Emergency treatment of tailings reservoir leakage pollution in watershed – taking manganese pollution as an example

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Abstract. In view of the frequent occurrence of secondary environmental pollution caused by the production safety accident in the tailings reservoir of our country, the typical case—Jinjiang River manganese pollution incident was selected, and the technical scheme of emergency response for this event is introduced, including the goal and the overall plan of emergency response, situation prediction, countermeasures, summary of emergency response, suggestions and event follow-up report. The countermeasures include pollution source cut off, chemical treatment, water dilution, the water plants' emergency plan etc. This case study can be used as a reference for the similar technology scheme of environmental emergency response in the future.

1. Introduction

The tailings reservoir is an important facility in the mining process which plays an important role in preventing tailings loss, regulating runoff and natural purification of tailings water[1]. The tailings reservoir is also an artificial debris flow hazard source with high potential energy, which has a danger of dam failure. Once it is wrecked, it is easy to cause serious accidents[2-3]. At present, there are more than 12,600 tailings reservoirs in China, and 40% of them are reservoirs with potential hazards[4]. Tailings reservoirs are different in types, vary in scale, numerous in number, and widely distributed[5], which have frequently caused environmental problems[6]. In recent years, secondary environmental pollution incidents caused by tailings reservoirs related accidents have frequently occurred: 52 cases of environmental incidents caused by tailings reservoirs were directly handled by the Ministry of Environmental Protection (MEP), China between 2006 and 2012[7]; such environmental incidents also keep emerging after 2012[8-10].

The team belongs to the Emergency Response Center – the only emergency-oriented secondary organization under the MEP, is specializing in emergency response to environmental emergencies and other related issues. Appointed by MEP, the team has handled 4 cases of environmental incidents caused by tailings reservoirs leakage between 2012 and 2017. This article introduces the process detail of the Jinjiang River manganese pollution incident caused by Wantai Manganese Corporation's tailings reservoir overflow in Wanshan District, Tongren, Guizhou Province, which was handled by the team in 2012. This incident is a typical secondary environmental pollution incident caused by the production accident of tailings reservoir, and the incident was successfully treated through the implementation of the team's technical scheme. The technical scheme of emergency environmental treatment for Jinjiang River manganese water pollution incident is summarized as follows.

2.Case background

At 16:00 on November 7, 2012, due to the impact of continuous precipitation, the Wantai Manganese's electrolytic manganese tailings reservoir drainage culvert was rusted by acid manganese slag, and the flood discharge pipe at the bottom of the reservoir was broken, which caused the manganese slag was discharged to the stream directly. The discharged manganese slag turned the Dashuixi River into a black color, and the total manganese concentration in the water was seriously exceeded limits. On November 8, the polluted water masses crossed the provincial boundary and entered Huaihua City, Hunan Province. Huaihua immediately launched an emergency plan and carried out emergency monitoring. The result showed that the manganese concentration at Guizhou-Hunan boundary exceeded standard 30-60 times, which caused a serious threat to the drinking water safety for the citizens along the river in Mayang, Chenxi and Luxi County. The MEP immediately sent a team to the scene to guide the Guizhou and Hunan provinces to carry out an emergency response. Appointed by the MEP, the key members of the Environmental Emergency Center of the South China Institute of Environmental Sciences (SCIES) were sent to the scene and undertook the main emergency response work for this environmental incident.

3.Emergency response's goals and overall plans

3.1 Emergency response's goals

Reducing the pollution load through engineering treatment measures, comprehensive water flow adjustment and implementation of the emergency operation of water treatment plants to minimize the pollution level of the accident to the downstream Mayang River. Restrain the pollution area within the upstream of Luxi River. Ensure the water quality reach standard when the contaminated water mass passing through Liling City. At the same time, start the emergency operation of water treatment plants to ensure drinking water supply and no one drinks contaminated water. Restrain the incident impact area within Jinjiang River's upper reaches of Liling. Minimize the disturbance of the incident to the society.

3.2 Emergency response's overall plans

Guizhou Province and Hunan Province respectively launched the Level II Emergency Plan of Environmental Emergencies, set up respective headquarters for the emergency response, and set up an emergency liaison department (in Human Command). At the same time, form an emergency expert group to arrange all resources and take all measures to find out sources of pollution and cut off all sources of pollution that may enter the river; to monitor and forecast the tendency of the pollution incident; to imply river channel pollutant reduction engineering measures, which minimise pollution load to the river; to arrange and adjust water flow in the watershed, which dilute the pollutant along Jinjiang River and its downstream; to start the emergency operation of water treatment plant, which ensure the water supply along the river meets the standards; to coordinate various emergency measures and continuously optimize the overall plan during emergency response; to guide the public opinion and minimize the social impact caused by the incident.

