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The Environmental Impact of The Plastic Products Industry in Jiaozuo City and the Species Subject to Priority Control

Junhui Yue*, Shaoxin Feng, Linghe Sun

College of Resources and Environment, Henan Polytechnic University, Jiaozuo, China
*Corresponding Author: Junhui Yue

ABSTRACT

As an important emission source of volatile organic compounds (VOCs), the plastic products industry has relatively few studies conducted on it. Therefore, this paper selects seven plastic products enterprises in Jiaozuo City for monitoring and analysis. By calculating the ozone formation potential and secondary organic aerosol formation potential of the plastic products industry, the environmental impact of this industry is understood. Through the calculation using the entropy method, the species subject to priority control in this industry are determined. The results show that in the plastic products industry of Jiaozuo City, the daily-use plastic products manufacturing industry has the highest VOCs concentration, which is 20.18 mg/m³, followed by the plastic pipe manufacturing industry (3.96 mg/m³), the synthetic leather made of plastics manufacturing industry (1.93 mg/m³), and the plastic packaging boxes and containers manufacturing industry (0.27 mg/m³). Among them, OVOCs are the main components of the plastic products industry, and the main contributing substances include ethyl acetate, n-butanal, 2-butanone, etc. The main contributing components of the plastic products industry to ozone formation and secondary organic aerosol formation are OVOCs and aromatic hydrocarbons respectively, and the main contributing substances are ethyl acetate, n-butanal, propionaldehyde, ethylbenzene, and toluene respectively.

KEYWORDS

Vocs; Plastic Products; Pollutants Subject to Priority Control.

1. INTRODUCTION

In response to the environmental air quality issues in China, the State Council has successively promulgated and implemented a series of environmental protection measures, such as the Action Plan for Air Pollution Prevention and Control, the Three-Year Action Plan for Winning the Battle for a Blue Sky, and the Action Plan for Sustained Improvement of Air Quality. These measures have improved the air quality in China. However, pollution problems mainly characterized by ozone and particulate matter still exist [1-4]. The Bulletins on the Ecological and Environmental Quality Status of Henan Province from 2018 to 2022 show that Jiaozuo City faces severe air pollution challenges. Among them, ozone pollution is the most serious, followed by fine particulate matter (PM2.5) and coarse particulate matter (PM10) pollution. These pollutants pose a serious threat to the physical health [5-7] and quality of life [4, 8] of residents. With reference to the Technical Specification for Environmental Air Quality Assessment (HJ 663-2013), based on the hourly data of air pollutants released by the China National Environmental Monitoring Centre, the annual average values of ozone, PM2.5, and PM10 in Jiaozuo City from 2019 to 2023 were calculated. It was found that the concentrations of ozone, PM2.5, and PM10 decreased from 112.79, 56.16, and 101.41 μg/m³ to 112.17, 46.18, and 92.56 μg/m³ respectively. However, there is still a certain gap compared with China's air quality standards.

Volatile organic compounds (VOCs), as common pollutants in the atmosphere, will undergo physical and chemical reactions in the air to form ozone and fine particulate matter [9-11]. Through the research on VOCs, it has been found that solvent use and technological processes are important sources of VOCs. For example, Huang et al. [12] established the emission inventory of air pollutants in Liaocheng City and found that the local VOCs mainly came from solvent use sources (37.11%) and technological process sources (22.86%). Song et al. [13] investigated the inventory of anthropogenic VOCs components in Nanjing City in 2021 and found that the emissions from technological process sources were as high as 182.94 kt, accounting for 60.41% of the total emissions. Tian et al. [14] studied the contribution of anthropogenic VOCs in the Yangtze River Delta region and found that the proportions of technological process sources and solvent use sources were 34.30% and 27.10% respectively. He et al. [15] constructed the emission inventory of anthropogenic VOCs in Jiaozuo City and found that the local technological process sources (36.19%) and solvent use sources (25.48%) contributed relatively high to VOCs emissions. As an emission source that cannot be ignored in the use of VOCs solvents and technological processes in the plastic products industry, the current research on its emission characteristics and environmental impacts is relatively insufficient [16].

Therefore, in this paper, referring to the Classification of National Economic Industries (GB/T 4754-2017), the local plastic products industry is divided into four categories, including the manufacturing industry of daily-use plastic products, the manufacturing industry of plastic pipes, the manufacturing industry of synthetic leather made of plastics, and the manufacturing industry of plastic packaging boxes and containers. The plastic products industry was investigated, sampled, tested, and analyzed. The Maximum Incremental Reactivity (MIR) method [17, 18], the Hydroxyl Radical Reaction Rate (L·OH) method [10], and the Toluene Weighted Mass Contribution (SOAP) method [19] were used to statistically analyze its environmental impacts. The entropy method was used to determine the species subject to priority control, with the hope of providing ideas for the refined management and control of VOCs in the plastic products industry.

