Environmental Risk Assessment of Sungun Copper Mine Tailing Dam Using EFMEA Method

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Received: 26 September 2019
Accepted: 14 March 2020

1. Introduction

Nowadays, the key role of mining industry in economic development, technology and urban growth in many countries around the world, including Iran, is not unknown. However, the mining industry is one of the high-risk industries and causes major environmental problems. Despite the positive achievements of mining, which has led to sustainable development in various countries around the world, due to the formation of huge volumes of waste materials from mineral activities, pollution from acidic drains, transfer of hazardous elements to surface and groundwater resources, and natural land and landscape destruction, it is one of the most dangerous industries and is one of the most important environmental problems. For this reason, environmental risk assessment has become particularly important in this industry. The purpose of this study was to evaluate the environmental risks of Sungun copper tailings dam using EFMEA method. The Sungun Dam tailing dam is considered a type of environmental threat because it is located in the upstream of agricultural lands and villages as well as one of the branches of Sattarkhan-e-Ahar river. To the best of authors' knowledge, no study has been conducted on tailing dams risk assessment in the country; hence, the present study has analyzed the risks and threats of the Sungun tailing dam using the new EFMEA method.

2. Study Area

The tailing dam of the Sungun copper complex of Tabriz and its associated facilities is located on an area of 1400 hectares near the copper mine and its average elevation is 2313 meters above sea level and is located 130 km north of Tabriz and 30 km from Varzaghan city. It is a rock fill dam with clay core and has been built for the purpose of storing waste material extracted and processed from various activities of Sungun concentrator plant which is in operation since September 2006. Tailings dam infrastructures include: 1- Primary or initial dam (built for early storage in early years of operation), 2- Seepage or returned water (all foundation and body leakages are collected in this dam's reservoir and pumped to the tailing dam reservoir station. Moreover, it has a maximum depth of 37.5 meters and length of 130 meters and prevents leakage of

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seepage water from the tailings dam to downstream) and 3- River diversion system (dam upstream cofferdam, temporary diversion channel, and diversion pipeline).

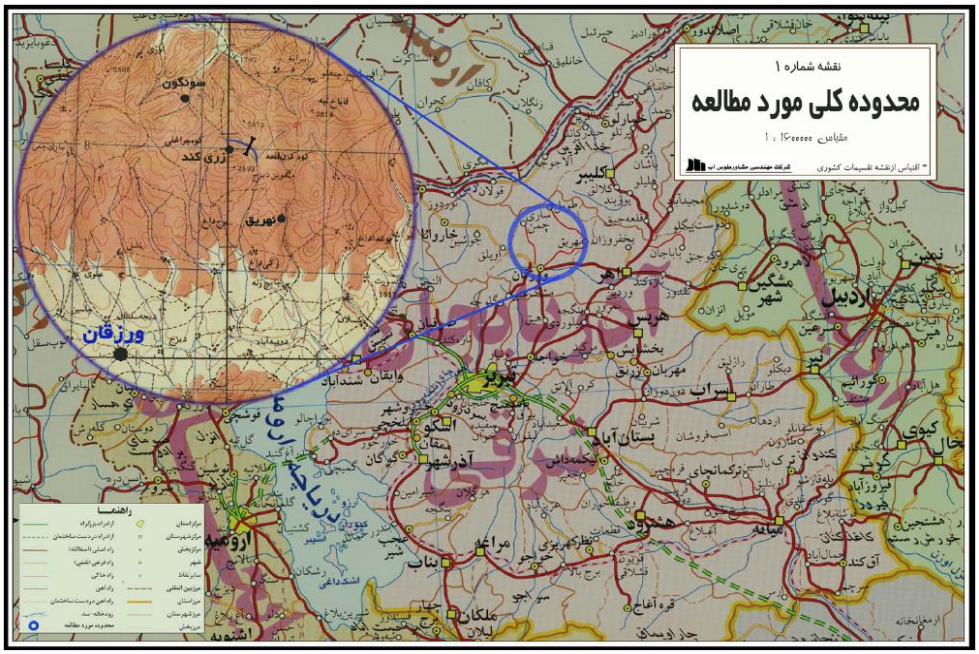

Figure: Location of the Sungun Complex

3. Materials and Methods

At the beginning of the research, the background and history of past studies and the guidelines related to the research problem are identified. Gathering information about the study area will be conducted using library studies (theses related to the studied area, reports of the environment agency, etc.). Then, to determine the risks, a visit to the Sungun complex was carried out to identify the activities and potential risks of the tailing dam. After identifying the risk generating activities, a questionnaire was distributed to 18 environmental, safety and health professionals and personnel of the Sungun tailing dam. In the next step, to prioritize the risks, another questionnaire was again given to the same experts. Finally, based on the opinions expressed by experts, the risk factors in the three accepting environments (physico-chemical, biological and socio-economic) were determined. Due to the fact that the data collected from the questionnaires were qualitative, EFMEA method was used to quantify and analyze them. In this method, to determine the severity and probability of detection and occurrence of any potential risk in the receiving environments, specific tables related to the method of EFMEA were used.

