Scientific and Social Research, 2024, Volume 6, Issue 6
https://ojs.bbwpublisher.com/index.php/SSR

Research on Policy Suggestions for Oil and Gas Recovery in Port Oil and Gas Chemical Terminal

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Abstract: The transportation industry is a forerunner of social and economic development and has always been an active green and ecological development practitioner. Jiangsu Province is a major port province. In 2023, the cumulative cargo throughput of Jiangsu ports has reached 3.51 billion tons, accounting for 20.67% of the total port throughput of the country. The overall development of China's port volatile organic compounds (VOCs) governance industry is still in the early stage, and most port enterprises in Jiangsu Province have not established a sound VOCs monitoring and regulatory system. Therefore, it is of great importance to carry out research on the regulatory countermeasures of VOCs emission in Jiangsu port for the green development of transportation in China and Jiangsu Province. The research results show that there are some problems in Jiangsu oil and gas chemical terminals, such as insufficient supporting policies for oil and gas recovery, non-standard operation mode of oil and gas recovery, high investment in oil and gas recovery construction, low enthusiasm of port and shipping enterprises in construction, low utilization rate of oil and gas recovery facilities, insufficient front space of built terminals, and oil and gas recovery technology maturity and safety need to be improved. Therefore, it is proposed to strengthen the management of the whole process of oil and gas recovery construction in new terminals, strictly implement the management measures of oil and gas recovery in terminals, and strengthen the regular detection of VOC emission concentration.

Keywords: Volatile organic compounds; Oil and gas recovery; Green development of transportation

Online publication: July 9, 2024

1. Introduction

During the operation of port petrochemical terminals and bulk chemical ships, more volatile organic compounds (VOCs) will be produced. VOCs are important precursors of ozone and PM2.5 in the atmospheric environment, which will cause atmospheric environmental problems such as haze and photochemical smog around the port. At the same time, it is difficult to establish VOCs pollution prevention and control system due to the complex sources of VOCs emissions, diverse forms of emissions, and many kinds of substances. Hence, ways to meet the actual situation in China to promote and carry out VOCs pollution control in port terminals is a difficult and complex task.

The oil and gas components emitted by oil products usually include alkanes, cycloalkanes, alkenes, and aromatic compounds, which are volatile organic compounds. VOCs include non-methane-containing hydrocarbons (alkanes, olefins, alkynes, aromatics, and so on), oxygen-containing organic compounds (aldehydes, ketones, alcohols, ethers, and so on), chlorine-containing organic compounds, nitrogen-containing organic compounds, sulfur-containing organic compounds, and so on, all of which can participate in atmospheric photochemical reactions. Liu et al. and Li et al. mentioned that VOCs in the petrochemical industry have the characteristics of complex composition, large emission, dispersed emission points, and mostly unorganized emission [1–2]. Some VOCs components have strong photochemical reactivity and are important precursors of PM2.5 and O3 in the atmospheric environment. Zhu et al. studied the assessment method of VOC leakage emissions of petrochemical enterprises, and the research showed that the petrochemical industry, as a key VOCs emission industry, ranked first in the emission of industrial sources in China [3]. Gao et al. studied the emission characteristics and pollution potential of volatile organic compounds in petrochemical enterprises, and the research showed that there were many VOCs emission links and complex components in petrochemical enterprises [4]. Volatile organic compounds (VOCs) can cause multiple adverse effects, so it is of great significance to study and install oil and gas recovery systems. The study of He et al. shows that VOCs usually contain some components that can directly affect human health [5]. Excessive inhalation in a short period of time will make people feel headache, nausea, vomiting, fatigue, and so on. In severe cases, convulsions and coma will occur and will harm people's liver, kidney, brain, and nervous system.

