Emergency treatment technology and case study of sudden environmental pollution caused by oil spill in river basin

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Abstract: Based on the characteristics of sudden oil spill environmental pollution in a river basin, this paper presented a method for emergency treatment of sudden oil spill environmental pollution in a river basin by analyzing and summarizing a large number of oil spill emergency treatment cases. Strategies such as pollution source blocking, sluice dam controlling and pollutant interception were applied to control and eliminate the pollution situation. Besides, typical oil spill emergency response cases were picked and analyzed to provide a reference and guidance for the emergency treatment of oil spill incidents in China.

1 Introduction

With the wide application of petroleum for domestic production and life, petroleum leakage might inevitably occur during the process of petroleum production, transportation and storage, leading to sudden environmental pollution incidents. In China, more than 60 petroleum-related environmental emergencies occurred in 2016[1]. Environmental emergencies are different from general environmental pollution. They have the characteristics of various forms, sudden outbreak, serious harm, and arduous handling and disposal. The occurrence of environmental emergency often causes severe damage to people's lives and national property. For example, on March 22, 2016, a heavy diesel tank trailer rolled over during entering Sichuan from Shaanxi to Heijiafen Village on National Highway 108, causing damage to the tank and leakage of nearly 20 t diesel. Due to lack of corresponding disposal technology and equipment, partial contaminants entered the Qianxi river in Guangyuan District, Sichuan, threatening the water security for the people in Chaotian District, Guangyuan City, and triggering major water pollution incidents across the province border. On November 7, 2016, a diesel vehicle overturned in a prefecture in the Xinjiang Uygur Autonomous Region, causing about 30 tons of diesel leakage into a major tributary of a river. The occurrence of this issue threatened the water quality of 173 km downstream in Kazakhstan, which should be disposed rapidly to avoid causing environmental pollution incidents across borders. This paper intended to summarize the emergency disposal experience and the emergency treatment methods of oil spills in river basin. In addition, the emergency disposal approaches for oil spill incidents in river basin were also clearly presented by combining typical cases to provide a reference for disposal emergency oil spill accident in the future.
2. Technical methods for emergency treatment of environmental pollution caused by oil spill in river basin

2.1 Pollution source blocking
Pollution source blocking is the most basic emergency treatment technology. When oil leaks are discovered, measures such as shutting down, blocking, and fencing should be taken immediately to cut off and control the source of pollution. This disposal can avoid or reduce the entry of oil into water body, and prevent or slow down the migration and diffusion of oil pollutants along with the water flow.

2.2 Dam control
When oil spills have entered or are about to enter surface waters, the water volume should be adjusted according to the water system of the river basin and the conditions of hydraulic structures along the line. This measure can maximize the control of the incident and the upstream and downstream water volume, and reduce the water flow in the contaminated area. If necessary, the river can be diverted to avoid or reduce the contact of water bodies with oil pollutants. Thus, the migration and diffusion of oil pollutants can be prevented or slowed down along with the water flow. The specific handlings are as followed.

1) If there are sluices in the upstream of the accident site, all sluices that flow through the upstream trunk and tributaries of the accident site should be closed as soon as possible. Diversion and drainage measures such as closing the sluices can be used to minimize the clean water flow into the accident site, reduce the flow rate of water, and control the pollution to a small range.
2) If there is a sluice downstream of the incident, the downstream sluice should be closed as soon as possible to reduce the flow rate of the river for stopping the spread of oil pollutants. This can save time for later disposal measures.
3) If the affected area can be isolated by engineering disposal, the accident site should be isolated as much as possible. River diversion is another measure that can avoid or reduce contact with oil pollutants as much as possible to prevent or slow down diffusion of pollutants.

2.3 Pollutant interception
After the leaked oil entering the ditches, rivers, etc., it can be intercepted by oil booms or dams. Among them, interception dams can be divided into retaining dams and adsorption dams.

2.3.1 Boom interception
An oil boom can be used to intercept and collect the leaked oil. The types of oil boom generally include fence type and curtain type. The curtain type can present as oil boom with solid float, inflatable float and beach type. This oil boom has strong resistance to garbage and debris, which is suitable for rivers with static waters.