4. Results and Discussion

Risk Priority Number (RPN) was calculated for each of the risks in the physico-chemical environment. The results show that seismicity with numerical value of 21.08 has the highest and flooding rate and flood risk with numerical value of 2.45 has the

lowest numerical risk value. The results of numerical calculation of risk in biological environment show that noise pollution with numerical value of 18.24 has the highest numerical risk value. The lowest risk priority number was associated with an animal mortality with risk value of 3.99. Furthermore, the results of numerical calculation of the risks identified in the socio-economic environment show that the highest numerical value of the risk is related to the effect on the landscape with 24.12 and the lowest numerical value of risk is related to the risk of reducing or closing the mine production with 0.81. Comparison of the results of this research with previous studies shows that the results of the present study are in good agreement with previous research.

According to the results of the present study, the most important risk in the physio-chemical environment was the seismicity of the region. In the literature review, it has been observed that the importance of this risk has been such that several studies have examined the effects of this risk in the field of mining and waste dams as a very important risk and concern of those in charge. Moreover, according to the regulations for designing buildings against earthquakes in Iran (Standard 2800), the main area of the Sungun copper mine tailings dam area is located on a relatively high seismic risk zone, which also confirms the importance of seismic risk in this dam.

Furthermore, the present study identified noise pollution as the most important risk in the biological environment of the project under study, which is affected by the sound of explosions in mines and the operation of machinery. According to researchers, for many mining activities, the management of noise emission levels is a very important point in the operational phase of mining. For this reason, the use of noise reduction equipment for employees should be seriously put on the agenda.

The risk of destructive effects on the landscape was also obtained as the most severe risk in the socio-economic environment of the Sungun copper mine tailings dam. Researchers have found that waste dams have a negative impact on the environment, such as the extinction of plant and animal species and the disturbance of the ecosystem's balance. In another study, ecosystem degradation was identified as the most important environmental risk in the Angoran zinc and lead mineral complex, which is consistent with the results of current research.

5. Conclusion

The main purpose of construction of tailings dams is to manage, collect and maintain tailings waste and effluents from mining activities. On the other hand, hazardous pollutants in acidic waste and scrap stored in tailings dams have the potential to cause adverse effects on the environment. In the present study, the environmental risks of the Sungun copper mine dam were evaluated by using EFMEA method in order to prevent accidental dam leakage or failure. In order to reduce or eliminate the risks and factors that cause environmental risks, inspection and monitoring periods in accordance with the identified risks should be considered as one of the most important objectives of the management programs. Moreover, it can also be concluded from the results of this research and its discussion that the method of analyzing the modes and effects of environmental failure (with regard to the non-detection parameter) is a suitable and efficient method for assessing environmental risks in tailing dams. Applying fuzzy logic

as well as assessing environmental opportunities can be considered as topics for future research.

Keywords: Risk assessment, Environment, Tailing dam, Sungun copper dam

References (In Persian)

Bozorgmehr, N. (2015). *ایران دارای هفت درصد ذخایر معدنی جهان است* [Iran has seven percent of the world's mineral reserves]. Tehran, Iran: IRNA.

Building and Housing Research Center, Ministry of Roads and Urban Development (2015). *آیین نامه طراحی ساختمانها در برابر زلزله (استاندارد ۲۸۰۰)* [Earthquake design regulations (Standard 2800)]. (4th ed). Tehran, Iran: BHRC.

Habibi, E. (2013). *ایمنی کاربردی وشاخص‌های عملکرد در صنعت* [Applied safety and performance indicators in industry]. Tehran, Iran: Fannavaran.

Jozi, S. A., & Mirsalimi, S. M. (2016). مدیریت ریسک زیست‌محیطی سنگ آهن ماد کانسار، شهرستان خرمبید با استفاده از روش‌های تلفیقی EFMEA و ویلیام فاین [Environmental risk management of Madkansar iron ore mine in Khorambid county using EFMEA and William Fine integrated approach]. *Mineral Resources Engineering Journal, 1*(1), 19-27.