Additionally, Cheng et al. showed that VOCs are also an important precursor of secondary pollutants formed by photochemistry, and their ozone generation potential is large [6]. Zhang et al. studied the source and activity of non-methane hydrocarbons (NMHC) in the atmosphere of Beijing and its surrounding areas [7]. It was mentioned in the paper that ozone is a light blue gas, about 90% of which is distributed in the stratosphere of the atmosphere, and about 10% of which is distributed in the troposphere near the ground. Ozone in the stratosphere has a protective effect on human beings and the environment. The tropospheric ozone is a kind of biological harmful pollutant that can cause urban photochemical smog and its harm to the environment and human health is very serious. Ozone has become the primary pollutant in many areas of the country, aggravating air pollution. Oil volatilization is usually caused by the volatilization of light components in oil products, and these light components are very important in improving the quality of oil products. Radian Corp et al. mentioned that oil evaporation not only poses a threat to the environment and employee health and safety but also reduces the quantity and quality of oil products due to the loss of volatile light components [8]. According to the research of Huang et al. and Mou et al. on the loss of oil storage and transportation, the volatilization of oil storage and transit accounted for about 8% of the total VOCs emission, which resulted in a large loss of oil and caused energy waste [9–10]. Therefore, it is of great significance to recover and utilize volatile oil and gas.

The transportation industry is a forerunner of social and economic development and has always been an active green and ecological development practitioner. The Law of the People's Republic of China on the Prevention and Control of Air Pollution promulgated in September 2015 proposed that "oil and gas storage depots, refueling stations, crude oil and refined oil terminals, crude oil and refined oil transport vessels and oil tanker and gas tank vehicles shall be installed and maintained in normal use following relevant state regulations." The government has implemented the "Air Pollution Prevention and Control Law of the People's Republic of China", the "Opinions on Deepening the Battle against Pollution Prevention and Control" and the requirements of the "14th Five-Year Plan" comprehensive work plan for energy conservation and emission reduction, strengthen the coordinated control of fine particulate matter and ozone and reduce the emission of volatile organic compounds from crude oil and refined oil terminals and oil tankers. On July 24, 2022, the

Ministry of Ecology and Environment studied and drafted a notice on promoting the treatment of volatile organic compounds in crude oil product terminals and oil tankers (draft for comment), which emphasized the need to raise awareness and regard crude oil product terminals and oil tankers as an important area for the current treatment of volatile organic compounds.

Jiangsu Province is a large port province with a riverside and a dense water network. It has Lianyungang Port, Yancheng Port, Nantong Port, and other major national coastal ports; Nanjing Port, Suzhou Port, Zhenjiang Port, and other major inland ports such as Xuzhou Port and Wuxi Port. In 2023, the cumulative cargo throughput of ports in Jiangsu Province will be 3.51 billion tons, accounting for 20.67% of the total throughput of ports in the country. At present, most port enterprises in Jiangsu Province have not established a sound VOC monitoring and supervision system, have not carried out leak detection and repair (LDAR) work, are limited by the VOCs monitoring capacity, do not regularly carry out VOC pollutant monitoring, so that a large number of VOCs have not been effectively treated and directly discharged. Therefore, it is of great significance to carry out research on the regulatory countermeasures of VOC emission in port areas of Jiangsu Province for controlling the unorganized emission of VOCs in ports.

2. Results and discussion

2.1. Policy and regulation analysis of oil and gas recovery construction at the terminal

In August 2015, the Ministry of Transport issued a notice on the Implementation Plan of the Special Action on Pollution Prevention and Control of Ships and Ports (2015–2020), in which it proposed to carry out special control of pollution from port operations in key areas such as the Bohai Sea, the Yangtze River Delta, the Pearl River Delta and the Yangtze River trunk line in batches and categories to carry out pilot work on oil and gas recovery at terminals. The government has also issued the "Terminal oil and gas recovery facilities construction technical specifications."

The 2015 revised version of the "Air Pollution Prevention Law of the People's Republic of China" promulgated in September 2015 also proposed that "oil storage and gas storage, refueling stations, crude oil, and refined oil terminals, crude oil and refined oil transport ships and tank trucks, gas tank vehicles, and so on, should be installed following the relevant provisions of the state and maintain normal use of oil and gas recovery devices."