2.3.2 Dam interception[2,3]
For ditches and creeks with less water or even dry, dam can be built at the low-lying downstream of the oil spill point to cut off the water in the ditches and creeks, as shown in the figure 1. If there are larger dry beaches, depressions, or other abandoned facilities (such as pit mines, ditches) near the leakage site, oil diversion trenches can be excavated for oil storage. The distance and height of the retaining dam should be designed based on the amount of desired stored, which can be set as one or more stages. In addition, anti-seepage materials such as plastic film and geomembrane shall be laid in the dam.
Retaining dams are generally made of local materials in the form as earth dam or earth-rock dam structure, with slope grading coefficient higher than 1:0.5. The dam body shall be equipped with waterproof materials such as plastic film and geomembrane to prevent penetration. The emergency supplies needed for the retaining dam construction include: shovel used to excavate the oil diversion ditch, oil gathering pit, plastic cloth to prevent oil penetration, and glass fiber bags. In addition, materials such as woven bags, straw bags, and linoleum should also be stocked for emergencies.

2.3.3 Adsorption dam interception[4,5]
If the affected river can not be cut off, adsorption dams can be used to intercept river water. The adsorption dam construction should be adapted to local conditions. It can be a single dam constructed by the adsorption material alone, or a composite dam in which the adsorption material is combined with the earth dam and earth-rock dam. The adsorption material can be selected according to the principle of convenient material extraction and good effect in emergency situations. Common absorbent materials, such as linoleum, activated carbon, straw, wheat straw, quilts, non-woven fabrics, etc., can be combined with one or more materials. In addition, the adsorption dam can also be arranged in one or more channels as required.

Single dam is made of absorbent material for the entire dam body. Its typical construction is to lay steel mesh and other materials on both the front and back water surfaces. And then adsorption material between the two steel meshes was fixed to form an adsorption dam. As shown in figure 2, the steel wire mesh can be fixed by steel pipe, channel steel, angle iron or others. The physical schematic diagram of the dam using wheat straw is also shown in Figure 3.
Figure 2. Schematic diagram of single dam

Figure 3. Schematic diagram of haystack dam
The structure of composite dam contains a lower layer as earth dam or earth-rock dam, and the upper part with a water-passing section constructed by adsorbent materials. As shown in Figure 4, composite dam can be built with absorbent material on the water-passing section and heavy objects such as stones on the top for avoiding washing away by water. Moreover, granular absorbent material should be bagged in a permeable bag. Another format of composite dam (Figure 5) can be constructed by installing one or more layers of concrete pipes or steel pipes on the cross-section of the water. The diameter of the pipe is generally above 600 mm. The height can be determined according to the water flow. Oil can be removed by the adsorbent when water pass the pipe with fixed adsorbent.

Emergency supplies for the adsorption dam are listed as followed. Adsorbent materials such as absorbent felt, activated carbon, and auxiliary supplies, woven bags, straw bags, etc., should be stored. Concrete pipes, steel pipes or other types of pipelines for the construction of composite dams, and auxiliary adsorption materials such as steel wire mesh, steel pipe, channel steel, angle iron and other materials, should be also prepared.
Figure 5. Schematic diagram of composite dam

2.3.4. other forms of interception
As shown in Figure 6, during emergency disposal, other pollutant interception methods can also be adopted according to local conditions, such as pulling wire ropes and fishing nets in the river to intercept or adsorb degreasing materials.

Figure 6. Schematic diagram other forms of interception
3 Typical cases

3.1 Xinjiang diesel tanker leakage

3.1.1 Overview of leakage incident and emergency handling
At 12:00 on November 7, 2016, a diesel vehicle overturned on a national highway in the Xinjiang Uygur Autonomous Region, causing about 30 tons of diesel to leakage into a first-level tributary of a transboundary river and threatening the water quality of a foreign river downstream. According to estimation, a particularly serious environmental pollution incident with a cross-border section exceeding the standard by about 5 times would occur without any emergency disposal. Appointed by the leadership of the Ministry of Ecology and Environment and the Emergency Center of the Ministry of Ecology and Environment, the emergency response technical team arrived at the scene at 23:00 on that night, and the team leader served as the expert leader to guide the emergency response work. On the basis of implementing source engineering blockade and optimizing hydraulic dispatch, 21 oil-blocking and oil-absorbing facilities had been built quickly for emergency treatment. Consequently, the cross-border section had never exceeded the water quality standard and successfully avoided the occurrence of a particularly important incident.