Jozi, S. A., & Seifossadat, S. H. (2014). ارزیابی ریسک محیط زیستی سد گتوند علیا در مرحلهٔ بهره برداری با استفاده از روش تلفیقی آنالیز مقدماتی خطر و تکنیک EFMEA [Environmental risk assessment of Gotvand-Olia dDam at operational phase using the integrated method of Environmental Failure Mode and Effects Analysis (EFMEA) and preliminary hazard analysis]. *Journal of Environmental Studies, 40*(1), 107-120.

Najafi, M., & Yarahmadi Bafghi, A. (2008). *بررسی ایمنی و آنالیز ریسک سدهای باطله* [Safety and risk aanalysis of tailings dams]. Paper presented at the 8th Conference on Safety, Health and Environment in Mines and Mining Industries, Tehran, Iran

Noorizadeh, H., & Faramooshi, M. A. (2008). *بررسی و تحلیل آمار حوادث ناشی از کار در معدن مس سونگون و ارزیابی ریسک حوادث* [Investigation and analysis of occupational accidents statistics at Sungun copper mine and accident risk assessment]. Paper presented at the 8th Conference on Safety, Health and Environment in Mines and Mining Industries, Tehran, Iran

Sayyadi, A. R., Monjezi, M., Heidari, M., Vahidi, M., & Habibi, E. (2007). ارزیابی اقتصادی و تحلیل ریسک معدن مس سونگون [Economic evaluation and risk analysis of Sungun copper mine]. *Mining Engineering Journal, 2*(3), 21-30.

Toos-Ab Consulting Engineering Company. (2003). *گزارش آشنایی با طرح مطالعات سد مس سونگون* [Report on the Sungun Copper Dam Study Plan]. Mashhad, Iran: ToosAb Consultant Publication.

Toos-Ab Consulting Engineering Company. (2003). *گزارش طرح تأمین آب و دفع پساب کارخانه تغلیظ مس سونگون* [Sungun Copper Concentrate Water Supply and Disposal Plan Report]. Mashhad, Iran: ToosAb Consultant Publication.

Toos-Ab Consulting Engineering Company. (2004). *گزارش تمهیدات کنترل نشت آلودگی به پایین دست در سد باطله مجتمع مس سونگون* [Report of Downstream Pollution Leakage Control Measures in the Sungun Copper Dam Tailings Dam]. Mashhad, Iran: ToosAb Consultant Publication.

References (In English)

Aghili, S., Vaezihir, A., & Hosseinzadeh, M. (2018). Distribution and modeling of heavy metal pollution in the sediment and water mediums of Pakhir River, at the downstream of Sungun mine tailing dump, Iran. *Environmental earth sciences*, *77*(4), 128.

Ardeshir, A., Mohajeri, M., & Amiri, M. (2016). Evaluation of safety risks in construction using Fuzzy Failure Mode and Effect Analysis (FFMEA). *Scientia Iranica*, *23*(6), 2546-2556.

Armstrong, M., Petter, R., & Petter, C. (2019). Why have so many tailings dams failed in recent years?. *Resources Policy*, *63*, 101412.

Chattopadhyay, S., & Chattopadhyay, D. (2019). Coal and Other Mining Operations: Role of Sustainability. In: Meyers R. (eds) Encyclopedia of Sustainability Science and Technology (pp.333-356). New York, NY: Springer.

Dudlák, T. (2018). After the sanctions: Policy challenges in transition to a new political economy of the Iranian oil and gas sectors. *Energy policy*, *121*, 464-475.

Golbarg, F., Nabi Bidhendi, G., & Hoveidi, H. (2018). Environmental management of oil pipelines risks in the wetland areas by Delphi and MCDM techniques: case of Shadegan international wetland, Iran. *Pollution*, *4*(2), 195-210.

Harper, T. G., McLeod, H. N., & Davies, M. P. (1992). Seismic assessment of tailings dams. *Civil Engineering*, *62*(12), 64.

Hatje, V., Pedreira, R. M., de Rezende, C. E., Schettini, C. A. F., de Souza, G. C., Marin, D. C., & Hackspacher, P. C. (2017). The environmental impacts of one of the largest tailing dam failures worldwide. *Scientific Reports*, *7*(1), 1-13.