In February 2016, to implement the task requirements of oil and gas pollution control at the terminal, the Ministry of Transport, the Ministry of Environmental Protection, the Ministry of Commerce, and the General Administration of Quality Supervision, Inspection, and Quarantine jointly formulated the Action Plan for Oil and Gas Recovery at the Terminal of Crude Oil Products. In the next step, relevant departments will promote the oil and gas recovery work at the terminal in an orderly manner according to the Action Plan. To implement the relevant requirements of the "Three-year Action Plan to win the Blue-Sky Defense War" and ensure the completion of the "13th Five-Year Plan" environmental air quality improvement goals and tasks, the Ministry of Ecology and Environment has formulated the "2020 Volatile Organic Compounds Management Plan." The plan clearly defined the objectives of the work, through the key actions, VOC emissions decreased significantly, and summer O3 pollution has been curbed to a certain extent, with the key directions including strengthening the supervision of oil storage, transportation, and marketing, and improving the monitoring and monitoring system.

In November 2021, the "Opinions of The State Council on Fighting the Tough Battle against Pollution Prevention and Control" was issued, proposing to fight the tough battle against ozone pollution. The plan focuses on ozone pollution in summer and autumn and vigorously promotes coordinated emission reduction of volatile organic compounds and nitrogen oxides. Focusing on petrochemical, chemical, painting,

pharmaceutical, packaging and printing, oil storage, transportation and marketing, and other industries, they can safely and efficiently promote the comprehensive treatment of volatile organic compounds and implement the source replacement project of raw and auxiliary materials and products. They should improve the volatile organic matter product standard system and establish a low volatile organic matter content product labeling system. The volatile organic compounds monitoring technology and emission calculation methods are improved by studying the timely inclusion of volatile organic compounds in the scope of environmental protection tax when the relevant conditions are met.

2.2. Analysis of standards and specifications for construction of oil and gas recovery facilities at wharfs

2.2.1. Foreign oil and gas recovery facilities construction standards and specifications

At present, developed countries or regions abroad have set up a relatively complete set of standards and norms for the construction and application of oil and gas recovery facilities. For example, Annex VI to MARPOL 73/78, Regulations for the Prevention of Air Pollution from Ships, includes the scope of the convention and the types of ships, the regulatory responsibilities of the member states, and the volatile organic compounds caused by liquid cargo ships are discussed. This involves the release of steam, the safety standards of steam collection systems, the implementation period of terminals with steam release control systems installed (three years after installation), and so on. The content of the SOLAS convention stipulates the inert gas composition, inert gas generation system, and oxygen content safety standards that must be equipped with tankers. The SOLAS Convention requires inert gas systems for cargo ships of 20,000 DWT or more built after July 1, 2002, and 8,000 DWT or more built after January 1, 2016. In addition, the volatile gases produced by oil tankers during the loading process are flammable and explosive dangerous gases. From the perspective of safety, the International Maritime Organization has issued relevant regulations, including MSC/Circ.585 circular: Standards on Steam Emission Control Systems, MEPC.69 (38) Amendments to the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code) in the MEPC Resolution List, and MEPC.70 (38) amendments to the Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (BCH Code).

2.2.2. Domestic oil and gas recovery facilities construction standards and specifications

Oil and gas recovery facility is a general term for oil and gas collection system and oil and gas recovery device. An oil and gas collection system refers to a system that collects oil and gas by using closed pipes, pipelines, and other process equipment. An oil and gas recovery device refers to a device for recovering oil and gas generated during the loading of oil products. At the same time, a complete terminal oil and gas recovery system, in addition to the onshore oil and gas collection system and oil and gas recovery device, also requires the ship transporting oil products to have a supporting closed cargo bin and oil and gas collection pipeline. The Code for Design of Oil and Gas Recovery Facilities for Oil Loading Systems (GB50759-2012), issued on May 28, 2012, clearly requires that “oil and gas recovery facilities should be provided in the loading system of gasoline, naphtha, aviation kerosene, solvent oil or similar oil products.” It also includes the safety design content of oil and gas recovery facilities of oil storage depots, gas stations, and chemical plants.

