, [online]. Available: https://worldpopulationreview.com/country-rankings/plastic-pollution-by-country
4. M. Osintseva. Assessment of soil properties in technogenically disturbed lands of Kemerovo Oblast – Kuzbass. *Qubahan Acad J* **2023**, *Volume 3*, no. 4, pp. 77-92.
5. R. Geyer; J. R. Jambeck; and K. L. Law. Production, use, and fate of all plastics ever made. *Sci Adv* **2017**, *Volume 3*, no. 7, p. e1700782.
6. Plastic pollution is growing relentlessly as waste management and recycling fall short, says OECD, 2022, [online]. Available: https://www.oecd.org/environment/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm
7. Notice of the General Office of the State Council on issuing the implementation plan for prohibiting the entry of foreign waste and advancing the reform of the solid waste import administration system, 2017, [online]. Available: http://gov.cn/zhengce/content/2017-07/27/content_5213738.htm
8. M. N. S. Pitol; S. Ahmed; H. Kumar; M. A. Islam; T. Dey; B. Kumar Bachar; and R. Kumar Ghosh. The Effects of the COVID-19 on Our Daily Lives in Bangladesh. *Qubahan Acad J* **2022**, *Volume 2*, no. 1. https://doi.org/10.48161/qaj.v2n1a90
9. Plastic waste management and burden in China, 2022, [online]. Available: https://ipen.org/sites/default/files/documents/ipen-china-2021-epa_v1_2.pdf
10. M. A. Zhanfeng; J. Wanjun; and Y. Sen. China plastics industry. *China Plast* **2020**, *Volume 34*, no. 5, pp. 102-106.
11. Suggestions from the Ministry of Ecology and Environment and National Development and Reform Commission on further strengthening the treatment of plastic pollution, 2020, [online]. Available: https://www.gov.cn/zhengce/zhengceku/2020-01/20/content_5470895.htm
12. The 14th five-year plan of action on plastic pollution control, 2021, [online]. Available: https://www.mee.gov.cn/xxgk2018/xxgk/xxgk10/202109/t20210916_945621.html
13. S. Qu; Y. Guo; Z. Ma; W. Q. Chen; J. Liu; G. Liu; Y. Wang; and M. Xu. Implications of China's foreign waste ban on the global circular economy. *Resour Conserv Recycl* **2019**, *Volume 144*, pp. 252-255.
14. W. Wang; N. J. Themelis; K. Sun; A. C. Bourtsalas; Q. Huang; Y. Zhang; and Z. Wu. Current influence of China's ban on plastic waste imports. *Waste Dispos Sustain Energy* **2019**, *Volume 1*, pp. 67-78.
15. Y. Ren; L. Shi; A. Bardow; R. Geyer; and S. Suh. Life-cycle environmental implications of China's ban on post-consumer plastics import. *Resour Conserv Recycl* **2020**, *Volume 156*, 104699.
16. Z. Wen; Y. Xie; M. Chen; and C. D. Dinga. China's plastic import ban increases prospects of environmental impact mitigation of plastic waste trade flow worldwide. *Nat Commun* **2021**, *Volume 12*, no. 425.
17. Y. Yang; L. Chen; and L. Xue. Looking for a Chinese solution to global problems: The situation and countermeasures of marine plastic waste and microplastics pollution governance system in China. *Chin J Popul Resour Environ* **2021**, *Volume 19*, no. 4, pp. 352-357.
18. Y. Deng; R. Wang; S. Li; K. Yu; Y. Liu; M. Shang; J. Wang; J. Shu; Z. Sun; M. Chen; and Q. Liang. Waste electrical and electronic equipment reutilization in China. *Sustainability* **2021**, *Volume 13*, no. 20, p. 11433.
19. Q. Q. Zhang; Z. R. Ma; Y. Y. Cai; H. R. Li; and G. G. Ying. Agricultural plastic pollution in China: Generation of plastic debris and emission of phthalic acid esters from agricultural films. *Environ Sci Technol* **2021**, *Volume 55*, no. 18, pp. 12459-12470.
