Analysis of Characteristics of Volatile Organic Compounds Pollution in Atmosphere in Kuitun City and Countermeasures

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Abstract. The "Kui-Du-Wu" area of Kuitun City is one of the largest petrochemical bases and important economic core areas in Xinjiang. According to the online monitoring data of total volatile organic compounds (VOCs) at Kuitun site, 102 species can be detected in the urban atmospheric environment volatile organic compounds, through the analysis of the sources of the top ten compounds with average concentration values throughout the year, their main sources are chemical production, oil volatilization, fuel combustion, and motor vehicle exhaust. The prevention and control countermeasures are to strengthen source control, implement pollution source compliance management, improve the city's comprehensive management level, and establish and improve a joint prevention and control system.

1. Introduction

In recent years, the "Kui-Du-Wu" regional economy has developed rapidly, and the number of motor vehicles has increased sharply. The resulting urban air pollution has attracted much attention, especially the pollution of volatile organic compounds in the atmosphere. Volatile Organic Compounds (VOCs) have a wide range of sources, including natural sources and anthropogenic sources. VOCs in the atmosphere of urban sites mainly come from various anthropogenic emissions, including vehicle exhaust emissions, industrial emissions, solvent use, and fossil fuel combustion, biomass combustion, etc. Some VOCs are toxic, carcinogenic and teratogenic, posing a direct hazard to human health, and many VOCs components have strong reactivity, can participate in atmospheric photochemical reactions to generate ozone $O_3$, and participate in various homogeneous and heterogeneous chemical reactions to generate secondary organic aerosols, thereby increasing the degree of regional haze pollution [1]. My country's newly revised "Air Pollution Prevention and Control Law of the People's Republic of China" and the "Air Pollution Prevention and Control Action Plan" promulgated by the State Council have made it clear that the control of volatile organic compounds (VOCs) is one of the focus of air pollution control.

The "Kui-Du-Wu" area where Kuitun City is located is one of the largest petrochemical bases and important economic core areas in Xinjiang, including Kuitun City, Dushanzi District, Wusu City and the Seventh Agricultural Division. The staggered layout of chemical parks and urban built-up areas once led to serious urban air environmental pollution. In 2014, the autonomous region government included Kuitun City, Dushanzi District, and Wusu City as one of the key areas for joint air pollution prevention and control in the autonomous region. A regional joint prevention and control work plan was formulated,
air quality monitoring was strengthened, and online monitoring equipment for total volatile organic compounds (VOCs) was added. This article intends to analyze the characteristics of volatile organic compounds in the atmospheric environment of Kuitun City, in order to provide a reference for the relevant government departments to introduce VOCs emission control and governance measures.

2. Environmental overview of the "Kui-Du-Wu" area where Kuitun City is located

The "Kui-Du-Wu" area includes Kuitun City, Dushanzi District, Wusu City and the Seventh Agricultural Division. It is located in the central area of the economic belt on the northern slope of the Tianshan Mountains. It is Xinjiang's largest petrochemical base and one of the important economic core areas. It mainly focuses on petroleum processing, electricity and heat production and supply, chemical raw materials and chemical products manufacturing, and food manufacturing. Within a radius of 20 kilometers from Kuitun City, there are Kuitun-Dushanzi Economic and Technological Development Zone, Dushanzi Petrochemical Base, Wusu Chemical Park and Tianbei Industrial Park of the Seventh Division of the Production and Construction Corps, all located in one of the three cities. The junction between the two is located around the crowded area, presenting a staggered layout of the chemical industry park and the urban built-up area.

Kuitun City, Dushanzi, and Wusu City are about 10 kilometers apart and are distributed in a triangle. The east-west height difference is about 120 meters, and the north-south height difference is about 685 meters. In winter, it is in the same inversion zone on the northern slope of Tianshan Mountain. Affected by the quasi-stationary front of Tianshan Mountain, cloudy and foggy weather occurs frequently. The prevailing wind in the year is dominated by the west wind, and the north wind prevails in the winter. Due to the Tianshan Mountains to the south, affected by the temperature difference between day and night and topography, the wind direction in the area is more complicated, with obvious changes in wind direction during day and night. During the day, there are more northeast winds (valley winds) and southwest winds (mountain winds) at night. The three places are in the same climate zone, and there are local mutual influences.