2. MATERIALS AND METHODS

2.1. Sampling Scheme

From September 11th to September 20th, 2023, seven plastic products enterprises in Jiaozuo City were selected, and the collection of VOCs samples was carried out when their production facilities were operating stably. The location information and basic situations of the research enterprises are shown in Figure 1 and Table 1. The sampling method refers to the Technical Specification for Manual Monitoring of Ambient Air Quality (HJ 194—2017) and Determination of Volatile Organic Compounds in Ambient Air—Canister Sampling/Gas Chromatography-Mass Spectrometry Method (HJ759-2015). Before sampling, the sampling canister (3.2L) was cleaned and evacuated (less than 10 Pa). During sampling, the flow controller and filter were installed on the sampling canister, and the valve of the sampling canister was opened to ensure that the VOCs gas entered the sampling canister at a flow rate of 48 ml/min. After sampling, the valve was closed, sealed with a sealing cap, and the sampling location and sampling time were recorded. A total of 7 sampling points were involved in this experiment, and one test sample was collected at each sampling point.

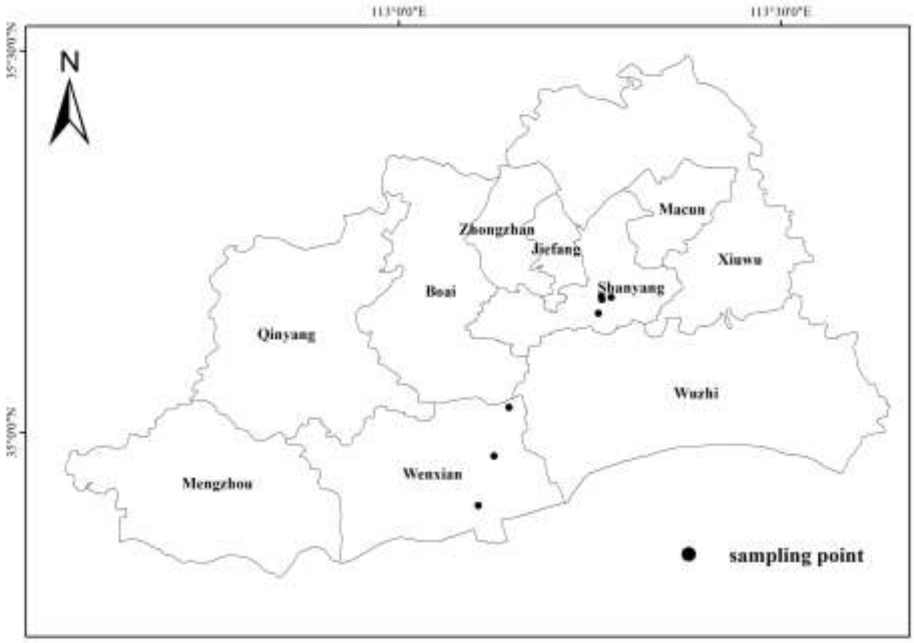


Figure 1 Schematic Diagram of the Distribution of Sampling Points

Table 1 Basic Information of Enterprises and Sampling Locations

Industry category	Enterprise number	Raw and auxiliary materials	VOCs treatment technology	Sampling location
Manufacturing industry of daily-use plastic products	1	Polyethylene, PP(polypropylene) resin	Photocatalytic degradation method	Outlet of the injection molding workshop
	2	Polypropylene granules, polyethylene granules, polypropylene film	Photocatalytic degradation method	Outlet of the injection molding + printing + compounding + curing process section
Plastic tube manufacturing industry	3	Polyvinyl chloride (PVC)	Photocatalytic degradation method, plasma technology	Outlet of the production workshop
	4	Polyvinyl chloride, polyethylene, modified polypropylene, calcium carbonate	Activated carbon adsorption	Outlet of the PE workshop
Manufacturing industry of synthetic leather made of plastics	5	Base, coated synthetic resin	Photocatalytic degradation method	Outlet of the surface treatment process section
Manufacturing industry of plastic packaging boxes and containers	6	Polyethylene, masterbatch	Photocatalytic degradation method	Outlet of the blow molding workshop
	7	Polyethylene, masterbatch	Photocatalytic degradation method	Outlet of the extrusion bottle workshop

