Assessment and countermeasure analysis of ship pollutant receiving, transshipment and disposal capacity-- take Port L as an example

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Abstract. In order to implement China's environmental protection laws, regulations and technical policies, the ministry of transport of the People's Republic of China has issued the guidelines for the construction of facilities for the reception, transfer and disposal of pollutants from ports and ships[1]. Based on Port L vessel pollutant receiving disposal scheme work, put forward to the ship pollutants measurement standard, evaluation ship oil sewage, chemical washing water, discharge of sewage, life rubbish and receiving ability in Port L, Put forward Suggestions on the integration of pollutant receiving, transshipment and disposal from ships, effectively enhance the level of L port vessel pollutant control.

1. Introduction
According to annex I to VI of marpol 73/78 convention[2], the pollutants of ships mainly include oil sewage, domestic sewage, chemical cleaning water and domestic garbage[3-4]. If discharged directly without treatment, these pollutants can have serious impacts on the surrounding waters. Port L is the main port in Sichuan, Yunnan and Guizhou, and the only channel for the southeast of Sichuan to go to sea and southwest of Chongqing to go to sea in southeast Asia. According to the relevant standards of the industry, considering the actual situation of ships in inland ports, it is of great significance to calculate the scale of pollutant production of ships, evaluate the level of pollutant reception, transfer and disposal of ships, find out the key problems existing in pollutant treatment of ships, and give corresponding construction measures.

2. Literature review
The development of shipping industry has brought about serious environmental pollution problems, so it is necessary to study the model of the capacity construction for the reception and disposal of ship pollutants. In recent years, the research on the acceptance, transshipment and disposal of ship pollution
is as follows.

Ye (2018)[5] proposed the connotation and composition of the vessel's pollutant reception and disposal capacity, and proposed the model selection. Bian (2016)[6] analyzed the common problems existing in the reception and disposal of vessel oil sewage in China's coastal ports based on the construction of vessel oil sewage reception and disposal capacity and the status quo and characteristics of operation management in coastal ports of Guangdong province, and proposed countermeasures and Suggestions for the prevention and control of vessel oil sewage in ports. Liu (2019)[7] took Jining city as an example to study the status quo of ship pollutant discharge, predicted its ship pollutant discharge, and developed a detailed model for the management of ship pollutant reception and disposal at Jining port. Tang (2018)[8] through the inland river port of jiangsu province, water service area, locks and other pollutant receiving transhipment on the disposal process of investigation and analysis, this paper points out the existing problems, put forward: change "- ship to shore" for ", ship, ship to shore "duplicate and joint supervision of the receive mode, speed up the informatization construction, strengthening the research suggested measures such as real-time monitoring technology. Zhong (2017)[9] analyzed the status quo and effective management countermeasures of pollutant reception, transfer and disposal facilities for ships in inland river ports in Guangxi province , so as to improve the capacity of pollutant reception, disposal and management control of ships in ports. Xie (2011)[10] started from the types and treatment methods of pollutants generated by inland water vessels, made an overall analysis of the causes of problems in the onshore receiving mode of pollutants from inland water vessels, and proposed improvement measures. Wu (2016)[11], in view of the environmental pollution caused by the development and expansion of shipping industry, analyzed the current situation of ship pollution in China and its treatment technology, and put forward reasonable Suggestions. Chen (2013)[12] through the analysis of the management of Guangzhou port vessel pollutant receiving industry present situation, the content as well as market conditions and requirements, a universal problem for the industry, to help improve the level of industry regulations and guide the enterprise development, put forward the strict market access, the research of planning, and clear management scope, build a supervision system, play a role of association and other measures. Sheng(2016)[13] to the IMO international convention on the prevention of pollution caused by the (MARPOL convention) proposed by the convention and rules of ship pollution prevention requirements are analyzed, through the analysis of foreign and domestic and international standards, puts forward the main problems of existing standards in our country, to solve these main problems concerning the development of ship pollution prevention standards are given.

