



# Risk Analysis and Countermeasures for Limited Space Operations in Sewage Disposal

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**Abstract.** Sewage disposal involves limited space operations, which entails tremendous safety risks. Also, most people in charge of sewage disposal don't have effective means to identify limited spaces. Based on the data we collected from 15 limited space accidents in sewage disposal, we summarize the characteristics of those accidents, and put forward countermeasures for safety management of limited space during sewage disposal, such as set up a professional cesspool cleaning team, improve risk identification system and equip operators with corresponding equipment, evaluate operation level and implement operation approval system and raise safety awareness and prevent unplanned rescues, aiming to provide new ways of management for enterprises and relevant authorities.

**Keywords:** Sewage disposal; limited space accident; operation; safety management

## 1 Introduction

In recent years, limited space accidents have frequently occurred during the sewage disposal process. It was reported from May to July 2021, eleven accidents of this kind occurred in China, all of which were found during sewage disposal. Among the six cases of limited space accidents released on the official website of the Ministry of Emergency Management of China, four of them were involved in sewage disposal. Inappropriate rescue operations in some accidents have resulted in bigger casualties, causing great losses to social production and people's livelihood.

Therefore, we focused on finding the regularities and characteristics of limited space accidents during the sewage disposal process occurring from 2019-2021 to study the precautions of these accidents. The absence of risk identification and safety management of limited space operations in the sewage disposal, coupled with the inappropriate rescue operations following the accidents, contributes to the frequent occurrence of limited space accidents in the industry and the serious consequences. Therefore, we should focus on improving the risk identification of limited space operations during sewage disposal. Relevant training should be conducted on those who work in the industry to equip them with more safety knowledge and raise their safety

awareness. It is of extreme urgency to improve the safety management of sewage disposal at the root.

## **2 Risk Analysis of Limited Space Operations in Sewage Disposal**

Among the potential risks during sewage disposal, all those involved in septic tanks take up the vast majority, with over 80% accidents occurring during cesspool operations. Therefore, identifying all the hazard factors in the cesspool (including industrial and domestic sewage) and adopting corresponding countermeasures are necessary if we want to ensure safe operations during sewage disposal[1].

### **2.1 Types of cesspools**

- (1) By location: indoor, semi-outdoor, and open-air cesspools
- (2) By height: cesspools above and below ground
- (3) By the types of the sewage: sewage from leather and paper factories, food companies, electroplate and circuit board manufacturers, and from printing and dyeing enterprises, domestic sewage, and septic tank sewage, etc.

### **2.2 Toxic and hazardous substances in various types of cesspools**

- (1) Sewage from leather and paper factories, as well as printing and dyeing enterprises: hydrogen sulfide, methane, ammonia, carbon dioxide (generated when organic matter decays, such as leather, paper and natural fibers), heavy metals like chromium, cadmium, barium and non-metal compounds (leather tanning agents and dyes, etc.), and corrosive acids and alkalis.
- (2) Sewage from electroplate and circuit board manufacturers: heavy metal compounds of chromium, cadmium, nickel, zinc, copper, gold and silver, cyanide, arsenide and corrosive acids and alkalis.
- (3) Sewage from food companies, domestic sewage, and that in septic tanks: hydrogen sulfide, methane, carbon dioxide, ammonia (generated when organic matter decays). Besides, carbon dioxide will naturally deposit at the bottom of underground cesspools, resulting in low oxygen content.

### **2.3 Major toxic and asphyxiating gas**

#### **(1) Hydrogen sulfide**

Hydrogen sulfide is the most primary cause of acute poisoning among safe production accidents in the industry. At room temperature, hydrogen sulfide exists in the form of colorless gas with a rotten egg smell. This kind of sulfide is soluble in water, and becomes flammable when the concentration reaches 4.3%-45.5% in the air. People will suffocate from the immediate contact with the gas, leading to coma or death.

(2) Methane

Methane is one of the major causes of acute poisoning accidents in the industry. At room temperature, methane exists in the form of colorless and odorless gas. With a weight lighter than air, methane is explosible in the air. Inhalation of the gas might cause delirium, convulsions, rapid coma, and asphyxiation that leads to coma or death.

(3) Carbon dioxide

Carbon dioxide is the secondary cause of acute poisoning accidents in the industry. Carbon dioxide exists as colorless and odorless gas at room temperature. It is heavier than air and non-flammable and explosible. Carbon dioxide is harmful only in the way of asphyxiation.

(4) Ammonia

Ammonia is the secondary cause of acute poisoning accidents in the industry. At room temperature, ammonia exists in the form of colorless and pungent gas that smells like urine.