2.2. Analysis method

A gas chromatography - mass spectrometry (GC - MS) instrument (Agilent 8890/5977B) was used for the quantitative analysis of VOCs samples. A 300 - ml VOCs sample was passed through a primary cold trap. Under the action of liquid nitrogen, the temperature of the VOCs was cooled to -150°C and then heated to 10°C. Subsequently, the VOCs were transported by helium (99.999%) to a secondary cold trap at - 15°C to remove moisture and carbon dioxide from the sample. Then, the VOCs were transferred to a tertiary cold trap for focusing. Finally, helium carried the target substances into the GC - MS system for separation and quantitative analysis. If the concentration of the original sample was too high, it was diluted using a high - precision diluter (JZY - 204 - 2018).

2.3. Quality Control and Quality Assurance

For each batch of samples, at least one transport blank should be set up. That is, take a sampling canister filled with high - purity nitrogen (99.999%) to the sampling site and subject it to the same treatment as the collected samples (transportation, storage, and laboratory analysis).During the sample analysis process, an experimental blank should be set up. Specifically, inject high purity nitrogen into a clean sampling canister as the experimental blank. An experimental blank sample test must be conducted before analyzing the samples. For each sample, three parallel samples should be prepared. The relative deviation of the target substances in the parallel samples should be less than or equal to 30%. Otherwise, the cause should be investigated and the samples should be reanalyzed. Calibrate the instrument once every 24 hours. Draw a calibration curve with six concentration points to ensure that the relative standard deviation of the response factors of the target substances is less than or equal to 30%.

2.4. Calculation method

2.4.1. Ozone Formation Potential

VOCs are one of the important precursors for ozone formation. In this paper, the Maximum Incremental Reactivity (MIR) method is adopted to calculate the Ozone Formation Potential (OFP) of the plastic products industry. The calculation formula is as follows:

$$OFP_{ij} = [VOCs]_{ij} \times MIR_i \quad (1)$$

In the formula, OFP_{ij} represents the ozone formation potential of VOCs component i in emission source j, with the unit of mg·m-3; $[VOCs]_{ij}$ represents the mass concentration of VOCs component i in emission source j, with the unit of mg·m-3. MIR_i represents the maximum incremental reactivity of VOCs component i, and the MIR_i coefficient is derived from the research of Carter et al. [20].

2.4.2. Hydroxyl Radical Consumption Rate

Under the irradiation of ultraviolet light, VOCs undergo a photochemical reaction with $\cdot OH$, generating intermediate products such asRO_2 ·and HO_2 ·. These intermediate products will react with NO_x to form ozone. In this paper, the hydroxyl radical reaction rate method is used to calculate the hydroxyl consumption rate (L·OH) in the plastic products industry. The calculation formula is as follows:

$$L_{ij,\cdot OH} = [VOCs]_{ij} \times K_{ij,\cdot OH} \quad (2)$$

In the formula, $L_{ij,\cdot OH}$ represents the $\cdot OH$ consumption rate of VOCs component i in emission source j, with the unit of s-1; $K_{ij,\cdot OH}$ is the rate constant of the reaction between VOCs component i in emission source j and $\cdot OH$, with the unit of m3·mg-1·s-1. The values of $K_{ij,\cdot OH}$ are taken from the studies of Grosjean et al. [21, 22] and Carter et al. [23].

2.4.3. Secondary Organic Aerosol Formation Potential

VOCs in the atmosphere generate secondary organic aerosols (SOA) through photochemical reactions. In this paper, the toluene-weighted mass contribution method (SOAP) is used to calculate the secondary organic aerosol formation potential of VOCs in the plastic products industry. The calculation formula is as follows:

$$SOAP_{ij} = [VOCs]_{ij} \times \frac{SOAP_i}{100} \times FAC_{toluene} \quad (3)$$

In the formula, $SOAP_{ij}$ represents the secondary organic aerosol formation potential of VOCs component i in emission source j. $SOAP_i$ is the secondary organic aerosol reaction rate of VOCs component i, which is taken from the research of Derwent et al. [24,25]. $FAC_{toluene}$ is the toluene aerosol fraction coefficient, with a value of 5.4%.