3. Methods used

3.1. Analysis method for the production of oily sewage, domestic sewage and garbage from ships

The production of oily sewage, domestic sewage and garbage from ships was analyzed using the empirical formula in ‘requirements for pollutant reception capacity of ports, wharves, loading and unloading stations and ships repairing and dismantling units’ (JT/T 879-2013).

\[ T_i = (f_N \cdot W_N \cdot N^+ + f_T \cdot W_T \cdot T^+ + f_G \cdot W_G \cdot G) \alpha \]

In the formula: \(T_i\)——Class i pollutant yield per ton/year;

\(i\) ——Class I pollutants,1~3, respectively represent oily sewage, domestic sewage and garbage of ships;
Weight coefficient, where in $\sum f_i = 1$, the parameter values are shown in Table 1:

- $W_N$ — The recommended mean amount of pollutants generated by ships per vessel, in tons per vessel, is shown in Table 1.
- $W_T$ — The recommended average amount of pollutants generated by ships per 10,000 gross tons is in tons per ton, and the parameter values are shown in Table 2-1.
- $W_G$ — The recommended average pollutant volume generated per ton of cargo throughput, in tons per ton, is shown in Table 1.
- $N$ — The annual total vessel number at the port shall be per vessel number per year;
- $T$ — The total tonnage of ships in and out of the port is 10,000 tons per year;
- $G$ — The annual port cargo throughput is 10,000 tons per year;
- $\alpha$ — The correction coefficient and the parameter values are shown in Table 1.

### Table 1. Calculates the parameter values

| Technical parameters | Tanker oily water ($i=1$) | Residual oil and sewage from engine room ($i=2$) | Ship garbage ($i=3$) | Sewage ($i=4$) |
|----------------------|---------------------------|-----------------------------------------------|---------------------|---------------|
| Recommended mean pollutant level | $W_N$ | 5.60 | 0.20 | 0.07 | 0.48 |
|                        | $W_T$ | 6.60 | 2.00 | 0.25 | 0 |
|                        | $W_G$ | 5.70 | 2.40 | 0.30 | 0 |
| Weight coefficient | $f_N$ | 0.31 | 0.10 | 0.10 | 1 |
|                        | $f_T$ | 0.37 | 0.90 | 0.40 | 0 |
|                        | $f_G$ | 0.32 | 0    | 0.50 | 0 |
| Correction coefficient | $\alpha$ | 0.90 | 0.30 | 0.35 | $t$ |

Note: 1. The average quantity parameter of domestic sewage is the average quantity of domestic sewage generated by each ship, and it is calculated according to the average number of crew members of each ship, which is 0.03 tons per person per day.

2. $t$ is the average length of stay in the port of each ship, in days.

### 3.2. Chemical tank washing water yield analysis method

The analytical method of chemical tank washing water yield can refer to the empirical formula of requirements for pollutant receiving capacity of ports, wharves, loading and unloading stations and ships repairing and dismantling units.

$$T = (0.1 \cdot WN \cdot N + 0.5 \cdot WT \cdot T + 0.4 \cdot WG \cdot G) \cdot 0.14$$

In the formula:
- $T$ — chemical tank washing water yield, unit ton/year;
- $WN$ — the recommended average quantity of pollutants generated by ships per vessel, in tons per vessel, 0.4;
- $WT$ — recommended value for the average amount of pollutants generated by a ship per 10,000 gross tons, 2.5 per ton;
- $WG$ — recommended value of average pollutant volume generated per ton of cargo throughput, in tons per ton, 1.5;
N —— total vessels entering the port annually, the unit is vessels per year;
T —— total tonnage of ships entering and leaving the port annually, in tons per year;
G —— annual port cargo throughput in tons per year.

4. Assessment of pollutant reception capacity of port to port vessels

4.1. L port pollutant estimation from incoming vessel

In order to systematically apply the calculation formula of ship pollutant production, we selected Port L in the Yangtze river basin to carry out the corresponding research. Port L is one of the only 28 major inland ports in Sichuan, Yunnan and Guizhou. A total of 60 cargo terminals and 107 berths (including 41 berths above 1000-ton level) have an annual comprehensive cargo handling capacity of 37.1 million tons. Port L international container terminal is the largest container terminal in Sichuan province, with a handling capacity of 1 million teu of containers and 3 million tons of groceries.