20. M. Hestin; T. Faninger; and L. Milios. Increased EU plastics recycling targets: Environmental, economic and social impact assessment, 2015, [online]. Available: https://kipdf.com/increased-eu-plastics-recycling-targets-environmental-economic-and-social-impact_5ab85d9a1723dd329c6494cb.html
21. China waste plastic recycling industry edited by China-Italy chamber of commerce, 2020, [online]. Available: https://www.sicab.net/wp-content/uploads/2020/05/04.-China-Waste-Plastic-Recycling-Industry-Report.pdf
22. China plastic recycling market analysis: Plant capacity, production, operating efficiency, demand & supply, end-user industries, distribution channel, regional demand, 2015-2030, 2021, [online]. Available: https://www.chemanalyst.com/industry-report/china-plastic-recycling-market-507
23. CRRA. *Development report on China's renewable plastics industry;* Beijing: China Plastic Recycling Association of China National Resources Recycling Association, 2020.
24. China Statistical Yearbook; Beijing: China Statistics Press, 2020.
25. M. Hussain. Reimagining the New World Order Post-Covid-19. *Qubahan Acad J* **2021**, *Volume 1*, no. 1, pp. 5-10.
26. R. Hasanli; I. Aliyev; N. Poladov; L. Azimova; and T. Tagiyev. Isothermal transformations in high-strength cast iron. *Sci Her Uzhhorod Univ Ser Phys* **2022**, no. 51, pp. 48-58.
27. China municipal solid waste management industry, 2020, [online]. Available: https://www.sicab.net/wp-content/uploads/2020/05/15.-China-Municipal-Solid-Waste-Management-Industry-Report.pdf
28. J. Liu; U. Yang; L. An; Q. Liu; and J. Ding. The value of China's legislation on plastic pollution prevention in 2020. *Bull Environ Contam Toxicol* **2022**, *Volume 108*, pp. 601-608.

29. Development report on recycling industry of renewable resources in China Beijing: Department of Circulation Industry Development, Ministry of Commerce, 2018, [online]. Available: https://recordtrend.com/research-report/development-report-of-chinas-renewable-resources-recycling-industry-from-ministry-of-commerce/
30. A. Yoshida. China's ban of imported recyclable waste and its impact on the waste plastic recycling industry in China and Taiwan. *J Mater Cycles Waste Manag* **2022**, *Volume 24*, pp. 73-82.
31. H.E. Khor; F. Zhai; and S. Y. Foo. Turning carbon neutrality vision into reality, 2022, [online]. Available: https://global.chinadaily.com.cn/a/202203/19/WS62351ecaa310fd2b29e51ea3.html
32. L. Goulder; and D. Yang. China's new carbon market aims to substantially reduce its emissions, 2021, [online]. Available: https://www.weforum.org/agenda/2021/11/new-carbon-market-slash-chinas-emissions/
33. Y. Sun; S. Liu; P. Wang; X. Jian; X. Liao; and W.Q. Chen. China's roadmap to plastic waste management and associated economic costs. *J Environ Manag* **2022**, *Volume 309*, p. 114686.
34. W.W.Y. Lau; Y. Shiran; R.M. Bailey; E. Cook' M.R. Stuchtey; J. Koskella; C.A. Velis; L. Godfrey; J. Boucher; M.B. Murphy; R.C. Thompson; E. Jankowska; A. Castillo; T.D. Pilditch; B. Dixon; L. Koerselman; E. Kosior; E. Favoino; J. Gutberlet; S. Baulch; M. E. Atreya; D. Fischer; K.K. He; M.M. Petit; U.R. Sumaila; E. Neil; M.V. Bernhofen; K. Lawrence; and J.E. Palardy. Evaluating scenarios toward zero plastic pollution. *Science* **2020**, *Volume 369*, no. 6510, pp. 1455-1461.