3. RESULTS AND DISCUSSION

3.1. VOCs Concentration Levels in the Plastic Products Industry

Through the detection of 116 kinds of VOCs in the plastic products industry in Jiaozuo City, the characteristics of VOCs components in the plastic products industry in Jiaozuo City were obtained (Figure 2). The analysis reveals that the VOCs concentration range in the plastic products industry in Jiaozuo City is 0.15 - 25.89 mg/m^3. Among them, the VOCs concentration in the daily-use plastic products manufacturing industry is the highest, reaching 20.18 mg/m^3. Followed by the plastic pipe manufacturing industry (3.96 mg/m^3), the plastic synthetic leather manufacturing industry (1.93 mg/m^3), and the plastic packaging box and container manufacturing industry (0.27 mg/m^3). The relatively high VOCs concentration in the daily-use plastic products manufacturing industry may be related to the aging of the end-treatment facilities in this industry. Studies have found that if phenomena such as the aging and poisoning of photocatalysts and insufficient light source energy occur during the use of photocatalytic degradation technology, it will lead to a decrease in the treatment efficiency of VOCs by the end-treatment facilities [26-28]. In addition, the influence of raw and auxiliary materials and the process cannot be excluded.

As is shown in Figure 2, OVOCs are the main components of VOCs in the plastic products industry in Jiaozuo City. However, in the study of VOCs components in the plastic products industry in Guangdong Province, aromatic hydrocarbons were found to be the main components, followed by OVOCs and alkanes. Through analysis of the reasons, it is found that this is related to the use of reagents such as thinners, inks, and composite adhesives in the production process of local plastic products enterprises in Guangdong Province [29-31].By analyzing the VOCs emission characteristics of various industries in Jiaozuo City, it is found that the proportions of OVOCs in the VOCs emitted by the daily-use plastic products manufacturing industry and the plastic pipe manufacturing industry in Jiaozuo City are both greater than 80%, reaching 93.46% and 82.16% respectively. This is related to the low treatment efficiency of the treatment facilities for OVOCs. In the VOCs emitted by the plastic synthetic leather manufacturing industry, the proportion of OVOCs is the highest (46.63%), followed by halogenated hydrocarbons (24.35%) and alkanes (16.06%). The composition of VOCs components in the plastic packaging box and container manufacturing industry is similar to that in the plastic synthetic leather manufacturing industry. In descending order, they are OVOCs (37.86%), halogenated hydrocarbons (26.75%), and alkanes (11.27%).

