Life Cycle Oriented Hazards Identification for Tailings Facility

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Abstract

The tailings accident-prone and the method of hazards analysis and identification are highly valued by Canada, Australia, European Union and other countries. These accidents brought huge loss and a profound lesson such as the “9.8” dam break accident of Shan Xi’s new tower, which reflected the limitations of our tailings management and the necessity of study. A method about Life cycle oriented hazards identification for tailings facility, and analyzed hazards of life cycle systematically from technical, human, environment and regulations, such as the unsafe state of tailings pond, the miscount of people, the deficiencies of management and the adverse conditions of environment, and the advice of accident disaster prevention measures for the corresponding life cycle stages was presented, the safety level of the tailing pond in China will be improved.

Keywords: Hazards, Tailings facility, Life cycle

1. Introduction

Tailings pond can not only protect the environment and mineral resources, and still can make full use of the water resources, which is an important production facility of concentrator. But the tailings pond also is a high potential energy of man-made debris flow hazards \cite{1}, and its running condition quality relates directly to the safety of mine production and people's life and property \cite{2}. The tailings pond is large amount and small scale, low degree of safety in China, so the safety level remains to be improved.

One of the important ways to reduce accident of tailings pond is to analyze and find out existing hidden danger in the tailings pond timely and accurately, then effective measures for protection of the tailings pond could be taken. According to the domestic current research situation of tailings pond production safety, the tailings pond accidents cause factors’ classifications are complex. For example, it is divided into the direct reasons (flood, the dam foundation subsidence, etc.) and indirect causes (safety regulation, maintenance); and it can be classified in accordance with the natural, design, construction and management factors. Tailings pond safety management is a whole process, and it involves the whole tailings life process. So the factors of classification must be integrity and systematic property. Therefore, it puts forward a hidden danger identification method based on the life cycle of the tailings pond in this paper.

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2. Research method

The life cycle of the tailings pond can be divided into four stages: construction, operation, closure and reclamation (re-mining). This paper will be based on the stages of the tailings pond life cycle, and combined with tailings pond factors set (environment, human, technical, laws and regulations) four aspects to carry out the research of tailings pond accidents cause, as the following fig. 1..

![Fig. 1. Framework based on the life cycle of the tailings pond hidden danger identification](image)

Use the life cycle of the tailings pond as the x axis and the factor as the y axis, and then form sixteen points of intersection. Each intersection point represents one aspect of the set of the accidents cause of a certain stage in the tailings pond life cycle. And then analyse and study the intersection point, and form a type of tailings pond accidents cause. After all, we can conclude the tailings pond accidents cause systemically and completely.

3. Hidden danger identification based on the life cycle of tailings pond

In the life cycle of the tailings pond, the construction phase consists of three parts: the reconnaissance, design and construction; the operation activity phrase reflected the safety, quality and reliability of the project; the closure phrase is treating pond which needs close; The reclamation or re-mining phrase is to take full advantage of resources. So the tailings incidents are often caused by the potential risks of the construction phase or operational phase, it’s the focus of this article analysis.

3.1 Hidden danger identification in the construction stage

Good design comes from the right address-choice, the standardized reconnaissance, the accurate data and the qualification and rich experience of personnel in exploration; the construction of the tailings pond include starter dam, the tailings structures and the safety facilities, it is the practice of reconnaissance and design, whether it will bring accidents or not, it depends on the construction quality and supervision. So the potential accident-causing factors from the four aspects of the environment, human, technical and laws and regulations will be analysed.

1) Environment

   Environmental factors on the influence of the tailings pond are mainly embodied in the reconnaissance part. These factors include earthquake, meteorological and hydrological and geological conditions of the terrain. Generally, geological conditions of the terrain can influence to the stability of dam base and abutment, also the leakage of tailings, and it makes the tailings pond occur slump or subsidence accident; Hydrographical meteorology condition can form heavy storm which can make the surface of dam saturate with water or flood overtopping; Hydrological and meteorological conditions on the impact of the tailings is also reflected in the rainfall to improve dam saturation line, making the dam surface saturation and swamp with water, a significant decline in the overall shear strength which easily lead to the dam, it can easily lead to dam failure. Therefore, it should choose a good meteorological and hydrological and geological condition of the terrain area, or seismic activity not frequent area, to be the best address for tailings pond.

