

# Characteristics and Analysis of Volatile Organic Compounds Emission from Petrochemical Facility

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## Abstract

**Petrochemical enterprises are major emission sources of volatile organic compounds (VOCs), which significantly impact ambient air quality. This paper systematically summarizes the research progress on the current status, characteristics, and potential environmental and health impacts of VOCs emissions from China's petrochemical industry. Based on the results of atmospheric pollution analysis in the regions where petrochemical enterprises are located, and in line with the actual needs for improving local air quality, this study takes the environmental impacts of different VOCs emission sources in petrochemical enterprises as the evaluation objects. It identifies critical challenges and gaps in VOCs management and proposes targeted strategies for future control and mitigation.**

## Keywords

**Volatile organic compounds; Petrochemical facility; Emission source; Air pollution.**

## 1. INTRODUCTION

In recent years, emissions of air pollutants such as particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), nitrogen oxides (NO<sub>x</sub>), and sulfur dioxide (SO<sub>2</sub>) in China have continued to improve. In contrast, emissions of anthropogenic volatile organic compounds (VOCs) have been on a steady rise, with their environmental impacts becoming increasingly prominent. According to China's Emission Standards for Pollutants from Petroleum Refining Industry, VOCs are defined as non-methane organic compounds that can participate in atmospheric photochemical reactions, including alkanes, alkenes, aromatic hydrocarbons, oxygen-containing organic compounds, sulfur-containing organic compounds, and nitrogen-containing organic compounds, among others.

VOCs are widely recognized as toxic and harmful air pollutants, most of which have pungent or foul odors. Moreover, 1,3-butadiene and benzene series exhibit high carcinogenicity, posing severe risks to human health. In addition, some VOCs components have high photochemical reactivity, which can form ozone and organic aerosols, deteriorating air quality [1]. At the current stage, the concentration of fine particulate matter (PM<sub>2.5</sub>) in China remains high, and ozone pollution is increasingly prominent. As a result, VOCs emissions have become a key pollutant factor restricting the improvement of air quality in urban and regional areas of China.

Petrochemical enterprises are widely recognized as major sources of VOCs emissions, exerting a critical impact on the ambient air quality of their respective regions. Research institutions both domestically and internationally have conducted relevant studies on the

emission characteristics and impacts of VOCs from petrochemical enterprises. This paper reviews the progress made in recent years, summarizes the consensus conclusions reached, and analyzes and prospects the existing problems and potential development directions.

## 2. EMISSION CHARACTERISTICS OF VOCs FROM PETROCHEMICAL ENTERPRISES

### 2.1. Compositional Characteristics of VOCs from Petrochemical Enterprises

Chen et al. [2] found that the VOC components emitted by petrochemical enterprises are related to the process. The alkanes emitted during the loading and unloading process are mainly C5-C8 components, and the aromatic hydrocarbons are mainly toluene; the main VOC components emitted by naphtha cracking units, aromatic hydrocarbon units, and tank farms are C3-C5 aliphatic hydrocarbons and BTX. Mo et al. [3] pointed out that in the Yangtze River Delta region of China, C2-C5 alkanes, C2-C3 alkenes, and aromatic hydrocarbons are the main VOC components emitted by petrochemical enterprises. Among them, polyolefin units mainly emit alkenes, and aromatic hydrocarbon units mainly emit aromatic hydrocarbons. Wu Liping et al. [4] studied the characteristics of unorganized VOC emissions from a refining and chemical enterprise in Xinjiang, China, and found that the main components of VOCs emitted by various process units are alkanes and halogenated hydrocarbons, but the relative contents of different components vary. Li Qinqin et al. [5] pointed out that the unorganized VOC components emitted by process units of refining and chemical enterprises in the Pearl River Delta region of China are mainly alkanes, and different units have different VOC emission characteristics.

**Table 1.** Major VOCs components emitted from petrochemical facility

Region	Sampling location	Main VOCs components	Main alkanes	Main alkenes	Main aromatic hydrocarbons
United States	Factory boundary	Hydrocarbon substances	C2-C7	C2-C3	Benzene series
Turkey	Factory boundary	Oxygen-containing compounds	C5	-	BTX
Greece	Factory boundary	Alkanes and aromatic Hydrocarbons	C5	-	BTX
Northern China	Inside the factory	Hydrocarbons	C3-C5	C3-C4	BT
Yangtze River Delta region	Inside the factory	Hydrocarbons	C2-C5	C2-C3	BTX
Pearl River Delta region	Inside the factory	Hydrocarbons	C3-C6	C3-C4	
Chinese Taiwan	Inside the factory	Hydrocarbons and oxygen-containing compounds	C5-C8	C3-C5	BTX

Basic information such as the VOCs component profiles and inventories of exhaust gases emitted from petrochemical enterprises plays a crucial role in formulating economically efficient VOCs control schemes. Relevant studies on the VOCs emission profiles of petrochemical enterprises have been conducted both domestically and internationally. Most of these studies have discussed the VOCs compositional characteristics of petrochemical enterprises as a whole, while a small number have focused on the VOCs emission profiles of specific units and processes within petrochemical enterprises. The VOCs component emission situations of some petrochemical enterprises are shown in Table 1.