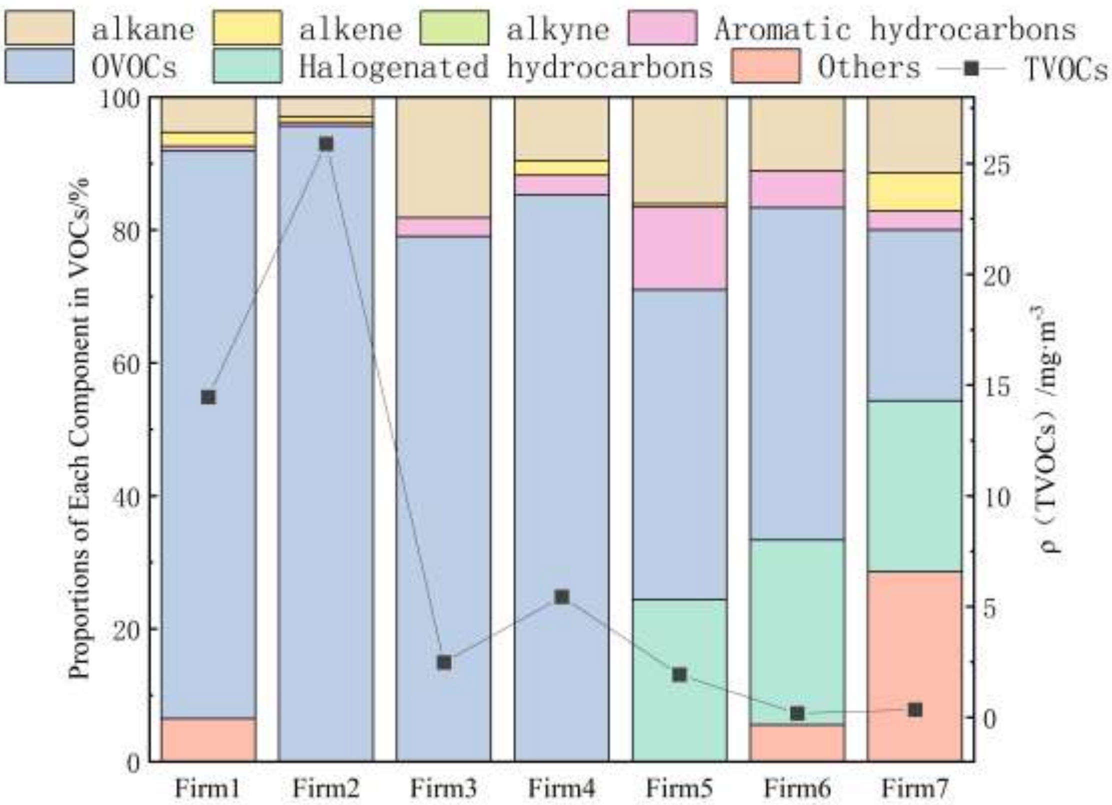


Figure 2 VOCs Concentration Levels and Composition of Plastic Products Enterprises in Jiaozuo City

3.2. VOCs Emission Characteristics of the Plastic Products Industry

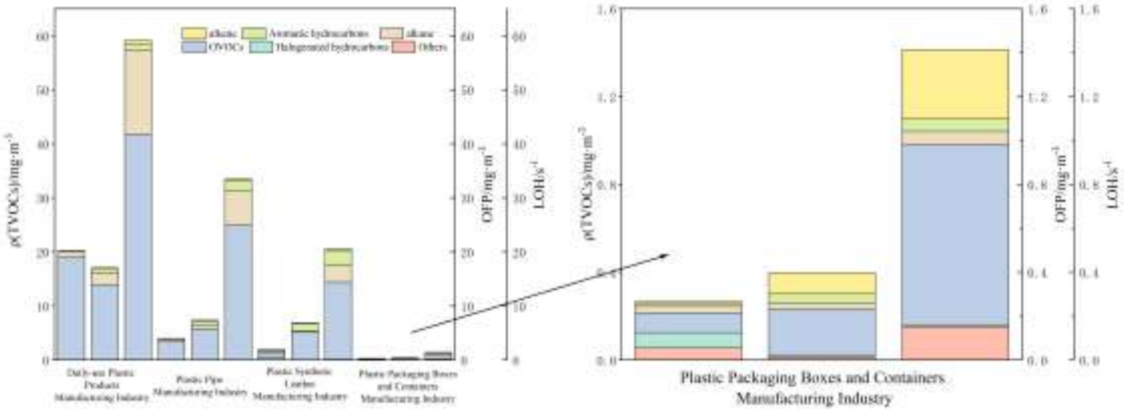
In order to explore whether there are regional differences in the composition of VOCs in the plastic products industry, the VOCs detection results of the plastic products industry in Jiaozuo City were normalized, and the results were compared with those of the plastic products industry in other regions (Table 2). In the local daily-use plastic products manufacturing industry, ethyl acetate (82.97%) makes a relatively large contribution to VOCs. However, in the daily-use plastic products manufacturing industry in Hebei Province, toluene makes a relatively large contribution to VOCs (41.07%), followed by ethyl acetate (25.53%) [32]. In the local plastic pipe manufacturing industry, the substances with higher contributions are ethyl acetate (45.58%), n-butanal (11.11%), isopropanol (9.72%), and 2-butanone (7.58%). However, Jiang et al. [16] studied the plastic pipe manufacturing industry in Guangzhou City and found that among the VOCs emitted by two local plastic pipe manufacturing enterprises, the substances with higher contributions are respectively ethyl acetate (28.06%), 2-butanone (11.79%), acetone (10.74%) and 2-butanone (25.94%), methylcyclohexane (22.88%), ethyl acetate (11.23%).It can be seen that there are differences in the VOCs components emitted by the same industry in different regions. In addition, since no relevant studies on the VOCs of the plastic synthetic leather manufacturing industry and the plastic packaging box and container manufacturing industry were found, no comparative analysis will be carried out here. In the VOCs emitted by the local plastic synthetic leather manufacturing industry, the substances with higher contributions are propionaldehyde (29.02%), dichloromethane (20.21%), dodecane (6.22%), and toluene (6.22%); in the VOCs emitted by the plastic packaging box and container manufacturing industry, the substances with higher contributions are carbon disulfide (20.75%), dichloromethane (20.21%), and acetone (9.43%).