As can be seen from Figure 2, the karst area is easy to form water cave because of its cave development, in some cases, it will be the leakage ore channel, and result in tailings seepage or slump and subsidence; When the location is loess area
where more voids and fissuring, when rainfall is excessive, it will produce collapsible deformation phenomenon, thus affecting the stability of dam [3]. Therefore, we should try to avoid the areas which include karst area, loess area, strata fissuring area, geologic structure malignant change area to be the address for tailings pond.

Under earthquake loading, the tailings dam will produce a continuous residual deformation on the basis of the static deformation, then resulting in dam partial longitudinal or transverse cracks and the formation of leakage channel due to the increase in pore water pressure. Examples of domestic and foreign tailings pond show that the earthquake damage is easy to liquefy tailings and loss of stability for dam. When an earthquake occurs, it will forming phenomenon such as the tailings liquefied, tailings dam cracks, structures fracture deformation and so on, and these can easily lead to slumping, collapse, and leakage and dam-break accident. Therefore, it should try to stay away from earthquakes area when recce reconnaissance; it’s likely to produce flash floods when occurs heavy rainfall, then it is very likely to lead to flood regulation capacity shortness and result in dam-break accident finally. When the rainfall is not heavy but large, it’s easy to cause phenomenon such as the saturation line of the tailings raise, the dam surface water saturation, rain carve the surface of dam. And these will result in declination of shear strength and surface of dam will been broken, even slumping and collapse accident.

Apart from the geology and topography, earthquake, rainfall, we should consider the windy and large temperature difference day and night and biological activity area during construction phase.

2) Human

Influence of human on tailings pond during the construction phase is important, it plays a decisive role for the quality of the project. These factors include qualification of workforce, capital investment, behavior of workers and safety evaluation.

The qualification of workforce determines the quality and safety of project. Experienced and qualified investigation team will follow appropriate procedures to explore and select the address of reasonable scientific site as the location for tailings; it needs qualified and experienced technical personnel and units to design when the design requirements of innovative, detailed and deal with the problems; a good working team can determine the quality and safe of construction, and the construction process be standard. The degree of standard implementation and proficiency of operation can affect the quality and safety performance of the tailing dam project. So the influence of the qualifications and experience of workforce to the tailings cannot be ignored.

The hidden dangers will be brought when the necessary production and construction costs are compressed. For example, the lack of funds for the exploration will reduce the amount and accuracy of reconnaissance and can’t get scientific and reasonable reconnaissance data, and it makes the future of the tailings’ design become extremely difficult; so necessary capital investment is essential. Below in figure 3(a), it’s the influence of qualification of workforce and investment on tailings pond.

The irregularities of workers can lead to the production safety accidents, shown in Figure 3(b). These behaviors include drink-driving & working, transport overloaded & over speed (Especially heavy fog), leave one’s position without authorization, unprotected live operation, adding fuel with open flame and working with illness or fatigue. These behave can lead to casualty accident. So it is necessary to have a pre-job training and safety education and develop a standardized operation and behavior manuals.
Safety evaluation is another important human factor for tailings pond. Enterprise can identify and analyze the hazard and harmful factor of system by safety evaluation, then it can formulate the appropriate preventive measures and decision by judging the accident likelihood and seriousness, it’s effective in preventing accidents, less property damage and human casualties. The safety evaluation which include pre-evaluation after complete of design, safety special articles, and completion acceptance evaluation are throughout the tailing pond construction period. Safety evaluation criteria, evaluation methods, evaluation content and evaluation procedures are important indicators to reflect the safety assessment is in place, shown in Figure 3 (c).

Fig.3. (a) the influence of qualification of workforce and investment on tailings pond and (b) the influence of misconduct of workers on tailings pond and (c) the influence of safety evaluation on tailings pond

3) Technical

The location is not reasonable, design content, method is obsolete, design program update untimely and so on, and all of above will affect the quality of the tailings design. It will have a significant impact to the tailings pond if Technical work does not reach the designated position during construction. In order to save the cost, it may be scamp work and stint material, dam base clean incompletely, dam density inhomogeneity, filter layer lying improper and flood emission facilities do not meet the prescribed standards and other problems lead to these accidents.

4) Laws and regulations

In China, tailing dam safety situation is grim, laws and regulations and technical procedures’ implement are ineffective, and the law system is not perfected. In the construction phase involves the relevant law regulations of accident-causing mainly is the irregular design market, such as Anchored design, design their own and so on. And the procedure of design and construction is also an embodiment of tailings standards.