35. Y. Chen; Z. Cui; X. Cui; W. Liu; X. Wang; X. Li; and S. Li. Life cycle assessment of end-of-life treatments of waste plastics in China. *Resour Conserv Recycl* **2019**, *Volume 146*, pp. 348-357.
36. R. Kumar; A. Verma; A. Shome; R. Sinha; S. Sinha; P.K. Jha; R. Kumar; P. Kumar; Shubham; S. Das; P. Sharma; and P.V. Vara Prasad. Impacts of plastic pollution on ecosystem services, sustainable development goals, and need to focus on circular economy and policy interventions. *Sustainability* **2021**, *Volume 13*, no. 17, p. 9963.
37. B. Khussain; A. Brodskiy; A. Sass; K. Rakhmetova; V. Yaskevich; V. Grigor'eva; A. Ishmukhamedov; A. Shapovalov; I. Shlygina; S. Tungatarova; and A. Khussain. Synthesis of Vanadium-Containing Catalytically Active Phases for Exhaust Gas Neutralizers of Motor Vehicles and Industrial Enterprises. *Catalysts* **2022**, *Volume 12*, no. 8, 842.
38. V. Romanenko; and S. Kovalevskii. Analysis of climate changes in the forest fund lands of Boyarka Forest Research Station. *Ukr J For Wood Sci* **2022**, *Volume 13*, no. 3, pp. 69-75.
39. A. Tanchak; K. Katovsky; I. Haysak; J. Adam; and R. Holomb. Research of spallation reaction on plutonium target irradiated by protons with energy of 660 MeV. *Sci Her Uzhhorod Univ Ser Phys*, no. 52, pp. 36-45, 2022.
40. Notice of the ministry of agriculture on issuing the action programme on agricultural film recovery, 2017, [online]. Available: http://moa.gov.cn/nybgb/2017/dlq/201712/t20171231_6133712.htm
41. N. Sarsembayeva; T. Abdigaliyeva; Z. Kirkimbayeva; Z. Valiyeva; A. Urkimbayeva; and A. Biltebay. Study of the degree of heavy and toxic metal pollution of soils and forages of peasant farms in the Almaty region. *Int J Mech Eng Technol* **2018**, *Volume 9*, no. 10, pp. 753-760.
42. Z. T. Bagasharova; A. S. Abdelmaksoud; G. Y. Abdugaliyeva; L. B. Sabirova; and G. Z. Moldabayeva. Recovery of water aquifers after the impact of in-situ leaching of Uraniumm. *Int Multidiscip Sci GeoConf Surv Geology Min Ecol Manag* **2015**, Volume 1, no. 4, pp. 19-26.
43. A. Lyubchyk; O. Lygina; S. Lyubchyk; I. Fonseca; M. Tulepov; Z. Mansurov; and S. Lyubchik. Activated carbons from co-mingled liquid and solid organic wastes. *Eurasian Chem Technol J* **2015**, *Volume 17*, pp. 47-65.
44. B.E. Paton; A.V. Chernets; G.S. Marinsky; V.N. Korzhik; and V.S. Petrov. Prospects of using plasma technologies for disposal and recycling of medical and other hazardous waste. Part 1. *Probl Spetsial'noj Electrometal* **2005**, no. 3, pp. 49-57.
45. B.E. Paton; A.V. Chernets; G.S. Marinsky; V.N. Korzhik; and V.S. Petrov. Prospects of using plasma technologies for disposal and recycling of medical and other hazardous waste. Part 2. *Probl Spetsial'noj Electrometal* **2005**, no. 4, pp. 46-54.
46. T. Fedoniuk; R. Fedoniuk; T. Klymenko; O. Polishchuk; and A. Pitsil. Bioindication of Aerotechnogenic Pollution of Agricultural Landscapes Caused by the Activities of Industrial Hubs. *Ekol Bratislava* **2021**, *Volume 40*, no. 2, pp. 115-123.