Table 2 Main VOCs Substances and Their Proportions in the Plastic Products Industry

Industry Category	Region	Proportion of VOCs Components	Reference
Daily-use Plastic Products Manufacturing Industry	Jiaozuo	Ethyl acetate (82.97%), isopropanol (8.40%), dodecane (1.61%), acrolein (1.24%), 1-pentene (1.19%)	This study
Plastic Pipe Manufacturing Industry	Jiaozuo	Ethyl acetate (45.58%), n-butanal (11.11%), isopropanol (9.72%), 2-butanone (7.58%), vinyl acetate (6.31%), dodecane (3.79%), decane (2.27%)	This study
Plastic Synthetic Leather Manufacturing Industry	Jiaozuo	Propionaldehyde (29.02%), dichloromethane (20.21%), dodecane (6.22%), toluene (6.22%), acrolein (5.18%), 2-butanone (4.66%), acetone (4.15%), 1,2-dichloroethane (4.15%)	This study
Plastic Packaging Boxes and Containers Manufacturing Industry	Jiaozuo	Carbon disulfide (20.75%), dichloromethane (9.43%), acetone (9.43%), 1,2-dichloroethane (7.55%), ethyl acetate (5.66%)	This study
Daily-use Plastic Products Manufacturing Industry	Hebei	Toluene (41.07%), ethyl acetate (25.53%), n-hexane (10.61%)	[32]
Plastic Pipe Manufacturing Industry	Guangzhou	Ethyl acetate (28.06%), 2-butanone (11.79%), acetone (10.74%)	[16]
Plastic Pipe Manufacturing Industry	Guangzhou	2-butanone (25.94%), methylcyclohexane (22.88%), ethyl acetate (11.23%)	[16]

3.3. Ozone Formation Potential of the Plastic Products Industry

Calculate the ozone formation potential (OFP) of VOCs and the hydroxyl radical consumption rate in the plastic products industry of Jiaozuo City, and obtain the contribution diagrams of VOCs ozone formation and hydroxyl radical consumption (Figure 3). It can be seen from the figure that the OFP values and L·OH values of the daily-use plastic products manufacturing industry, plastic pipe manufacturing industry, plastic synthetic leather manufacturing industry, and plastic packaging boxes and containers manufacturing industry are 59.14, 33.54, 20.58, and 1.41 $mg \cdot m^{-3}$, and 20.18, 3.96, 1.93, and 0.27 s^{-1} respectively. The main contributing components for ozone formation in the plastic products industry are OVOCs, which is basically consistent with the main contributing components for ozone formation in other regions [29, 33, 34]. Among them, the main contributing components for ozone formation in both the daily-use plastic products industry and the plastic pipe manufacturing industry are OVOCs, while the main contributing components for hydroxyl radical consumption are OVOCs and alkanes respectively. This is because the conversion of VOCs into ozone is a multi-step chemical reaction, and the consumption of hydroxyl radicals is just one of the links. The magnitude of the hydroxyl radical consumption rate only represents the ability of VOCs to react with hydroxyl radicals, and does not represent the ozone formation ability of VOCs. The main contributing components for ozone formation and hydroxyl radical consumption in the plastic synthetic leather manufacturing industry are OVOCs, and OVOCs, alkanes, and aromatics respectively. The main contributing components for both ozone formation and hydroxyl radical consumption in the plastic packaging boxes and containers manufacturing industry are OVOCs.



From left to right: VOCs concentration, OFP和$L_{\cdot OH}$

Figure 3 Ozone Formation Potential and Hydroxyl Radical Consumption Rate of VOCs in the Plastic Products Industry of Jiaozuo City

In order to understand the contribution ability of various substances in the plastic products industry of Jiaozuo City to ozone formation, the substances that make a relatively large contribution to ozone formation in the plastic products industry were statistically analyzed (Table 3). The main substances contributing to ozone formation in the daily-use plastic products manufacturing industry are ethyl acetate (61.89%), acrolein (10.93%), and 1-pentene (10.15%). The main substances contributing to ozone formation in the plastic pipe manufacturing industry are n-butanal (35.66%), ethyl acetate (15.44%), and vinyl acetate (10.86%). The main substance contributing to ozone formation in the plastic synthetic leather manufacturing industry is propionaldehyde (67.79%), followed by acrolein (10.86%). The main substances contributing to ozone formation in the plastic packaging boxes and containers manufacturing industry are n-butene (24.45%), propionaldehyde (17.79%), and n-butanal (15.00%). It can be seen from this that the plastic products industry in Jiaozuo City should attach great importance to the emissions of substances such as ethyl acetate, n-butanal, propionaldehyde, and n-butene, so as to reduce the impact on ozone formation.

