Determine Environmental Risks to Provide Water Quality Remedies (Case Study: Doosti Dam Reservoir)

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Abstract

Water quality protection of reservoirs requires the identification of sources and impact of environmental hazard. Due to different remedial measures and plans for water quality preservation, and their cost, it is necessary to rank the risk of each sub-basin. Doosti Dam is located on the border of the three countries of Iran, Turkmenistan and Afghanistan, and has a basin area of 54000 square kilometers. More than 70 percent of its basin is located in Afghanistan. The purpose of this research is to identify and rank the environmental risk affecting the quality of water in the Doosti reservoir to provide remedial solutions. For this purpose, first, the basin was divided into several sub-basins. Then the environmental risks were divided into six main categories. After that, by using amatrix-based approach,"Likelihood"and "Severity" of each risk in sub-basins was calculated.

The results revealed that "IR-2" sub-basin has high risk in "agricultural activities" and "industrial and mining activities"."AF-8" sub-basin in Afghanistan and Turkmenistan (joint),has high risk in "terrorist attacks". One of the suggested solutions in this regard is to control and reduce surface runoff by preventing degradation and creating suitable vegetation in the sub-basin of "IR-2" as well as the "AF-8".

Keywords: Doosti Dam, environmental risks assessment, matrix-based approach.

1. INTRODUCTION

Water resources are vital to the safety of the human community, which directly influence human life[1].It can affected by natural or human activities.Thelarger the basin is, the more diverse the effects will be.Risk assessments can be used in ranking the level of water environmental risk, and contribute to provide economical remedial solution in basin.

The term "Risk" means the probability of specific events that can become reality[2]."Risk assessment" is the process of identifying potential risk to minimize the likelihood of risk, including risk identification, risk analysis (identifying the factors and consequences of each risk, damage assessment and determining risk levels) and risk control[2].According to one definition, risk in water resources are generally divided into two main categories: natural disasters, and anthropogenic activities[2; 3; 4; 5]. Natural disasters include earthquake, flood,avalanche, tornado, storm, hail, landslides, insect and animal invasion, volcanoes, tsunami, drought, etc. Anthropogenic activitiesare very diverse and include chemical explosions, atmospheric pollution, marine accidents, oil pollution, industrial pollution, chemical pollution, hazardous waste, soil erosion, transport and road accidents, facility failure, burial and distribution of hazardous waste, terrorist attacks, oil leakage, etc. In addition, there is also a correlation between economic development and water basin environmental risks [6].

Due to the diverse resources and complicated components, water environmental risks are difficult to control [7], thus water environmental risk assessments are essential for effectively controlling water environmental risks[1].

2. MATERIALS AND METHODS

The Doosti dam basin includes three countries: Iran, Afghanistan and Turkmenistan.This dam has a large basin (54000 square kilometers), so for preserving the quality of reservoir, it is important to identify the main source of risks, and their impact area on the basin.Therefore, in this study, first total basin is divided into several little sub-basins. After that, the six main riskamong the list of risk categories were identified. Finally, a matrix-based category approach were applied for each sub-basin.

2.1. STUDY AREA

The Doosti (means friendship) dam is located on the northeast of Iran, on the border of Iran and Turkmenistan, in RazaviKhorasan province, about 180 kilometers east of Mashhad, at the geographic coordinate $35^{o}\ 56^{/}\ 50^{//}$ north, and $61^{o}\ 9^{/}\ 45^{//}$ east (fig. 1). This dam is an embankment dam, with a height of 78 meters from foundation, and a normal reservoir volume of 1250 million cubic meters (MCM).

The dam is constructed on Harirud River,which originates from the central mountains of Afghanistan, and reaches the Doosti dam after about 690 kilometers. More than 100 kilometers of this river is the international border between Iran and Afghanistan, and 45 kilometers of it is the international border between Iran and Turkmenistan. The length of reservoir is more than 25 kilometers, and the total area of the river basin at Doosti dam is more than 54000 square kilometers (or 20849 square mile).