On September 1, 2017, the Ministry of Transport issued the “Technical Specification for the Construction of Oil and Gas Recovery Facilities in Terminals” (JTS 196-12-2017), which summarizes the experience of design, construction, inspection, acceptance, and maintenance management of oil and gas recovery facilities in terminals in China, extensively solicits opinions and suggestions from inside and outside the industry, and draws on the construction standards and experience of foreign oil and gas recovery facilities in terminals. It is

formulated according to the development needs of China's oil wharf construction. The code puts forward clear requirements for the design, construction, inspection and acceptance, operation, and maintenance management of terminal oil and gas recovery facilities. Among them, it is mandatory to stipulate that "when the oil and gas recovery device is arranged on the dock, the treatment process that may produce open flame shall not be used" and "oil and gas recovery facilities are strictly prohibited from overloaded operation." At the same time, it is also clearly required that "the safety facilities of the newly built terminal project and the oil and gas recovery system should be designed, constructed, and put into use at the same time as the main project."

To protect the safety of ships, wharves and oil and gas recovery devices, shore safety devices should be set up in the wharfs' oil and gas recovery facilities according to relevant standards and specifications. In July 2020, the Ministry of Transport issued the "Onshore Safety Device for Quay Oil and Gas Recovery Vessels" (JT/ T 1333-2020), which puts forward specific requirements for the manufacturing, inspection, and use of onshore safety devices for quay oil and gas recovery facilities, and specifies the composition, technical requirements, test methods and inspection rules of onshore safety devices for quay oil and gas recovery vessels. The formulation and release of this standard provide an important safety guarantee for the promotion and application of oil and gas recovery devices in wharves.

On December 28, 2020, the Ministry of Ecology and Environment approved and issued the "Air Pollutant Emission Standards for Oil Storage terminals" (GB20950-2020), which put forward mandatory provisions for the operation of oil distribution to oil tankers, requiring that "the corresponding oil storage terminals of the terminals with 10,000-ton and above oil berths should be closed to collect oil and gas generated when oil distribution to the oil tankers controlled by GB 20951 and sent to the oil and gas treatment unit for recycling."

3. Analysis of the current situation and problems of oil and gas recovery (Taking Jiangsu Province as an example)

3.1. Analysis of typical cases

3.1.1. The wharf built by the enterprise

Due to the limited loading and unloading space at the front of the terminal, the Wuxi City Changshan Oil Depot of Jiangsu Jiangyin Petroleum Branch of Sinopec invested 5.8 million yuan in 2013 to build a set of oil and gas recovery system in the rear reservoir area. The main cargo is naphtha, and the processing capacity of the oil and gas recovery system is 500 m^3/h by using lean oil absorption and adsorption processes. In 2013, Jiangyin Municipal Environmental Protection Bureau conducted an environmental protection inspection on the oil and gas recovery system of the oil storage depot, and issued a notice of qualification, requiring third-party testing institutions to carry out annual monitoring work on the oil and gas recovery project and submit annual monitoring reports. After monitoring by the testing institution, the concentration of exported oil and gas is about 2.13 g/m^3, and the removal efficiency is 97.4%, which meets the emission requirements of the Technical Specification for Acceptance and Testing of Air Pollution Control Projects of Oil Storage and Gas Stations (HJ/ T431-2008).

3.1.2. General oil, gas, and chemical terminals

Changshu City Changshu Huihai Chemical Storage Co. Ltd. invested 6 million yuan in 2012 to build two sets of oil and gas recovery systems in the rear reservoir area due to the limited loading and unloading space at the front of the terminal, mainly loading and unloading of refined oil products, using condensation-membrane separation-adsorption process, oil and gas recovery system processing capacity of 200 m^3/h.

Changshu Municipal Environmental Protection Bureau conducts environmental protection inspections on the oil and gas recovery system and issues a notice of qualification, requiring third-party testing agencies to

carry out annual monitoring work on the oil and gas recovery project and submit annual monitoring reports. After monitoring by the testing institution, the concentration of exported oil and gas is about 3.35 g/m^3, and the removal efficiency is 98.4%, which meets the emission requirements of "Technical Specifications for Acceptance and Testing of Air Pollution Control Projects of Oil Storage and Gas Stations" (HJ/ T431-2008).

3.2. General case analysis

3.2.1. Large-capacity oil and gas recovery facilities

Nanjing Yangzi Petrochemical Co. Ltd. invested 7 million yuan in 2014 to build a set of oil and gas recovery systems at the ship-shore interface, using a condensation + adsorption process, oil and gas processing capacity of 700 m^3/h. However, the port of the ship has not been reformed, so the system has not been put into use. Yangzi Petrochemical-BASF Co. Ltd. invested 5 million yuan in 2015 to build a set of oil and gas recovery systems at the ship-shore interface, with a processing capacity of 500 m^3/h.