Heidari, M., & Osanloo, M. (2019). Sustainability Assessment of Angouran Lead and Zinc Mining Complex. In *Proceedings of the 27th International Symposium on Mine Planning and Equipment Selection-MPES 2018* (pp. 523-534). Springer, Cham.

Herrmann, M. (2019). *Contributions to the Risk Assessment of Natural and Induced Seismicity: Producing High-Resolution Catalogs and Improving Risk-Based Decision-Making* (unpublished doctoral dissertation). Zurich, Germany: ETH.

Jozi, S. A., & Salati, P. (2012). Environmental risk assessment of low density polyethylene unit using the method of failure mode and effect analysis. *Chemical Industry and Chemical Engineering Quarterly*, *18*(1), 103-113.

Karami, S., Nabibidhendi, G., Jafari, H., Hoveidi, H., & Hedayati, A. (2014). Risk assessment of chemical exposures using multi criteria decision making case study: Arak Petrochemical Plant. *Iranian Journal of Health and Environment*, *7*(2), 229-238.

Kossoff, D., Dubbin, W. E., Alfredsson, M., Edwards, S. J., Macklin, M. G., & Hudson-Edwards, K. A. (2014). Mine tailings dams: Characteristics, failure, environmental impacts, and remediation. *Applied Geochemistry*, *51*, 229-245.

Kurtar, H., Kapusuzoglu, A., & Ceylan, N. B. (2019). Investment Decision Process in Oil Economy for Major Oil Exporting and Importing Countries. In *Handbook of Research on Global Issues in Financial Communication and Investment Decision Making* (pp. 236-255). IGI Global.

Lèbre, É., Corder, G. D., & Golev, A. (2017). Sustainable practices in the management of mining waste: A focus on the mineral resource. *Minerals Engineering*, *107*, 34-42.

Liebenberg, K., Smit, A., Coetzee, S., & Kijko, A. (2017). A GIS approach to seismic risk assessment with an application to mining-related seismicity in Johannesburg, South Africa. *Acta Geophysica*, *65*(4), 645-657.

Mihut, N. M. (2019). Noise and Vibration Effects on Human Organism, Produced by the Development Activities of the Pinoasa Minier Perimeter. *Fiability & Durability/Fiabilitate si Durabilitate*, *1*, 236-239.

Monteiro, N. B. R., da Silva, E. A., & Neto, J. M. M. (2019). Sustainable development goals in mining. *Journal of Cleaner Production*, *228*, 509-520.

Piechowski, M., Szafer, P., Wyczolkowski, R., & Gladysiak, V. (2018, August). Concept of the FMEA method-based model supporting proactive and preventive maintenance activities. In *IOP Conference Series: Materials Science and Engineering* (Vol. 400, No. 6, p. 062023). IOP Publishing.

Procter, T. G., & Brown, A. L. (2019). The use of Probabilistic Noise Modelling in the Design of Open-cut Mines. In *Proceedings of ACOUSTICS* (pp. 1-8). Australian Acoustical Society, Cape Schanck, Victoria, Australia.

Ruokonen, E., & Temmes, A. (2019). The approaches of strategic environmental management used by mining companies in Finland. *Journal of cleaner production*, *210*, 466-476.

Saeidi, P., Saeidi, S. P., Sofian, S., Saeidi, S. P., Nilashi, M., & Mardani, A. (2019). The impact of enterprise risk management on competitive advantage by moderating role of information technology. *Computer Standards & Interfaces*, *63*, 67-82.

Spitz, K., & Trudinger, J. (2019). *Mining and the environment: from ore to metal*. CRC Press.

Stefaniak, K., & Wróżyńska, M. (2018). On possibilities of using global monitoring in effective prevention of tailings storage facilities failures. *Environmental Science and Pollution Research*, *25*(6), 5280-5297.

Sun, K., Azman, A. S., Camargo, H. E., & Dempsey, P. G. (2019). Risk assessment of recordable occupational hearing loss in the mining industry. *International journal of audiology*, *58*(11), 761-768.

Vazdani, S., Sabzghabaei, G., Dashti, S., Cheraghi, M., Alizadeh, R., & Hemmati, A. (2017). FMEA techniques used in environmental risk assessment. *Environment & Ecosystem Science (EES)*, *1*(2), 16-18.

Yoneda, M., & Mokhtar, M. (Eds.). (2018). *Environmental risk analysis for Asian-oriented, risk-based watershed management: Japan and Malaysia*. Singapore, Singapore: Springer.