(5) Hydrogen cyanide

At room temperature, hydrogen cyanide exists as colorless gas with a bitter almond taste. Momentary inhales of gas with high-concentration hydrogen cyanide (300mg/kg) may lead to immediate death.

### 3 Analysis of Limited Space Accidents during Sewage Disposal Operations

#### 3.1 Industry distribution

We analyzed 13 limited space accidents during sewage disposal operations in the past three years (See Table 1). Five of them occurred during sewage pipeline construction of municipal engineering, three in the food industry, and the rest in the paper-making, electronics and chemical industries. We can see from the table that limited space accidents often occur during sewage pipeline construction of municipal engineering and food processing, which means we should keep a close eye on these two industries.

**Table 1.** Recent limited space accidents during sewage disposal

No.	Time	Location	Field	Operation type	Worker source	Death toll	Number of operators	Cases of inappropriate rescue
1	2021.7.29	Xi'an, Shanxi	Municipal services	Pipeline valve maintenance	Enterprise employee	2	2	0
2	2021.7.18	Weinan, Shanxi	Agriculture	Sewer cleaning	Enterprise employee	2	2	0
3	2021.7.3	Haining, Zhejiang	New material	Cesspool dredging	Enterprise employee	3	1	2
4	2021.6.13	Chengdu, Sichuan	Food	Cesspool maintenance	Enterprise employee	6	2	4
5	2021.5.31	Nanning, Guangxi	Municipal services	Sewer pipeline construction	Outsourcing	3	1	2
6	2021.5.26	Jiangmen, Guang-	Municipal services	Sewage well dredging	Outsourcing	4	4	0

		dong						
7	2021.5 .24	Yibin, Sichuan	Food	Sewage treatment site maintenance	Employee + residents in the neighbor- hood	7	2	5
8	2021.5 .19	Guang- shui, Hubei	Food	Pipeline valve maintenance in sewage lifting stations	Enterprise employee	1	1	0
9	2021.5 .15	Nanchong, Sichuan	Municipal services	Sewer cleaning	Outsourc- ing	2	2	0
10	2021.5 .1	Shanwei, Guang- dong	Electronic engineer	Water tank cleaning	Outsourc- ing	4	4	0
11	2021.5 .1	Guang- zhou, Guang- dong	Jewelry	Cesspool cleaning	Outsourc- ing	1	1	0
12	2020.1 0.30	Shenmu, Shaanxi	Chemical engineer	Sewage treatment tank	Enterprise employee	3	1	2
13	2020.5 .1	Wuhu, Anhui	Municipal services	Sewer network repair	Outsourc- ing	3	1	2
14	2019.9 .23	Wuhan, Hubei	Municipal services	Sewer network dredging	Outsourc- ing	3	1	2
15	2019.2 .15	Dongguan, Guang- dong	Pa- permaking	Cesspool cleaning	Enterprise employee	7	3	4

### 3.2 Most operators from the third parties and outsourcing companies

From the 13 limited space accidents that happened during sewage disposal, 47 people have lost their lives, 3.6 lives have been lost per accident, with a maximum death toll of seven for a single accident. Among those accidents, seven involved victims employed by the third parties, and five of the municipal engineering projects were conducted by subcontracting companies. Operations by the third parties and subcontractors are commonly seen in sewage treatment. Most frontline construction workers who engaged in municipal engineering are less-educated and highly mobilized. On the other hand, limited space construction requires a certain degree of professionalism. If the management and construction workers all turn a blind eye to the danger of such operations, there would be no room for the safety supervision, and the risks and challenges of on-site safety supervision have increased.

### 3.3 Operation types

Commonly-seen limited space operations for sewage disposal include inspection, maintenance, dredging, cleaning and surveying. Statistically speaking, out of the 13 limited space accidents, five (38.5%) occurred upon entering a limited space for dredging operations, five (38.5%) belonged to inspection and maintenance operations, and two (15.4%) were cleaning operations. Therefore, dredging, maintenance and

cleaning take up around 92.4% of all the accidents in sewage treatment and are of extreme danger.

### **3.4 Operation procedure**

The safety supervision and management departments of pipeline construction have complicated divisions, including housing construction, water utilities, transportation, etc. Outsourcing is commonly seen in construction projects. Most of the dredging and maintenance operations in enterprises are performed by the third-party companies. Therefore, among all the accidents, no limited spaces, no hazardous and harmful factors in the surrounding areas have ever been identified, along with other risks like poisonous and suffocating gases. In that case, the operation procedure of “ventilation, testing and operation” was not followed.