3.3 Pollution source determination

Since the accident has contaminated the Jinjiang River, the source of pollution was confirmed as the overflow of the Wantai Manganese's tailings reservoir in Wanshan District, Tongren, Guizhou Province. The conventional slag leaching's manganese concentration is about 1600 mg/L according to the literature; the flow rate of tailings reservoir overflow was 2 m^3/s, and the estimated leakage time is 50 hours. Using the formula Q=CqT, the manganese accident leakage was 576 tons. Another approach: the manganese concentration at provincial boundary exceeded the standard 30-60 times (calculated as 45 times); the river flow rate was 287 m^3/s (calculated as 300 m^3/s), using the formula Q=CqT, the manganese leakages were 243 tons. From the analysis of the two calculations, the estimated quantity of manganese leakage was 300-400 tons.

Therefore, the manganese flushed into the river was hundreds of tons, and the polluted section in Guizhou Province was about 30 km. If no effective measures were taken, the discharge of polluted water masses will affect Fuling County, and the affected river sections in Hunan will exceed 200 km. The estimated area of influence is shown below.

Figure 1. Preliminary estimation of affected area

To prevent additional pollution accidents during the emergency response process which increase the difficulty of the treatment, identifying all the tailings ponds in the pollution area was recommended. Search whether there are still unregistered illegal tailings ponds in the area to prevent additional pollution to the rivers.

4. Situation perdition

By the time the emergency team arrived, the manganese concentration in the Guizhou-Hunan boundary exceeded limit 30-60 times, and the flow rate of Jinjiang was about 280 m^3/s. The manganese flushed into the river was 300-400 tons (analyzed in section 2.3). According to the preliminary simulation performed by the emergency team, if no any pollutant reduction measures were taken, the pollutants was diluted by the reservoir water along the existing river channel, the following situation could be predicted: the polluted water masses will approximately arrive Mayang on November 12th, arrive Chenxi on November 17th (manganese exceed limit 10-20 times), arrive Luxi on November 22nd (manganese exceed limit about 5 times). The polluted water masses will eventually arrive Liling on November 30th, and the manganese concentration could meet the standard after water dilution from Lishui reservoir. About 200 km of Jingjian River section in Hunan will be affected by this incident. However, if pollutant engineering reduction measures were taken at the river section between Guizhou and Chenxi, the water quality could meet the standard before reaching Luxi County.

5. Emergency response measures

5.1 Pollution source cut off

The principle of cutting off the source of pollution: thoroughly remove the tailings slag and tailings sand that entering the river; repair the damage tailings reservoir and slag yard; construct a floor discharge channels for tailings reservoir or slag yard to prevent recurrence of similar pollution accidents. Further, detect and search for hidden sources of pollution to ensure the source of pollution is completely cut off.

The implementation method of cutting off the pollution source: first, construct the diversion pipe, and discharge all the upstream water to the downstream ditch to ensure that no surface water flows into the manganese tailings reservoir. Second, since the incident area is Karst Landforms, deep excavation in the hill before the manganese slag reservoir to collect the underground water into the diversion pipe to prevent underground water seepage flow into the manganese slag reservoir. Third, guide and organize soldiers and local citizens to use the sandbags and straws to seal the rupture of the flood discharge pipe of the manganese slag reservoir. The fourth is to build a collection pool at the exit of the manganese slag reservoir to collect and treat the overflowed stagnant water and pump it back

into the diversion pipe. The fifth is to suspend and inspect all manganese-related company in Tongren to avoid additional pollution sources to the downstream.

5.2 Chemical dosing and pollutant reduction

5.2.1 Pollutant reduction principle

Manganese contained water is mainly treated by the following methods: coagulation and sedimentation method, iron filings microelectrolysis method and nanofiltration method[11-14]. Yuchuan Fan[15] uses the lime-basic aluminum chloride coagulation sedimentation method to treat manganese-containing wastewater. The experiment results showed that the manganese was reduced from 397 mg/L to 0.2 mg/L under the condition of pH=8.5-10. Therefore, the team decided to use the "lime-basic aluminum chloride" method to move manganese from the water.

5.2.2 Implementation site

Considering the operability of on-site dosing and the reaction distance of the agent in the river channel is 5-20 km, multi-stage dosing was implemented to reduce the river pollution load. The implementation sites in Guizhou Province were located from the incident site to the boundary of the two provinces, with more than 20 intercepting dams were built along the river.

5.2.3 Monitoring points set up

In order to collect effective information to guide the treatment process, monitoring points were set up before the implementation site and after the dosing site (choose a place 2-10 km downstream from dosing site) to continuously monitor the water quality. The pH value and the manganese concentration were monitored in real time, and the agent dosage and dosing method were adjusted at any time to optimize the treatment implementation.

5.3 Flow control and water dilution

5.3.1 Flow control

The Hongxinxi Hydropower Station, Jinhe Hydropower Station, Jiangkou Hydropower Station and Majiao Hydropower Station were close to reduce discharge flow rate and slow down the moving speed of polluted water masses which promote the sedimentation of pollutants.