The internal regulation of enterprise is the other side of the influence of the regulatory on tailings pond. The main purpose of establishing enterprise rules is making the management standardization, and regulating employee behaviour and the management of enterprise. The internal regulation of enterprise is reflecting the management level and the overall safety level of enterprise. So it should establish safety, censorship, educational training and supervision & management system, and the emergency drills and rescue treatment should be prepared too.

3.2 Hidden danger identification in the operation stage

The operation is the longest stage for the life cycle of the tailing pond, during the operation, it can reflect the quality of reconnaissance, design and construction is good or bad, and the extent of the level of management and production safety.

1) Environment

The influence of environmental factors is particularly evident in the operation stage of the tailing pond. Excessive rainfall, earthquake, rain scouring the tailing may cause the corresponding accident disasters. Especially when there is a severe storm forming mountain torrent, it leads to the drainage system of the tailing overload. When the water draining is not timely, exceeding flood storage capacity, it will not only cause the dam-break danger because of the floods overflowing the top, but also because of the flood take the tailing and water out, affecting the surrounding environment and polluting water, etc.

2) Technical

The technical factors leading to the accidents in the operation stage includes tailing emissions, construction of tailing dams, drainage systems and the maintenance of the dams, etc. If the trouble is not handled well in the operation stage,
lightly it will cause the tailing leakage, dam slump, water and soil pollution and other phenomena; seriously it will lead to accidents like the tailing dam break.

3) Human

Whether the tailing safe or not depends on the design and management. Bad management, it is likely to bring some accidents and faults for the tailing. The management of the tailing begins with the early completion of the tailing dams to delivery to the business operation and ends with the maintenance work after the tailing are closed. This process, which may last several years or several decades, is a long process.

4) Laws and regulations

The operation stage, regulatory factors cannot be ignored, the major regulatory factors leading to the accident are:
1) Rules and regulations are imperfect, resulting in defects of management itself;
2) No corresponding emergency plans or measures; or there are emergency measures, but no drill.

The above aspects will result in many defects of the management of the tailing, causing the safe operation of the tailing cannot be guaranteed.

3.3 Hidden danger identification in the closure stage

It is necessary to analyze the accident causes in the closure stage to work out the correct disaster prevention measures.

1) Environment

The natural hazard factors of the tailing after the operation stage mainly are the earthquake and rainfall. Especially in the rainy season we should pay attention to the flood control and promptly remove the water exceeding the tailing capacity.

2) Technical

There is the possibility that the accident of the tailing may happen in the design of tailing closure. For example, the design companies designing the closure of tailing haven’t the corresponding qualifications or lack of experience, the designed data is not scientific or reasonable, which will lead to the closed tailing design be defected inherently; If the closed tailing design exceeds the service life of the tailing, the tailing cannot be timely closed, leading to the accidents of the tailing.

3) Human

The closed tailing stage also has man-made accidents. For example, the acceptance of the tailing is not in place, the maintenance investment of the tailing closed is less, the supervision and monitoring after tailing closed is slack and so on, which are all potential tailing accidents causes.

4) Laws and regulations

Rules and regulations are not sound and imperfect, emergency drills could not be implemented and appropriate monitoring and supervision is not in place, making the management deficiencies.

3.4 Hidden danger identification in the reclamation (re-mining) stage

The reclamation of the tailing is one of the central tasks of land reclamation work in extractive industry [3], and re-mining of the tailing is full use of resources. The stability of the dam is the basic in this stage. Therefore, the main accidents in the reclamation or re-mining stage have a relationship with the stability of the tailing in some way.

In the blind exploitation without the mining technical demonstration, safety reliability analysis, engineering design and safety evaluation, the potential risks are likely to become accidents by some factors; reclamation construction procedures are not standard, and re-exploitation does not construct and operate in accordance with the normal tailing, which are both the important causes to the tailing accidents.

4. Conclusion

How to identify the tailings hidden danger from the construction, operation, closure and reclamation or re-mining four stages in the life cycle of the tailing was described. These factors mainly are the unsafe behavior of people, the unsafe state of material, the adverse conditions of environmental and the deficiencies of management. Based on the analysis of the above factors, the evolutionary path of the corresponding factors and recommendations appropriate to prevent the accidents was given. Tailing accidents begin with the hidden danger, which are not enough to pay attention to. Therefore, we should identify hidden danger correctly, accurately and timely, understand the evolutionary path of the hidden danger, and set the corresponding safety prevention measures timely to reduce the unnecessary casualties and property losses, which is particularly important.
References