The main purpose of this dam isto supply Mashhad drinking water (which is Iran's second most populous city), agricultural water supply for Iran and Turkmenistan, controlling floods, preventing erosion of the river banks, and constructing a hydroelectric power plant (under design).

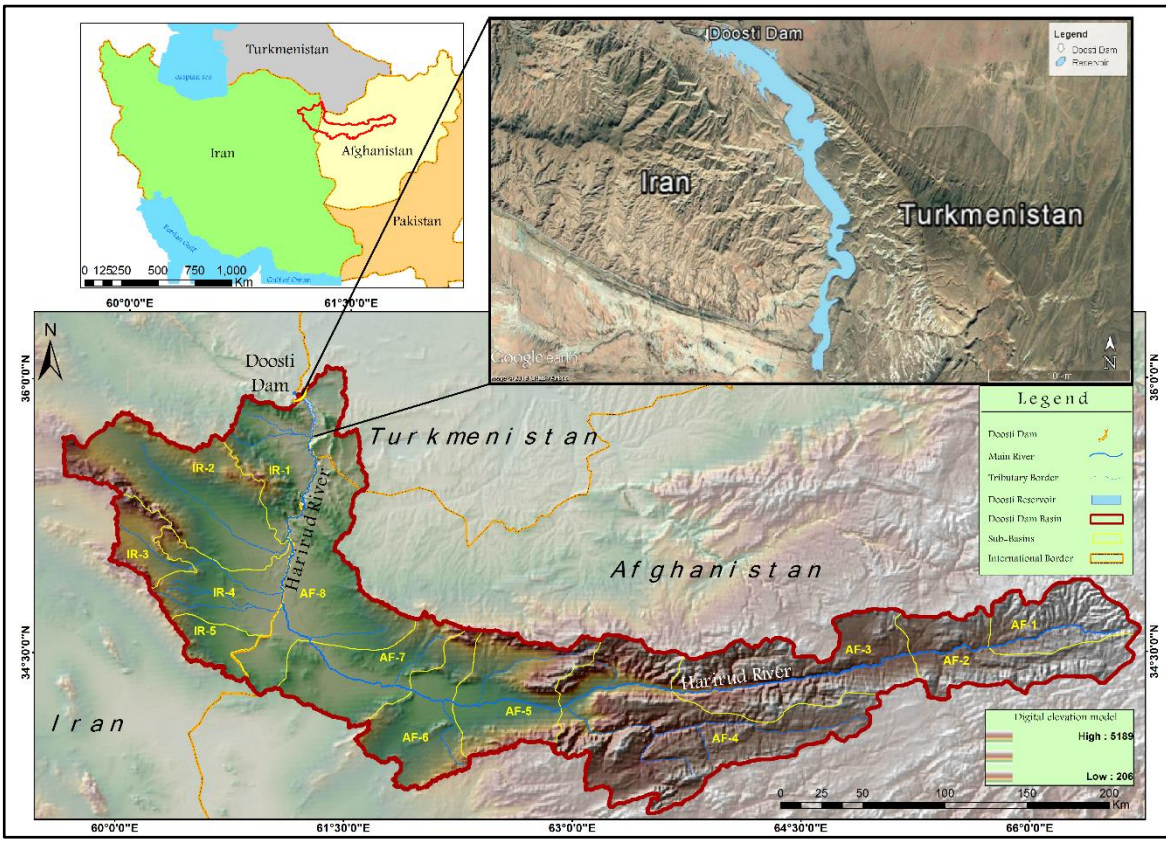

Figure 1. Doosti Dam position, its basin and sub-basins and reservoir

2.2. RISK ASSESSMENT METHOD

Numerous studies have been carried out on risk assessment methods so far [8; 9; 10; 11; 12; 13;14;15; 16]. Most of them use tow factor for risk assessment. The approach applied to this study is a matrix-based category approach based on the system described in reference [14]. This method was selected for Doosti dam basin because it accounts for all risk types and uses a rating system that ranks rare but severe risks[11].