The specific method is as followed.
1) Engineering blocking the source of the accident
   The incident was only 20 m away from the river. Because the local soil was sandy soil, the diesel oil leaked quickly into the soil and entered the river through groundwater. In order to stop the leaked diesel keeping contaminating the river, a coffer dam was constructed to cut off the water flow, leading the flow downstream along the other side of the incident site, for minimizing the total amount of pollutants entering the river.
2) Optimizing water dispatch
   Because there are hydropower stations upstream and downstream of the incident, sluices were used to regulate the water volume. The upstream sluice at the incident site was immediately closed to reduce the water flow rate and save time for emergency response. The sluice downstream of the incident was located on a tributary, and a two-step control method was adopted. The sluice was closed to reduce the flow rate before the polluted water mass arrived, or opened for dilution when the contaminated water mass reached the dam.
3) Pollutants interception
   Due to the width of the river exceeding 1 km, the dam could not be intercepted in this incident. Meanwhile, Because of the shortage of on-site materials and the long transportation distance, air transportation of oil-absorbing materials from Urumqi was arranged overnight and 5,600 people was urged overnight by the local government to build 21 oil blocking and suction facilities within 12 hours. During the construction, local materials such as quilts, straws, and non-woven fabrics were used.

3.1.2 Experience, problems and enlightenment of incident emergency response
1) Scientific research and estimation of pollution situation were the key to effective response to environmental emergencies
   After the incident, emergency experts rushed to the scene to hold a meeting as soon as possible. It was believed that the pollution prevention and control situation in this incident was not optimistic. If no measures were taken, the pollution group would leave the country within 12 hours. Thus, it is necessary to seize the time that night to intercept and deal with it.
2) Proper implementation of measures was the core of effective response to environmental emergencies
   The Songhua River pollution incident in 2005 caused a transnational pollution incident due to improper handling. For this incident, through situation studies and judgments, a team of thousands of people was organized overnight to build an interception device using local materials, resulting in the pollutants effectively controlled.
3) Emergency monitoring was the foundation of the whole process of emergency response

Emergency monitoring and routine laboratory monitoring should be quite different. The first step is situation estimation. At this stage, emergency monitoring data can be qualitatively and semi-quantitatively conducted fastly. The data is not required to be very accurate, and only the characteristic pollution factors but no Full indicator need to be monitored, which can save more time for scientific decision. However, the monitoring staff monitored the water samples with all 24 indicators of surface water during the incident, which was against the essentials of emergency monitoring and also wasted precious time. Meanwhile, due to insufficient reserves of petroleum-based analysis reagents, monitoring data could not be monitored in the second half of the emergency response, which reflected the lack of local emergency monitoring capabilities and lack of experience.

3.2 Diesel tanker rollover incident in Fengxian County, Shaanxi Province

3.2.1 Overview of emergencies and emergency handling

At 9:45 on July 12, 2019, a diesel tanker driving from Yulin to Hanzhong overturned with oil tank placing next to the artificial lake under the Jialing River Bridge in Huangniupu, Fengxian County. All 32 tons of diesel in the tank leaked, part of which entered the artificial lake in the Jialing River causing water pollution. After receiving the report, the relevant departments of the Shaanxi provincial government responded immediately by setting up an emergency headquarters and forming 6 working groups. Half an hour after the incident, emergency personnel and materials arrived, and emergency measures were launched quickly. Measures included the following 3 items.

3.2.1.1. Cutting off the source of pollution

After receiving the incident report, the city and county emergency management, fire protection, traffic police and other departments were immediately organized to conduct traffic control on the scene. At about 13:00 on the 12th, the accident vehicle was lifted to cut off the source of the leakage.

3.2.1.2. Pollutant interception

Three oil barriers were set up within 150 m from the starting point to the artificial lake rolling dam, and an activated carbon dam was set up on the rolling dam and at the outlet to prevent oil spills. Immediately the upstream interception dam sluice was closed and two sand-gravel interception dams upstream of the accident site were built to reduce the inflow of water. The clean-up of oil pollution was carried out by organizing firefighting, public security officers, state-owned enterprise emergency teams and local people with more than 1,400 people and more than 50 machines. Fire-fighting suction to waters was adopted where oil pollution is concentrated on the river surface. The absorbent felt and adsorption bag adsorption were also applied to quickly reduce oil concentration in artificial lakes.