3.2.2. Small capacity oil and gas recovery facilities

Zhenjiang City Jinhai Hongye (Zhenjiang) Petrochemical Co., Ltd., invested 2 million yuan in 2017 to build a set of oil and gas recovery systems in the rear reservoir area due to the limited loading and unloading space at the front of the terminal, using the condensation + adsorption process, with processing capacity of 300 m^3/h.

3.3. Summary

Existing oil and gas recovery system facilities in Jiangsu Province have a total processing capacity of 4600 m^3/h. Among them, the oil and gas processing capacity of Nanjing Yangzi Petrochemical Co., Ltd. and Changshan Oil Depot of Jiangsu Jiangyin Petroleum Company is 700 m^3/h and 580 m^3/h respectively. The oil and gas recovery system of other oil and gas chemical terminals is relatively small, and most of them are 300 m^3/h, mainly serving ships along the river and inland trade. There is no equipment and facilities with large oil and gas processing capacity, and the construction of oil and gas recovery systems in coastal oil and gas chemical terminals is relatively slow.

3.4. Analysis of the main problems

3.4.1. Lack of supporting policies and control means for oil and gas recovery

The oil and gas management work of the oil and gas chemical terminal involves many departments such as environmental protection, port transportation, safety supervision, and so on. For a long time, the competent Department of Environmental Protection has been responsible for approving the environmental impact assessment of construction projects and the acceptance of environmental protection facilities, but the acceptance and management department of the oil and gas recovery system has not been clearly stipulated. At the same time, the port authorities, as the industry management department, are also less involved in environmental protection supervision, and the management department has no enforcement power and punishment means. There is no mandatory provision for the construction of an oil and gas recovery system at the built crude product terminals.

3.4.2. The operation mode of oil and gas recovery is not standardized

At present, the process of connecting ships to oil and gas recovery facilities and the identification of related safety responsibilities have not been standardized. Except for the terminals of enterprises such as PetroChina and Sinopec, the oil products transported by ports belong to the owners, and the ports only have the right to transport the oil products, without the right to sell the oil products. Therefore, after the installation of oil and gas recovery equipment, there are problems with ownership of the recovered oil and sales disposal.

3.4.3. The investment in oil and gas recovery construction is high, and the enthusiasm of port and shipping enterprises is not high

The investment in the terminal oil and gas recovery system includes the cost of the processing plant and the cost of the receiving plant. At present, the investment in the construction of a set of oil and gas recovery equipment needs millions of yuan, and the enterprise is worried that the utilization rate will not be high after the completion, resulting in the difficulty of equipment and facilities investment recovery, so the port enterprise is not enthusiastic about transformation.

3.4.4. Low utilization rate of oil and gas recovery facilities

Up to now, Jiangsu Province has built oil and gas recovery system facilities, the total treatment capacity of the existing facilities is 4600 m^3/h, and the actual use of treatment capacity is 3900 m^3/h. Due to the lack of installation of oil and gas receiving pipelines, standard connectors, and inert gas generation devices, most oil and gas recovery conditions are not available for oil and gas collection.

3.4.5. There is insufficient space at the front of the built wharf, which affects the reconstruction and construction

There is insufficient space for the renovation of the front loading and unloading area of the existing oil and gas chemical terminals. The requirements for the construction of oil and gas recovery at the terminals were put forward during the "12th Five-Year Plan" period, but most of the existing terminals have not reserved the construction conditions for the installation of oil and gas recovery equipment, and there are problems such as limited site space, no gas pipeline, no ship docking safety unit, gas transmission arm without emergency disconnection device, and inadequate auxiliary facilities.