In this method, in order to evaluate and quantify the risk of water resources, two indicators of "Likelihood" and "Severity" are used.Table 1 is used in order to quantify each of these two indices.According to this table, the higher the "Likelihood" (such as several times during the year) and the greater its "Severity" (such as the risk to ecosystems), the higher the rank from 1 to 5. The opposite is also correct.

After quantifying the above two factors, it is necessary to express these results qualitatively. For this purpose, Table 2 is used. According to this table, the higher the rankings of two factors of "Likelihood" and "Severity", the sub-basin has the higher the risk. The opposite is also correct.

Table 1- Risk assessment calculation [14]

Likelihood			Severity		
Level		Example Description	Level		Example Description
1	Rare	May occur only in exceptionalcircumstances. May occuronce in 100 years	1	Insignificants	Insignificant impact or not detectable
2	Unlikely	Could occur within 20 years orin unusual circumstances	2	Minor	Health: Minor impact for small population. Environment: Potentiallyharmful to local ecosystem with local impacts contained. to site
3	Possible	Might occur or should beexpected to occur within a 5- 10 year period	3	Moderate	Health: Minor impact for large population. Environment: Potentiallyharmful to regional ecosystem with local impacts primarily contained to on site
4	Likely	Will probably occur within a 1 to 5 year period	4	Major	Health: Major impact for small population. Environment: Potentiallylethal to local ecosystem; predominantly local, but potential for off-site impacts
5	Almost certain	Is expected to occur with aprobability of multipleoccurrences within a year	5	Catastrophic	Health: Major impact for large population Environment: Potentiallylethal to regional ecosystem or threatened species; widespread on-site andoff-site impacts

Table 2- Risk assessment ranking method [14]

		Consequences				
Likelihood		1	2	3	4	5
	1	Low	Low	Low	High	High
	2	Low	Low	Moderate	High	Extreme
	3	Low	Moderate	High	Extreme	Extreme
	4	Low	Moderate	High	Extreme	Extreme
	5	Low	Moderate	High	Extreme	Extreme

3. RESULT AND DISCUSSION

In order to risk evaluation in Doosti dam basin, first the basin is divided into 13 sub-basins(fig. 1). This division is done based on contour line of physical geography of basin, location of cities and villages,land use, roads, industrial parks, fault, and international border.Itis done by GIS software and digital elevation model (DEM). In fig. 1, those sub-basins were located in Iran is labeled from IR-1 to IR-5, and others is labeled from AF-1 to AF-8.

After that, from theextensive list of risk categories, six main categories including “road accident”, “earthquake”, “oil transmission lines”, “terrorist attacks”, “agricultural activity”and “industrial and mining activities” was considered for Doosti basin. Finally for each sub-basin,the “Likelihood” and the “Severity” are evaluated (using Table. 1), and the risk is ranked (using Table. 2). In this ranking, in addition to the “Likelihood” of occurrence, the effect of the factors or “Severity” is taken into account. The summary results are shown in Table.3 and fig. 2.

For “road accident” risk, river crossing with road,types of roadand road accidents in the past were considered. In some cases, transportation of hazardous materials or petroleum products can lead to disasters such as leakage of waste and the release of these materials into the environment, leading to environmental pollution. According to the collected data, Iran's roads are far from the river, as a result sub-basin IR-1 to IR-5 were ranked as a low-risk category. Instead, in some parts of Afghanistan, roads are crossing with rivers, as a result, AF-4, AF-5, AF-6 and AF-8 were ranked as a medium-risk category,and others were ranked as a low-risk category(fig. 2).