5.3.2 Water dilution

The water from Yaoli River can be used to dilute the manganese, and its flow rate was about 200 m^3/s without any adjustment. Suppress the flow rate of Bali River to less than 200 m^3/s by adjusting discharge flow from water reservoirs upstream. Once the polluted water masses' arrival was detected, increase the discharge flow rate from Yaoli River to dilute the contaminated water.

5.4 Water plant emergency measures

All water plants along the Jinjiang River from Mayang County to Fuling County applied their emergency plan. For plants were not in the affected area, increase their production load to ensure drinking water supply; for plants were in the affected area, set up monitoring site and increase monitoring frequency to the river at 5 km, 15 km and 25 km upstream from the water intake. Once the polluted water was detected 15 km upstream from the water intake, start the emergency plan and use the backup water source for production.

5.5 Enhanced monitoring along the river

Set up monitoring section 300m before dosing treatment and 2-10 km after dosing treatment to observe the main changing points of polluted water masses and the effects before and after treatment. Also, the upstream section of the water plants was key monitoring points. Sampling sites were set up 5

km, 15 km and 25 km before intake of water plants in the affected area. Take one water sample every 2-hour when the polluted water masses were passing through the area; take 1 to 4 water samples per day after the polluted water masses passed the area. Monitoring can be stopped only when the manganese concentration drops to the same level as the water before pollution. Once a monitoring site at upstream has detected the polluted water masses, the following monitoring site at downstream should start sampling.

To ensure the water monitoring work, 67 members from Hunan's provincial and municipal monitoring stations were sent to the scene to assist the emergency monitoring work in Mayang, Chenxi and Luxi County. Analytical instruments were urgently purchased and deployed to the scene, and an on-site temporary laboratory was set up in Jinhe, 40 km away from Mayang County, to make up for the lack of analysis and monitoring of hardware facilities. In addition, the emergency team has coordinated with the government to send 46 vehicles, rented 17 vessels and a certain number of motorcycles to join the water sampling work.

5.6 Information disclosure

Manganese is a necessary trace element in normal organisms, but excessive intake of manganese can have adverse effects on the body. Fan et al. performed the "Acute toxicity test of potassium permanganate on *Carassius auratis*" and showed that: a study on potassium permanganate for goldfish (*Carassius auratis*, length 5.4 ± 0.3 cm, weight 10.1 ± 0.3g) using conventional bioacoustic test methods. The result indicated the 24-hour median lethal concentration (MTL) of potassium permanganate for *Carassius auratis* was 4.34 mg/L. According to reports, acute manganese poisoning occurs when the manganese content in the human body exceeds 2 g, while chronic manganese poisoning occurs when the human body exposed to manganese for a long time[16].

Dealing with pollution accidents is not only the process of preventing pollution that caused damage to human health and the environment but also the process of maintaining social stability. Considering the current situation, the accident was controllable, and no observable environmental health damage would occur. According to the historical data, there is no case of manganese poisoning caused by drinking water in the country, so that the public can be assured. Therefore, it must reasonably guide public opinion, appease the citizens, avoid irrational emergency behaviors, guarantee the normal order of the social economy, and ensure the normal life of residents.

6. Summary and recommendations

6.1 Summary

The emergency response plan was scientifically formulated immediately after the Jinjiang River incident. During the emergency treatment process, the team swiftly and accurately predicted the incident tendency after the implementation of various emergency measures by improving the layout of monitoring sites. The team guided the implementation of the efficient and accurate watershed flow control and the pollution control measures, which successfully restrained the polluted water masses in the intersection of Jinjiang and Lishui and secured the drinking water safety for Liling City. The emergency response was called to the end on the 16th, and the team successfully fulfilled its emergency response duty and provided comprehensive technical support, which was highly evaluated by leaders from ministerial, provincial and municipal departments.

6.2 Recommendations

Emergency environmental accident response is a system engineering requires cross-operation from various departments and technologies. For the cross-province pollution accident, it requires provincial governments to establish an emergency response headquarter which contains members from environmental protection, urban construction, water conservancy, health, publicity departments and local governments. It coordinates and guides the cooperation of various departments, gathers experts

from various fields to form an expert group which supports the work of the headquarters at the technical level.

7. Event follow-ups

On November 15, 2014, the People's Procuratorate of Wanshan District, Tongren City, Guizhou Province, filed a lawsuit accused the defendant Wantai Manganese Industry Co., Ltd. and defendant Huaxing Luo was guilty of environmental pollution (Indictment: Tongwan's Public Prosecution, 2014, No. 76). After the case was accepted, a collegiate panel was formed according to law, and the case was publicly heard on December 16, 2014, and a verdict was issued: the defendant, Wantai Manganese Industry Co., LTD., committed the crime of environmental pollution and was fined ¥350,000 and indemnify for the ¥92,540,572 loss caused to the Wanjiang district government; the defendant, Huaxing Luo, was sentenced to one year's probation and two years' imprisonment for the crime of environmental pollution and was also fined ¥50,000.

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