4.1.1. Estimation of oil and sewage production from ships

The output of oil and sewage from ships in Port L is in accordance with the 《requirements of pollutant receiving capacity of ports, docks, loading and unloading stations and ship repair and dismantling units》. In JT/T 879-2013, the calculation requirements for pollutant receiving capacity of ships in ports are as follows:

\[ T_1 = (fN \cdot WN + fT \cdot WT + fG \cdot WG \cdot G) \alpha \]  

In the formula:  
\( T_1 \) —— oil and sewage production per ton/year;  
\( f \) —— weight coefficient;  
\( WN \) —— the recommended average quantity of oil and sewage generated by ships per vessel, in tons per vessel;  
\( WT \) —— recommended average quantity of oil and sewage generated by ships per 10,000 gross tons, in tons per ton;  
\( WG \) —— recommended average quantity of oil and sewage generated per ton of cargo throughput, in tons per ton;  
\( N \) —— total vessels entering the port annually, the unit is vessels per year;  
\( T \) —— total tonnage of ships entering the port annually, in tons per year;  
\( G \) —— annual port cargo throughput, in tons per year;  
\( \alpha \) —— correction coefficient, parameter values are shown in the table 2.

| Table 2. calculated parameters of pollutant production |
|--------------------------------------------------------|
| Technical parameters | Residual oil and sewage from engine room (i=1) |
| Recommended pollutant level | WN | 0.20 |
| | WT | 2.00 |
| | WG | 2.40 |
| Weight coefficient | fN | 0.10 |
| | fT | 0.90 |
| | fG | 0 |
| Correction coefficient | \( \alpha \) | 0.30 |
According to the throughput of each port area of Port L, refer to the statistical data of vessel number and total tonnage of vessels entering and leaving Port L by the maritime bureau of L city, as shown in table 2 and 3.

**Table 3.** statistics table of total throughput, fleet number and gross tonnage of Port L in 2016

| The port areas | Vessel to port | Port throughput (tons) | Gross tonnage (tons) |
|----------------|----------------|------------------------|----------------------|
| L port areas   | 24599          | 3458.57                | 959.1                |

According to the calculation method of formula (1) and the relevant data in table 2 and table 3, the output of oil-containing sewage from ships in L port is preliminarily estimated, and the specific value is shown in the table 4 below.

**Table 4.** estimated annual oil and sewage production from ships at L port

| pollutants | Ship oil sewage (ton) |
|------------|-----------------------|
| discharge  | 666                   |

4.1.2. *Estimation of chemical washing water production*

The estimation and measurement of chemical tank washing water at Port L shall be in accordance with the calculation requirements of chemical tank washing water in "requirements on pollutant receiving capacity of ports, wharfs, loading and unloading stations and ships repairing and dismantling units". The calculation formula of chemical tank washing water at Port L is as follows:

\[
T2=(0.1 \cdot WN \cdot N + 0.5 \cdot WT \cdot T + 0.4 \cdot WG \cdot G) \cdot 0.14
\]

(2)

In the formula: T2 -- chemical tank washing water yield, unit ton/year; 
WN -- the recommended value of the average amount of chemical washing water generated by each vessel, in tons per vessel, is 0.4; 
WT -- recommended average amount of chemical tank washing water generated by a ship per 10,000 gross tons, 2.5 per ton; 
WG -- recommended average amount of chemical washing water generated per ton of cargo throughput, in tons per ton, 1.5; 
N -- the total fleet number of chemical vessels entering the port in a year, the unit is fleet number per year; 
T -- the total tonnage of chemical vessels entering the port annually, in tons per year; 
G -- the annual port cargo throughput of chemical vessels is 10,000 tons per year.

According to relevant surveys, statistics on the throughput of liquid chemicals in each port area of L port, and statistics on the fleet order and total tonnage of chemical vessels entering and leaving L port by L city maritime bureau are also referred to, as shown in table 5.

**Table 5 statistics of throughput, number and gross tonnage of liquid chemicals in Port L in 2016**

| Port area | Number of ships entering the port | Port throughput (10000 tons) | Total inbound tons (10000 tons) |
|-----------|-------------------------------|------------------------------|---------------------------------|
| Port L    | 560                           | 86.1                         | 49                              |

According to the calculation method of formula (2), the current generation of chemical tank washing water in Port L is preliminarily estimated. See the table below for specific values.

**Table 6 estimated annual production of chemical tank washing water in Port L**

| Contaminants | Chemical tank washing water (T / a) |
|--------------|-------------------------------------|
4.1.3. Production estimation of domestic sewage and garbage from ships

The domestic sewage and garbage from ships arriving at Port L are closely related to the number of ships entering and leaving the port and the number of crew members. Therefore, the calculation is carried out according to formula (3-3).