47. J. Cramer. Key drivers for high-grade recycling under constrained conditions. *Recycling* **2018**, *Volume 3*, no. 2, p. 16.
48. D.V. Sannikov. Problems of land legislation of Ukraine and European Union integration. *J Leg Ethical Regul Issues* **2017**, *Volume 20*, no. Special issue 1.
49. V.M. Shevko; Y.Y. Akylbekov; G.Y. Karataeva; and A. D. Badikova. Recycling of chrysotile-Asbestos production waste. *Metall Res Technol* **2022**, *Volume 119*, no. 4, 410.
50. O.V. Chernets; V.M. Korzhyk; G.S. Marynsky; S.V. Petrov; and V.A. Zhovtyansky. Electric arc steam plasma conversion of medicine waste and carbon containing materials. *GD 2008 – 17th International Conference on Gas Discharges and Their Applications*, 2008, pp. 465-468.

51. K.A. Bissenov; S.S. Uderbayev; and U.Z. Shalbolova. Environmental and economic efficiency of using insulated wood concrete in building based on agricultural and industrial wastes. *Actual Probl Econ* **2014**, *Volume 151*, no. 1, pp. 304-311.
52. U.Z. Shalbolova; S.M. Yegemberdiyeva; S.S. Uderbayev; M.A. Elpanova; and L.A. Kazbekova. Specifics of oil pipeline systems' risks management. *Life Sci J* **2014**, *Volume 11*, no. 11, pp. 591-594.
53. Y. Huang; and D. Han. Analysis of China's oil trade pattern and structural security assessment from 2017 to 2021. *Chem Technol Fuels Oils* **2022**, *Volume 58*, pp. 146-156.
54. S. Lyubchyk; O. Shapovalova; O. Lygina; M.C. Oliveira; N. Appazov; A. Lyubchyk; A.J. Charmier; S. Lyubchik; and A.J.L. Pombeiro. Integrated Green Chemical Approach to the Medicinal Plant Carpobrotus edulis Processing. *Sci Rep* **2019**, *Volume 9*, no. 1, 18171.
55. U.Z. Shalbolova; R.A. Narmanova; E.B. Tlessova; and Z. Ryskulova. Economic efficiency of cold oil bituminous mastic production. *Espacios* **2017**, *Volume 38*, no. 46, 36.
56. O. Strashok; O. Kolesnichenko; R. Kalbarczyk; M. Ziemiańska; D. Bidolakh; and V. Strashok. Assessment of model grass plots of the city of Kyiv in eco-conditions of anthropogenic load. *Ukr J For Wood Sci* **2022**, *Volume 13*, no. 1, pp. 58-71.
57. Q. Wang; J. Qu; B. Shi; N. Chen; M. Nie; and S. Yang. Prevention and control of waste plastics pollution in China. *Strateg Stud Chin Acad Eng* **2021**, *Volume 23*, no. 1, pp. 160-166.
58. E. Shahini; D. Shehu; O. Kovalenko; and N. Nikonchuk. Comparative analysis of the main economic and biological parameters of maize hybrids that determine their productivity. *Sci Horiz* **2023**, *Volume 26*, no. 4, pp. 86-96.
59. T.P. Fedoniuk; and O.V. Skydan. Incorporating geographic information technologies into a framework for biological diversity conservation and preventing biological threats to landscapes. *Space Sci Technol* **2023**, *Volume 29*, no. 2, pp. 10-21.
60. M. Eriksen; M. Thiel; M. Prindiville; and T. Kiessling. Microplastic: What are the solutions, in *The Handbook of Environmental Chemistry*; Cham: Springer Cham, 2018; pp. 273-298.
61. J. Nikiema; and Z. Asiedu. A review of the cost and effectiveness of solutions to address plastic pollution. *Environ Sci Pollut Res* **2022**, *Volume 29*, pp. 24547-24573.