## 2.2. Emission Rates and Relative Contributions

A comparison was made of the VOCs emission rates of petrochemical enterprises and the contribution ratios of different emission sources across various countries and regions, with the results shown in Table 2. According to estimates by the U.S. Environmental Protection Agency (EPA U.S.), the VOCs emission factor of refineries in the United States is approximately between 0.011% and 0.032% [6]. The latest infrared remote sensing measurement results indicate that the VOCs emission factor of refineries in the European Union is about 0.18%. An analysis of VOCs emission data from several petrochemical enterprises in China revealed that the VOCs emission rate of typical petrochemical enterprises in China ranges from 0.05% to 0.08%.

**Table 2.** Emission rate of VOCs from petrochemical facility and relative contribution from different emission source

Refineries	Emission rate(%)	Contribution ratio(%)			
		LDAR	Storage tank	Oil loading and unloading	Wastewater treatment
Chinese refineries	0.05~0.08	10~40	25~50	10~20	5~15
U.S. Refineries	0.011~0.032	-	-	-	-
EU refineries	0.18	25~33	31~61	-	10~18
EU	-	20~50	20~40	5~10	5~30
IPIECA	-	40~50	10~15	30~40	10~15

Different emission sources in petrochemical enterprises contribute varying degrees to the total VOCs emissions. Infrared remote sensing measurement results of EU refineries show that VOCs emissions from crude oil and product tank farms, device areas (pipeline and valve leaks), coking units, wastewater treatment, and flares account for 31%–61%, 25%–33%, 23%, 10%–18%, and 2.25%–3.2% of the total emissions, respectively. The Best Available Techniques Reference Document for Pollution Control in EU Oil and Gas Processing recommends that [7], VOCs emissions from equipment and pipeline valve leaks, crude oil and product storage tanks, loading/unloading facilities, and wastewater treatment units account for 20%–50%, 20%–40%, 5%–10%, and 5%–30% of the total refinery emissions, respectively. A report by the International Petroleum Industry Environmental Conservation Association (IPIECA) suggests that equipment and component leaks, oil loading/unloading, storage tanks, and wastewater treatment account for 40%–50%, 30%–40%, 10%–15%, and 10%–15% of the total VOCs emissions from refineries, respectively [8]. An analysis of VOCs emission data from several refineries in China shows that in Chinese refineries, the proportions of VOCs emissions from equipment and pipeline valve leaks, crude oil and product storage tanks, oil loading/unloading, and wastewater treatment units are 10%–40%, 25%–50%, 10%–20%, and 5%–15%, respectively.

## 3. ENVIRONMENTAL IMPACTS OF VOCS EMISSIONS FROM PETROCHEMICAL ENTERPRISES

The impact of VOCs emissions from petrochemical enterprises on ambient air is particularly manifested in exacerbating environmental problems such as ozone pollution. In recent years, the concentration of surface ozone in China has been continuously rising, and the situation of ozone pollution has become increasingly severe. Ozone pollution incidents occur frequently in key regions and cities, and ozone has become the primary pollutant affecting air quality [9]. Studies have shown that surface ozone mainly comes from the photochemical reaction between

VOCs and NO<sub>x</sub>. This reaction process is affected by many factors and has a very complex mechanism. To a large extent, global ozone pollution originates from anthropogenic VOCs emissions, and petrochemical enterprises play a key role in ozone pollution incidents in key regions.

Recent studies have confirmed that intense photochemical reactions occur at the boundaries of petrochemical enterprises, exerting a significant impact on the atmospheric environment of their surrounding areas. Ryerson et al. [10] conducted a detailed analysis of ozone pollution incidents in the Houston area of the United States, concluding that VOCs emitted by refining and chemical enterprises are the main cause of the substantial increase in ambient ozone concentrations in the surrounding environment. Ozone in ambient air mainly originates from highly reactive components such as ethylene and propylene emitted by these enterprises. Additionally, other studies have pointed out that different refining and chemical units have varying degrees of impact on ambient ozone in the surrounding environment, with fluid catalytic cracking units having the greatest impact on ozone.

#### 4. CONCLUSION

This paper systematically analyzes and summarizes the research status, existing problems, and development trends regarding VOCs emissions from petrochemical enterprises and their environmental impacts, with the main conclusions as follows:

a) Petrochemical enterprises are significant sources of VOCs emissions and play a key role in environmental pollution issues. The organic waste gases emitted by petrochemical enterprises can significantly increase the concentration of VOCs in the surrounding atmospheric environment, with the increase reaching dozens of times. VOCs emitted by petrochemical enterprises will raise the risk of health hazards in the surrounding environment, cause ozone concentrations to rise, and exacerbate ozone pollution.

b) The basic information on VOCs components emitted by China's petrochemical enterprises is insufficient, and research on the emission characteristics of key sources such as intermediate material storage tanks and sewage transfer pools is inadequate. Additionally, the research foundation for assessing the impact of VOCs emissions from petrochemical enterprises on the surrounding environment is weak. Important research directions include analyzing the emission characteristics of key VOCs sources in petrochemical enterprises, establishing high-resolution VOCs component profiles and emission inventories, and quantitatively evaluating the environmental risk impacts of VOCs emissions from petrochemical enterprises based on the needs for improving local air quality.

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