3.4.6. The development and safety of oil and gas recovery technology need to be improved

The complete terminal oil and gas recovery system consists of three parts: a transport vessel with a closed hold and a gas phase loop; the coastal receiving device of marine oil and gas and the pipeline connecting to the processing device; and onshore oil and gas recovery and treatment equipment. There is no uniform standard for the interface (breathing valve) specifications of the coastal receiving device of the ship's oil and gas, and the problem is particularly obvious for the multi-cargo foreign trade terminals. At the same time, the escaped oil and gas is actually a mixture of various liquid petroleum, and its volume ratio in the air is about 1% to 10%, which is a flammable gas, and the risk of oil tanker fire and explosion should be strictly controlled, which is also an important safety factor restricting the promotion and application of oil and gas recovery technology at the terminal. The stability and safety of the oil and gas recovery system itself need to be constantly tested in use, and relevant technologies are still being improved. Shipping companies are worried that the oil and gas recovery system will be subjected to harmful impacts during the loading process, which will threaten the safety and stability of the ship system and affect the shipment schedule.

4. Countermeasures and suggestions

4.1. Strengthen the management of the whole process of oil and gas recovery construction of new terminals

Strict planning in the planning stage to fully consider the reduction of emissions, environmental protection, and other factors, to promote the integration of resources along the river and the coastline, from the source to achieve ecological and environmental protection. For port projects that have not passed the EIA review,

the relevant departments shall not approve or record, shall not provide land, shall not approve the start of construction, and shall not issue port operation licenses. Strict design and construction in the preliminary design review to ensure that the environmental protection design of the special article meets the "Port Engineering Environmental Protection Design Code" (JTS 149-1-2007) and "Terminal Oil and Gas Recovery Facilities Construction Technical Code" (trial) (JTS 196-12-2017) Article 3.0.5. The safety facilities of the oil and gas recovery system shall be designed, constructed, and put into use at the same time as the main project, which is a mandatory provision, strengthening the management of the whole process of the oil and gas recovery construction of the new terminal, and ensuring that the oil and gas recovery system and the main project of the terminal are designed, constructed and put into operation simultaneously.

4.2. Implementing measures to recover oil and gas from terminals

Local municipal people's governments are responsible for the work of oil and gas recovery and management within their administrative areas, formulating oil and gas recovery and management plans, and strictly controlling and planning to reduce the total VOC emissions and achieve the goal of improving atmospheric environmental quality.

The local port transport administrative department shall assist the environmental protection administrative department in urging and guiding enterprises to formulate oil and gas management plans, organizing inspection and acceptance work, and filing with the local port transport administrative department. In the process of use, the supervision and inspection of the oil and gas recovery and management of crude oil products terminal are carried out, and the problems found in the inspection are required to clarify the work responsibilities of port operators, implement management measures, and rectify and improve within a time limit. At the same time, regularly carry out on-site inspection of oil and gas return facilities, following the relevant emission standards in the "Technical Specifications for the Construction of Oil and Gas Recovery Facilities at Terminals" (JTS 196-12-2017), check and report the implementation of relevant work of enterprises, and ensure the completeness rate of oil and gas recovery equipment and facilities that have been built.

Port operators, under local air pollution prevention and control requirements, relevant standards and norms for oil and gas recovery and management, as well as the "Evaluation Standards for the management of oil and gas recovery Facilities at Docks" planned to be compiled and issued, and combined with the actual situation, prepare oil and gas recovery and management plans, implement personnel responsibilities, management costs, work measures, completion time, and management targets. It can be implemented in stages according to the construction scale of oil and gas recovery facilities, oil and gas processing capacity, and investment.

4.3. Strengthen the regular detection of VOCs emission concentration

Municipal port transportation management departments in collaboration with environmental protection authorities, based on pilot demonstrations, vigorously support the construction of VOC detection points in major ports in the province, implement regular testing of emission concentrations, and accelerate the grid of VOC detection points covering the province's crude product terminals. They should also install VOC testing equipment in the terminal area engaged in the loading and unloading of oil and gas chemicals and report the testing data statistics to the municipal environmental protection department following the relevant technical requirements, and the port transportation management department can obtain the VOCs testing data record form at any time. At the same time, port operators regularly grasp the effectiveness of port oil and gas recovery management measures through VOC detection data and strengthen the control effect of VOCs.

Funding

The 2023 Youth Science and Technology Innovation Project of the Water Transport Science Research Institute of the Ministry of Transport; Project name: The study on VOC emission monitoring technology and regulatory measures in port areas; Project number: 0100062310

Disclosure statement

The authors declare no conflict of interest.

Author contributions

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