Formula:

\[ T3 = WN \cdot N1 \cdot D1 \cdot S1 + WN \cdot D2 \cdot S2 \]  \hspace{1cm} (3)

- **T3** — The amount of domestic sewage or garbage produced by the ship;
- **WN** — Per capita pollutant production. 0.03 (ton) for domestic sewage and 0.001 (ton) for ship garbage;
- **N1** — The total number of cargo ships entering the port throughout the year;
- **D1** — The pollutant storage time of each cargo ship is 1 day;
- **S1** — Average crew number of cargo ship. According to the statistics of maritime ships, the cargo transport ships are mainly third-class ships, with a total capacity of 200-600 tons. According to the rules for minimum safety manning of ships, the number of crew members of third-class ships is about 4.
- **D2** — The pollutant storage time of each passenger ship is 0.125 days.
- **S2** — Passenger ships carry passengers throughout the year.

(1) Calculation of domestic sewage and garbage generated by cargo ship:

According to statistics, 24,599 vessels entered L port in 2016. According to formula (3-3), domestic sewage generated by cargo ships can be calculated as 2,951.9 tons and 98.4 tons of domestic garbage.

(2) Calculation of domestic sewage and garbage production from passenger ships

According to the statistics, since foreign passenger ships do not receive domestic sewage and ship garbage when they enter the port, this calculation is only based on the number of passengers carried by domestic passenger ships. In 2016, the passenger number of L port was 384,400. According to formula (3), the domestic sewage generated by passenger ships can be calculated as 1441.5 tons and 48.1 tons of domestic garbage.

**Table 7.** Estimated production of domestic sewage and domestic garbage from ships at L port

| Ship type     | Annual production of domestic sewage (ton) | Annual output of domestic garbage (tons) |
|---------------|-------------------------------------------|----------------------------------------|
| Cargo ship    | 2951.9                                     | 98.4                                   |
| Passenger ship| 1441.5                                     | 48.1                                   |
| A combined    | 4393.4                                     | 146.5                                  |

To sum up, the estimated annual production of four types of pollutants in L port are shown in table 8.

**Table 8.** Estimated annual pollutant production from ships of the four types of L ports

| pollutants       | Ship oil sewage (ton) | Ship's garbage (tons) | Ship domestic sewage (ton) | Chemical tank washing water (ton) |
|------------------|-----------------------|-----------------------|---------------------------|-----------------------------------|
| discharge        | 666                   | 146.5                 | 4393.4                    | 18.9                              |
4.2. Assessment of pollutant capacity of incoming vessels at Port L

4.2.1. Oil sewage
In terms of vessel oil and sewage, there is no special vessel oil and sewage receiving vessel in Port L. However, according to the estimation, the annual oil and sewage production of vessels in 2016 is about 666 tons, and the actual receiving volume is 0 tons. Therefore, vessel oil and sewage receiving capacity of Port L is insufficient.

Through the comparison of pollutant production and disposal capacity, it can be seen that the current receiving capacity of Port L does not meet the requirements of receiving and disposing oil and sewage from Port L.

4.2.2. Chemical cleaning water
At present, it is estimated that the annual chemical tank washing water in Port L is about 18.9 tons. Ships in Port L do not undergo tank washing operations. Ships need to be washed in other places.

4.2.3. Sewage
In terms of the reception and disposal of ship domestic sewage, Port L does not receive, transfer and dispose of ship domestic sewage. According to the current ship inspection code, ships with a gross tonnage of more than 400 tons should be equipped with domestic sewage treatment equipment. At present, the annual domestic sewage volume is about 4,393.4 tons, 11 ships with a gross tonnage of more than 400 tons at L port have not installed domestic sewage treatment equipment, and 295 ships with a gross tonnage of less than 400 tons have not installed domestic sewage treatment equipment. Due to the lack of domestic sewage collection facilities ashore, the domestic sewage receiving capacity of ships is insufficient.

4.2.4. Living garbage
In terms of ship domestic garbage, according to the estimation, it is estimated that the ship domestic garbage generated in Port L in 2016 is 146.5 tons, and there is only one ship garbage receiver. The ship garbage received in 2016 is 27.5 tons, which can meet the receiving requirements. Garbage bins are set up at each wharf to receive domestic garbage from ships.

4.3. problem

4.3.1. The environmental protection facilities of the old wharf are inadequate
Most of the port docks are far away from the municipal sewage treatment plant, and are not connected to the municipal pipe network. Some of the old docks lack environmental protection facilities, domestic sewage is currently in extensive discharge, domestic sewage only simple natural precipitation after discharge, or direct discharge.