Table 3 Main Contributing Species to Ozone Formation in the Plastic Products Industry

Industry Category	Main Composition Components
Daily-use Plastic Products Manufacturing Industry	Ethyl acetate (61.89%), acrolein (10.93%), 1-pentene (10.15%), isopropanol (6.07%)
Plastic Pipe Manufacturing Industry	n-butanal (35.66%), ethyl acetate (15.44%), vinyl acetate (10.86%), acrolein (6.57%), 2-butanone (6.03%)
Plastic Synthetic Leather Manufacturing Industry	Propionaldehyde (67.79%), acrolein (10.86%), toluene (7.00%), 1,2,3-trimethylbenzene (5.23%)
Plastic Packaging Boxes and Containers Manufacturing Industry	n-butene (24.45%), propionaldehyde (17.79%), n-butanal (15.00%), toluene (10.05%), 2-butanone (5.58%), hexanal (5.47%)

3.4. Secondary Organic Aerosol Formation Potential of the Plastic Products Industry

By calculating the secondary organic aerosol (SOA) formation potential of VOCs in the plastic products industry of Jiaozuo City, the contribution diagram of its secondary organic aerosol formation was obtained (Figure 4). It can be seen from the figure that the SOA formation potentials of the four types of plastic products industries, from high to low, are the daily-use plastic products manufacturing industry (166.43×10^{-4} mg/m³), the plastic synthetic leather manufacturing industry (149.05×10^{-4} mg/m³), the plastic pipe manufacturing industry (79.71×10^{-4} mg/m³), and the plastic packaging boxes and containers manufacturing industry (5.48×10^{-4} mg/m³). Among them, the main contributing components of the daily-use plastic products manufacturing industry and the plastic pipe manufacturing industry are similar, with alkanes and aromatics contributing the most. Their contribution ratios are 47.16%, 47.05% and 47.29%, 51.26% respectively. The main contributing components of the plastic synthetic leather manufacturing industry are also aromatics and alkanes, but the contribution ratio of aromatics (78.70%) is much larger than that of alkanes (20.13%). The main contributing component of the plastic packaging boxes and containers manufacturing industry is aromatics, and its contribution ratio is 98.52%.