3.2.1.3. Carrying out early warning measures

In the three towns of Huangniupu, Honghuapu and Fengzhou along the downstream of the accident site, 12 sand-gravel dams were built to slow down the river water discharge. Twenty oil barriers and two activated carbon dams were set up from the bottom of the dam to the county seat of 32 km. Special personnel were assigned to guard each place and responsible for putting and replacing the linoleum felt. In a short period of time, more than 1483 pieces of absorbent felt, adsorption packs, oil barriers, and 25.1 tons of activated carbon were put in, which effectively blocked the migration of pollutants downstream.

3.2.2 Experience and enlightenment of incident emergency response

1) The urgent concern and command on site of leaders were the basis for the successful handling of this environmental incidents. After the incident, the leaders of the city and county rushed to the scene as soon as possible, reflecting the high awareness of the local leaders and the importance of handling emergencies, and ensuring the maximum concentration of manpower and material resources to deal with
emergencies.

2) Ensuring the information communication on environmental emergencies was the key to effective response to environmental incidents. Through traffic accident information, emergency management information, ecological environmental protection information, and government information channels, it was ensured that the local party committee and government could respond as soon as possible. Emergency treatment within half an hour could be carried out to intercept the pollutant group within the lake, preventing further impact by the incident. At the same time, Baoji City installed GPS positioning equipment on all transit vehicles for hazardous chemicals and take them back out of the country. The accident vehicle branched at 7:13 on the 12th to the 212 provincial highway Weibin joint checkpoint for routine inspection and installed with a GPS positioning device. After the accident, the location of the accident vehicle was quickly determined, which provided the possibility for the first emergency response.

3) Strengthening emergency preparedness was the guarantee for the successful handling of environmental incidents. Provincial highway 212 in Shaanxi Province is the only transportation channel for hazardous chemicals in the western region. In recent years, similar environmental emergencies have occurred many times in this area, and all counties, towns, and villages along the 212 provincial highway in Baoji City have rich experience in response. Meanwhile, a sufficient reserve of emergency supplies was also a guarantee for effective and rapid handling of this incident. All towns and villages in Baoji City have built emergency supplies reserves. After the "7.12" occurred, Baoji City, Fengxian County, and all the townships downstream of the incident were able to response as soon as possible. With emergency personnel and materials quickly assembled and disposal work handling quickly, the pollution situation was quickly controlled.

4 Conclusions

1) The emergency response of oil spill incidents mainly adopted the methods including pollutant cut-off, water conservancy control and pollutant adsorption interception. The adsorbents used were linoleum felt and activated carbon. Meanwhile, scientific decision-making, emergency monitoring, leadership attention, unblocked information, and adequate preparation were indispensable for the success of emergency response.

2) With years of experience from oil spill emergency response, the technical methods for sudden environmental pollution incidents of oil spills in the river basin were relatively mature. However, the emergency facilities and equipment were seriously inadequate or lack the corresponding standards. Most of the equipment was temporary construction, which was time-consuming and labor-intensive and would delay timing of emergency response.

3) In the future, it is necessary to accelerate the construction of the national emergency resource information database, and promote the construction of emergency material warehouses in the provinces, cities, and counties in high-risk areas according to regional characteristics. Accelerate the construction of emergency material filing systems and promote the construction of emergency material reserve warehouses are also necessary. All kinds of information and resources should be ensured quickly invoked in the event of an environmental emergency and the situation need to be quickly controlled to minimize the impact.

4) It is recommended to strengthen emergency drills and improve on-site response capabilities. Emergency drills should be carried out once a year along the hazardous chemical channels, important water function areas, and other key sensitive areas to accumulate experience and enhance the ability to respond to emergencies.

5) Strengthen the management of hazardous chemicals transportation and prevention at the source. It is recommended to conduct risk assessment and grading of hazardous chemicals transportation sections, and import the risk assessment results into the navigation system of hazardous chemicals vehicles to remind drivers to be vigilant and minimize the occurrence of hazardous chemicals transportation vehicle traffic accidents.
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