4.3.2. The port terminal does not have the ability to receive ship pollutants
According to 《the law of the People's Republic of China on prevention and control of pollution by vessels in inland water environment management regulations》, as well as 《the law of the People's Republic of China》 the newly revised in 2017 through on the prevention and control of water pollution, port, loading and unloading station should have that can meet the needs of its throughput capacity of loading and unloading of goods and pollutant receiving or processing capabilities, meet the needs of the ship to the port. In addition to passenger ship garbage, at present, the port terminal of Port L does not receive ship pollutants, nor does it have the corresponding pollutant receiving capacity.

4.3.3. Vessel oil sewage receiving capacity is insufficient
There is no vessel oil and sewage receiving unit within the jurisdiction of Port L, and the oil and sewage generated by vessels during the voyage cannot be received and disposed of in Port L.
4.3.4. The crew's awareness of environmental protection is weak, and the ability of pollutant reception, transport and disposal supervision needs to be improved.

It was found that the oil sewage treatment equipment and domestic sewage treatment equipment were not used as required occasionally, as well as the crew casually threw the garbage into the channel. Causing environmental pollution to navigation waters. On the one hand, the crew's overall awareness of environmental protection is relatively weak; on the other hand, the acceptance, transfer and disposal of ship pollutants involves the supervision of multiple departments at different links. But in the concrete implementation, each department failed to establish an effective joint supervision mechanism. In the process of pollutant handover, information sharing was not realized, and there were blind areas in the functional interface of departments, which led to the failure of effective management of the whole process of pollutant generation, storage, receipt, transfer, treatment and post-treatment discharge.

5. Policies and measures

5.1. To enhance the receiving, transshipment and disposal capacity of pollutants from incoming vessels.

Facilities for the reception and treatment of pollutants from ships should be built in new ports. Port enterprises already in operation should optimize the current mode of pollutant reception, transshipment and disposal from ships, and encourage port enterprises to renovate and build facilities for pollutant reception and disposal from ships.

Has operations of port enterprises should according to oneself circumstance, choose the construction of ship building pollutant receiving and disposal facilities, signed with the third-party enterprise with good reputation or port ship pollutants to receive, transport and disposal of a cooperation agreement to entrust the port ship pollutants to receive, transport and disposal work, to ensure that the port enterprises in Marine pollutant receiving and disposal ability during the operation.

Through the implementation of the responsibilities of port enterprises within the scope of L city, key problems existing in the current situation should be solved, and the equipment and operation of anti-pollution facilities in port yards should be strictly checked to improve the receiving capacity of pollutants in ports and ships.

5.2. Establishing a joint supervision mechanism

The reception, transfer and disposal of ship pollutants involves a wide range of tasks and requires the full cooperation of multiple functional departments in L city. It is suggested that the municipal government should take the lead and set up a special working group, with the competent leaders of the municipal government as the group leader, the municipal finance bureau, the municipal urban management and law enforcement bureau, the municipal transportation bureau, the municipal environmental protection bureau, the municipal maritime safety administration and the people's government of the district and county where the port is located as the member units, and the office of the special working group should be set up in the municipal transportation bureau. Each member unit shall designate working group members and liaison officers to be responsible for work promotion and communication. At the same time, the above functional departments have their own responsibilities and work together to determine a joint regulatory mechanism to ensure the smooth implementation of the receipt, transfer and disposal of pollutants at L ports and ships.

5.3. Establishing a joint system for the supervision and control of pollutants from ships
With reference to the joint order system for the transfer of hazardous wastes, a joint order system for the supervision of pollutants from ships will be established to form a supervision chain covering the whole process of the receipt, transfer and disposal of pollutants from ships. Relevant enterprises shall, in accordance with the uniform format, conditions and requirements, fill in and register truthfully the pollutants handed over, transported and disposed of by ships, and further improve work efficiency and supervision level by means of information technology.

The establishment of joint listing system can effectively promote the supervision of ship pollutants. The joint supervision and control system, namely the four-party joint supervision and control system of the vessel, the receiver, the transshipment party and the disposal party, mainly accepts, transfers and discharges the garbage, oil and sewage, residual oil and domestic sewage and other pollutants from vessels sailing, berthing and operating within the territory of city. In addition, the ship, receiving unit, transshipment unit and disposal unit shall fill in the joint form and establish a fixed ledger during the work handover process, register and summarize the operation records, and regularly submit the records of the combined operation to the relevant administrative departments.

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