The chemical components of PM$_{2.5}$ in the "Kui-Du-Wu" area are mainly composed of mineral dust, organic matter and sulfate. The concentration of regional particulate matter is greatly affected by dust, volatile organic compounds (VOCs) and coal combustion. In 2016, the average PM$_{2.5}$ concentration in the "Kui-Du-Wu" area was 56μg/m$^3$, an increase of 23.4% compared to 2015. Among them, Kuitun, Dushanzi, and Wusu were respectively 63μg/m$^3$, 54μg/m$^3$, 52μg/m$^3$, an increase of 18.9%, 28.6% and 23.8% compared with 2015. The annual average concentrations of SO$_2$, NO$_2$, CO, and O$_3$ are 6μg/m$^3$, 25μg/m$^3$, 1.4mg/m$^3$, and 89μg/m$^3$, respectively. The annual average concentrations of SO$_2$ and CO were the same as in 2015, and the concentrations of NO$_2$ and O$_3$ increased by 8.7% and 2.3% compared with 2015.

3. Analysis of the composition characteristics of VOCs in the atmospheric environment of Kuitun City

3.1. Types and concentration levels of VOCs in the atmospheric environment

There are many types of volatile organic compound VOCs in the atmosphere, and there are certain differences in the composition of VOCs in the atmospheric environment of different regions. 102 kinds of volatile organic compounds can be detected in Kuitun's atmospheric environment, including 58 kinds of non-methane hydrocarbons, 13 kinds of oxygen (nitrogen) VOCs, and 31 kinds of halogenated hydrocarbon VOCs. Among them, non-methane hydrocarbons include 7 kinds of low-carbon alkanes C$_3$-C$_5$, 11 kinds of low-carbon alkenes C$_3$-C$_5$, 33 kinds of high-carbon alkanes C$_6$-C$_{13}$, 1 kind of high-carbon alkenes C$_6$-C$_{13}$, 1 kind of alkynes, 16 benzene series; oxygen (nitrogen) VOCs contain 6 aldehydes, 5 ketones, 1 ethers, 1 nitrogenous organics; halogenated hydrocarbons VOCs contain 5 halogenated aromatic hydrocarbons, 16 kinds of halogenated alkanes, 7 kinds of halogenated alkenes, 3 kinds of Freon.
According to the online monitoring data of total volatile organic compounds (VOCs) at the Kuitun site, the total concentration of volatile organic compounds in the atmospheric environment of Kuitun City in 2018 reached an average of 49.370 ppb, the highest value was 81.784 ppb in December, and the lowest value was 27.840 ppb in July. The change trend of the concentration in each month of the year is shown in Figure 1, showing that the concentration of VOCs in winter coal-fired heating in January, February, November, and December is significantly higher than other months.

The top ten compounds with the average concentration of VOCs in the atmospheric environment of Kuitun City throughout the year are acetylene (5.872 ppb), ethane (5.416 ppb), propane (5.054 ppb), n-butane (3.016 ppb) and isopentane (2.676 ppb), isobutane (2.606 ppb), ethylene (2.421 ppb), n-pentane (1.750 ppb), carbon tetrachloride (1.701 ppb), acetone (1.351 ppb), they are in total volatile organic compounds the ratio in Figure 2.

3.2. Source analysis of VOCs in the atmospheric environment
The emission sources of VOCs in the atmospheric environment include natural sources and anthropogenic sources. Natural sources mainly refer to VOCs emitted by plants, and most cities mainly...
emit VOCs from anthropogenic sources. Anthropogenic sources can be divided into three categories: stationary sources, mobile sources and fugitive emission sources. Among them, stationary sources include fossil fuel combustion, solvent (paint, coating) use, waste combustion, petroleum storage and transportation, as well as petrochemical and steel industries and metal smelting; mobile sources include emissions from vehicles, airplanes, ships and other vehicles, as well as emissions from non-road emission sources; unorganized emission sources include biomass combustion and the volatilization of solvents such as gasoline and paint. Studies have shown that different VOCs species are closely related to different sources, and the sources of VOCs can be identified by molecular marker methods. For example, acetylene and ethylene are important indicator species for fossil fuel and biomass combustion [2], ethane, propane are components of motor vehicle exhaust emissions [3], isopentane, n-pentane, isobutane, and n-butane are characteristic substances of oil volatile [4], and isopentane is often used as an indicator of oil volatile tracer.

There are many industrial enterprises around Kuitun, especially Dushanzi to the south. Dushanzi Petrochemical has 10 sets of oil refining units including 10 million tons of distillation, 2 million tons of hydrocracking, 1 million tons of ethylene, 900,000 tons of polyethylene, and 550,000 tons of poly 11 sets of chemical plants such as propylene. The raw materials for the production of polyethylene and ethylene all include ethane and acetylene. However, ethane, propane, and acetylene have relatively low activity. They have a long life in the atmosphere and can exist stably in the atmosphere. This partly explains the sources of acetylene, ethane, and propane, which are the top three volatile compounds in Kuitun’s atmospheric environment throughout the year. In addition, Figure 3 shows the seasonal variation of the concentration of main volatile compounds in Kuitun’s atmospheric environment. The concentrations of acetylene, ethane and propane in the ambient atmosphere of Kuitun are higher in spring and winter. On the one hand, it shows that coal-burning waste gas for heating in winter is one of the sources of VOCs in the atmosphere. The main fuel of the factory is also coal, which emits a large amount of olefin and paraffin waste gas. In addition, Kuitun is affected by topography in winter and is located in the inversion zone on the northern slope of Tianshan Mountain. It is affected by the quasi-static wind of Tianshan Mountain. The frequency of quiet wind in winter is high, and the average wind speed is only 1.3 m/s. Therefore, the poor diffusion of pollutants in Kuitun in winter has exacerbated the problem of volatile organic compounds in the urban atmosphere.