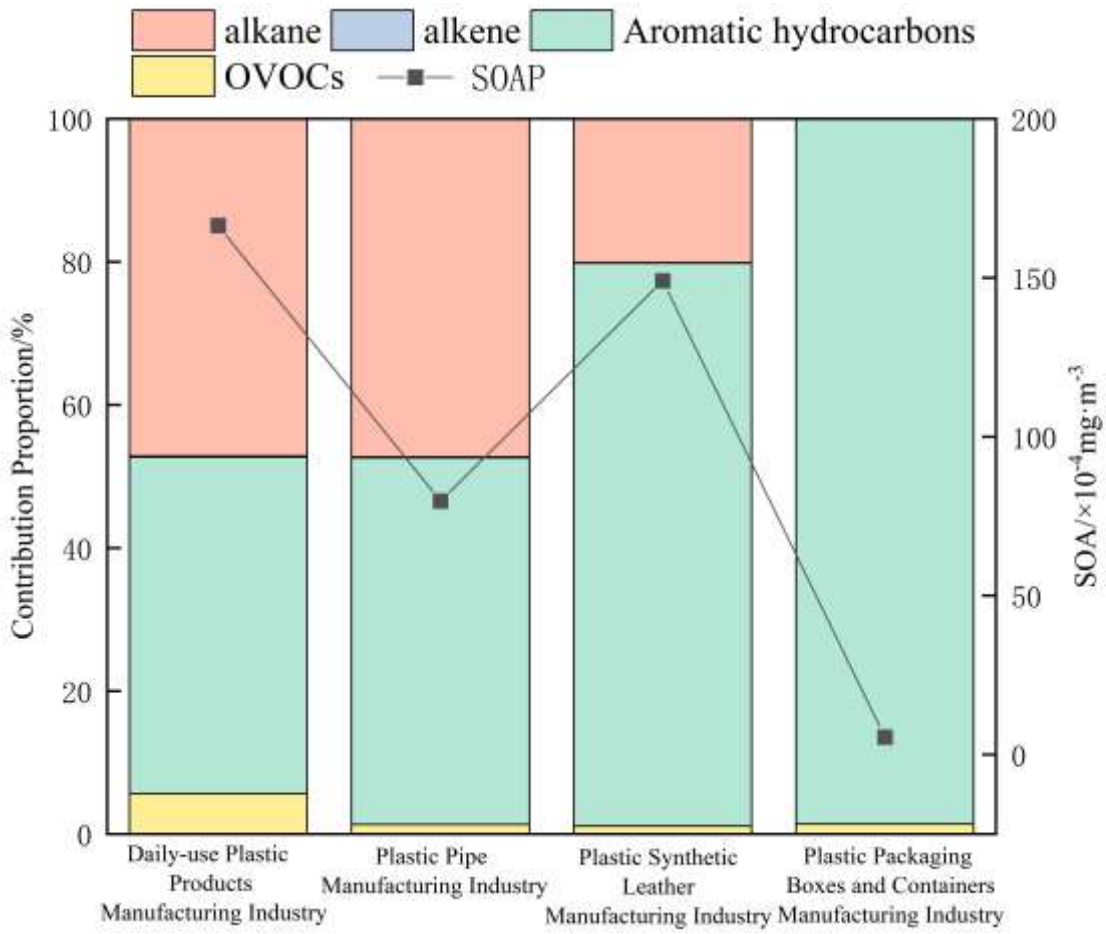


Figure 4 Contributions of VOCs in Different Plastic Products Industries to the Formation of Secondary Organic Aerosols

As can be seen from Table 4, the main substances contributing to the formation of secondary organic aerosols in the daily-use plastic products manufacturing industry are dodecane, ethylbenzene, and o-xylene, with their contribution ratios being 36.38%, 36.21%, and 10.85% respectively, and the contribution ratios of other substances are all less than 10.00%. The main substances contributing to the formation of secondary organic aerosols in the plastic pipe manufacturing industry are dodecane (35.06%), ethylbenzene (15.12%), o-xylene (12.94%), and m-xylene and p-xylene (12.38%). The main substances contributing to the formation of secondary organic aerosols in the plastic synthetic leather manufacturing industry are toluene (43.48%), dodecane (15.00%, it should be noted that you might have a typo here, perhaps you mean dodecane), ethylbenzene (12.13%), and o-xylene (10.38%). In the plastic packaging boxes and containers manufacturing industry, toluene contributes the most to the secondary organic aerosols, accounting for 98.52%.

Table 4 Main Contributing Species to the Formation of Secondary Organic Aerosols in the Plastic Products Industry

Industry Category	Main Composition Components
Daily-use Plastic Products Manufacturing Industry	Dodecane (36.38%), ethylbenzene (36.21%), o-xylene (10.85%), undecane (9.72%), ethyl acetate (5.43%), decane (1.02%)
Plastic Pipe Manufacturing Industry	Dodecane (35.06%), ethylbenzene (15.12%), o-xylene (12.94%), m-xylene and p-xylene (12.38%), undecane (7.68%), 1,2,3-trimethylbenzene (7.43%)
Plastic Synthetic Leather Manufacturing Industry	Toluene (43.48%), dodecane (15.00%), ethylbenzene (12.13%), o-xylene (10.38%), m-xylene and p-xylene (7.95%), 1,2,3-trimethylbenzene (4.77%)
Plastic Packaging Boxes and Containers Manufacturing Industry	Toluene (98.52%), acetone (0.74%), propionaldehyde (0.49%), ethyl acetate (0.15%)

4. CONCLUSIONS

(1) The concentration range of VOCs in the plastic products industry in Jiaozuo City is 0.15 - 25.89 $mg \cdot m^{-3}$. The concentrations of VOCs in the plastic products industry, from high to low, are as follows: the daily-use plastic products manufacturing industry (20.18 $mg \cdot m^{-3}$), the plastic pipe manufacturing industry (3.96 $mg \cdot m^{-3}$), the plastic synthetic leather manufacturing industry (1.93 $mg \cdot m^{-3}$), and the plastic packaging boxes and containers manufacturing industry (0.27 $mg \cdot m^{-3}$).

(2) The VOCs components emitted by the plastic products industry in different regions are different. The main contributing substance in the daily-use plastic products manufacturing industry in Jiaozuo City is ethyl acetate (82.97%). The main contributing substance in the plastic pipe manufacturing industry is ethyl acetate (45.58%). The main contributing substances in the plastic synthetic leather manufacturing industry are propionaldehyde (29.02%) and dichloromethane (20.21%). The main contributing substances in the plastic packaging boxes and containers manufacturing industry are carbon disulfide (20.75%) and dichloromethane (20.21%).

(3) The main contributing components to ozone formation in the plastic products industry in Jiaozuo City are OVOCs, and the main contributing substances are ethyl acetate, n-butanal, and propionaldehyde. The main contributing components to the formation of secondary organic aerosols are aromatics and alkanes, and the main contributing substances are dodecane and toluene.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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