### **3.5 Inappropriate rescue**

In limited spaces, once an accident occurs, the surrounding rescue workers might enter the limited spaces without taking effective and enough precautions due to their psychological stress, negligence, or lack of safety knowledge, resulting in the escalation of those accidents. The reason why there were so many inappropriate rescue operations is that the victims are often the relatives and colleagues of rescuers, who might lose rationality due to overwhelming emotions[2]. Out of the 13 limited space accidents we investigated, 23 lives were lost for inappropriate rescue operations in nine cases, equal to half of the total death toll.

### **3.6 Cause analysis**

For a long time, construction workers have been turning a blind eye to the limited space risks entailed in sewage treatment, not to mention those risks are well-concealed. First of all, some toxic and harmful gases are colorless and odorless, making them difficult to detect and alert to them. Secondly, though some of the gases, such as hydrogen sulfide, have a rotten egg smell, they can cause nerve paralysis, which means you may have lost your smell even before realizing their existence. Thirdly, some gases have been adsorbed and dissolved in the sludge, and they will gradually volatilize into the air once the sludge has been stirred or the temperature rises during operations. The volatilization of toxic and harmful gases into the air may change the gas composition in the working environment and cause accidents.

## **4 Conclusions**

Based on the above analysis on limited space accidents in the sewage-disposal industry above, the conclusions are obtained as below:

It is shown that accidents of this kind tend to occur in the municipal engineering and food industries.

The construction workers mainly come from contractors or outsourcing companies. In terms of operation types, inspection, maintenance, dredging and cleaning take up the majority.

We propose the following countermeasures targeting existing failure to identify limited spaces and inappropriate rescue operations:

#### **4.1 Set up a professional cesspool cleaning team**

It is necessary to explore and establish the mechanism of commissioning, joint operation, contracting and operations such as dredging. Professional services shall be provided to prevent any malpractices caused by illegal operations and inappropriate rescue operations. For enterprises that perform operations themselves, a pre-operation reporting system shall be launched[3]. Training will be conducted prior to each operation and everything shall be put under close monitoring during the operation to ensure the safety of limited space operations.

#### **4.2 Improve risk identification system and equip operators with corresponding equipment**

In occasions of safety risk inspection, relevant departments shall urge companies to check whether there are potential risks of limited space operation by organizing self-inspection and correction. For food, papermaking, textile, printing and dyeing and warp knitting companies, limited space both above and below ground should be confirmed in those checks. The persons in charge of those enterprises should strengthen their internal safety education or training, and improve risk identification capabilities of personnel related to limited space operations through professional training of relevant knowledge. Toxic and harmful gases shall be clarified, based on which corresponding protective gear and operation equipment shall be purchased to equip their staff during operations[4].

#### **4.3 Evaluate operation level and implement operation approval system.**

Special campaigns shall be launched on sewage treatment and related enterprises should be urged to grade the risk level of various operations, formulate and implement concrete approval procedures for limited space operations. For operations that require the entrance into limited spaces, such as cleaning and maintenance operations, the supervision and approval standards shall be elevated so that divisions at all levels will be part of the approval, the operation process will be put under close monitoring and the safety of the construction workers can be ensured[5].

#### **4.4 Raise safety awareness and prevent unplanned rescues.**

Enterprises should strengthen the identification and management of limited spaces and manage sewage disposal facilities as limited space of the highest level. Visible

warning signs, fences, operational rules and instructions shall be set up. During the operation, workers shall be equipped with corresponding emergency equipment and protect gears. Operation supervision and management shall be improved and safety awareness shall be instilled in every worker's mind. Without approval, irrelevant personnel are forbidden to step in the operation area to prevent unplanned and inappropriate rescue operations.

The research on the regularities of production safety accidents in limited space operations and targeted precautions according to the regularities could effectively promote the safe production in limited space operations in the sewage-disposal industry. Departments responsible for emergency management and safety production supervision shall strengthen the supervision of limited operations within the industry. More efforts should be made on publicity, helping compile the industry guidelines for high-risk operations such as dredging, cleaning, and maintenance in limited spaces. Relevant enterprises shall pay more attention to limited space operations, strengthen risk identification, enhance the workers' safety awareness, develop ways to accurately identify all hazardous factors during limited space operations, purchase corresponding protective gear and emergency equipment, improve management of limited space operations, prevent inappropriate and unplanned rescue, so as to minimize the risks of limited space operations and protect workers' lives by all means. In the future days, we should focus on improving the training of special personnel for municipal construction, sewage-disposal, etc.

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