Figure 3. Seasonal changes in the concentration of main volatile compounds in the atmospheric environment of Kuitun City
In spring (March, April, May) the temperature rises and the average wind speed is relatively high, so the volatile organic compounds (TVOC) value should decrease. However, from Figure 3, the concentration of acetylene, ethane and propane in Kuitun’s atmospheric environment is rather large. This is mainly due to the resumption of work and production in many small and medium-sized industrial enterprises around Kuitun in the spring, and industrial production has caused a large amount of volatile organic compound emissions. In addition, ethane and propane are also components of motor vehicle exhaust emissions. The concentration of these two components in Kuitun’s atmosphere is high throughout the year, which also indicates the existence of mobile vehicle pollution. The isopentane, n-pentane, isobutane, and n-butane, which are characteristic of oil volatile substances, are all in the forefront of the concentration of atmospheric volatile organic compounds in Kuitun, indicating that oil volatilization is also the main source of pollution. In short, the main sources of volatile organic compounds in the atmospheric environment of Kuitun are chemical production, oil volatilization, fuel combustion, and motor vehicle exhaust.

4. Countermeasures for the prevention and control of VOCs in the atmospheric environment of Kuitun City [5]

4.1. Strengthen source control and implement pollution source compliance treatment

According to the analysis of the chemical composition and source of volatile organic compounds in the Kuitun atmosphere, reducing industrial source emissions is the foundation of governance. First, we must strengthen source control. Adjust the energy structure, control coal consumption, formulate raw coal reduction plans, and clarify the reduction tasks of all parties. Strict environmental access, prohibiting new construction of petrochemical, thermal power, steel, cement, coal chemical, industrial silicon and other "three high" projects in the "Kui-Du-Wu" area, and strictly control the amount of new sewage. Secondly, we must implement pollution source compliance treatment. Clean up and rectify "scattered and polluted" enterprises, implement discharge standards for industrial enterprises, implement special discharge limits for petrochemical, thermal power, steel, cement, and coal-fired boiler industries, achieve stable discharge of various industrial pollution sources, and environmental compliance has become the ultimate goal of normalcy.

4.2. Improve the comprehensive management level of the city, establish and improve the joint prevention and control system

The effective prevention and control of volatile organic compounds in the urban atmosphere is closely related to the level of urban comprehensive management. It is necessary to speed up the renovation of decentralized coal-fired boilers, eliminate coal-fired heating boilers with a steam capacity of less than 20tons/hour, and implement cogeneration, gas-fired transformation, and electric heating transformation. Controlling the sources of solvent usage and vehicle exhaust emissions is also an effective measure to significantly reduce VOCs emissions in the short term. In addition, the use of plants to restore the atmospheric environment [6] is also a beneficial exploration, that is, to use the ideas and technologies of atmospheric bioremediation to guide urban landscaping, environmental planning and ecological environment construction, select appropriate plant species, and strengthen the ecological protection system around the city. And greening construction on both sides of the road, vigorously promote the greening project of industrial enterprises. In addition, a regional air environment joint law enforcement supervision mechanism should be established, and regional air environment joint law enforcement inspections should be carried out to rectify illegal polluting enterprises. Jointly investigate and deal with cross-border air pollution cases, and report accidental emissions information in a timely manner. Carry out the construction of a regional air environment quality forecast system to realize risk information research and judgment and early warning functions. Improve environmental supervision capabilities, build regional air quality monitoring networks, build regional air monitoring super stations, and increase
monitoring stations. Full coverage of online monitoring of key pollution sources, and promotion of
online monitoring of volatile organic compounds.

5. Conclusion
The "Kui-Du-Wu" region is densely populated with industrial enterprises and is located in the periphery
of crowded areas. The regional atmospheric composition is complex, the concentration of VOCs is high,
and the natural environmental problems are serious. Strengthen regional environmental protection
efforts as the main line, take comprehensive reduction of air pollutant emissions as a means, establish a
unified planning, unified monitoring, unified supervision, unified assessment, unified and coordinated
regional air pollution prevention and control work mechanism, and do a solid job in air pollution
prevention and control.

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