For “earthquake” risk, faultsmap, historical record of happen earthquakes in the basin, and location of water facilitieswere considered.Earthquakes can have adverse effects on some facilities whose their destruction can contaminate groundwater or the environment. Based on this data, to data some earthquake measuring less than 4 on the Richter scale occurred in the basin. Besides that, if an earthquake occurs in sub-basin IR-1 and AF-8, it may have damaging effects on the reservoir due to its short distance to the Doosti reservoir. As a result, IR-1 and AF-8 were ranked as a medium-risk category, and others were ranked as a low-risk category (fig. 2).

For “oil transmission lines” risk, data weregathered from Iranian Oil Pipelines & Telecommunication Company. According to the inquiry, the oil pipelines to the northeast of Iran are the safest in the country. The critical points have been secured, and the monitoring of these pipelines, whether in oil or gas, is done with the latest technology in the world. In the sub-basin area of Turkmenistan and Afghanistan, there are no oil pipelines. As a result, all sub-basin were ranked as a low-risk category (fig. 2).

For “terrorist attacks” risk, recorded data of terrorist activities within the basin, especially at the border were investigated.Researches were showed that most of terrorist activities have been carried out near the international border between Iran and Pakistan. However, some events have so far occurred around the city of Taybad (sub-basin IR-4& IR-5). As a result, this twosub-basin were ranked as a medium-risk category. On the other hand, the sub-basin AF-8 can be hazardous in this regard due to its short distance to the Doosti reservoir, and its location in neighboring countries (which are not directly monitored). As a result, this sub-basin was ranked as a high-risk category. Others were ranked as a low-risk category (fig. 2).

For “agriculturalactivity” risk, land uselayer of basin was considered, and the percentages of different land use category (including poor range, moderate range, good range,forests, irrigated farming, dry farming,gardening, mountain, rock, bare land, and urban) were extracted.Among this categories, irrigated farming have the most potential effects on the water resources, from the perspective of “agricultural activity”. Calculations showed that most irrigated farming is located around the city of Torbat-e-Jam (sub-basin IR-2). As a result, this sub-basin was ranked as a high-risk category. On AF-8 sub-basin, there are some agricultural activities, and because of its close distance to Doosti reservoir, it was ranked as a medium-risk category.Others were ranked as a low-risk category (fig. 2).

For “industrial and mining activities” risk, the location, type and capacity of industrial parks, mines and factories were analyzed. Based on collected data, there are just few factories near the city of Torbat-e-Jam and Fariman (sub-basin IR-2). In addition, most of the active mines in Doosti dam basin are in sub-basin IR-2. As a result, this sub-basin was ranked as a high-risk category. Others were ranked as a low-risk category (fig. 2).

Finally, the results showed that sub-basin IR-2 (in Iran) and AF-8 (in Afghanistan and Turkmenistan (joint)) were subjected the most risk, among the basin. One solution that can be

used in this sub-basins is planting and making vegetation in this sub-basins, especially in river banks, to control and reduce surface runoff.

4. CONCLUSIONS

Six main risk categories (including “road accident”, “earthquake”, “oil transmission lines”, “terrorist attacks”, “agricultural activity” and “industrial and mining activities”)were assessed in Doosti dam sub-basins, using the matrix-based approach. To do that, first basin is divided into smaller sub-basins. Then for each sub-basin, "Likelihood" and "Severity" are evaluated using Table. 2. Finally, risks are qualified using Table. 3. The results revealed that among sub-basins, AF-8 is subjected to the most risk categories (“High” risk in terms of “terrorist attacks”, and “Medium” risk in terms of “road accident”, “earthquake” and “agricultural activity”). This is mainly due to its closeness to the Doosti reservoir, as well as the lack of direct monitoring. Among the sub-basins located in Iran, sub-basins IR-2 is subjected “High” risk in terms of “agricultural activity” and “industrial and mining activities”. This is mainly due to its land use and the location of mines. One of the best solution for this sub-basins is planting and making vegetation to control and reduce surface runoff.

Table 3- Summary of risk assessment result in Doosti basin

country	sub-basin	Type of Risk					
		road accident	earthquake	oil transmission lines	terrorist attacks	agricultural activity	industrial and mining activities
Iran	IR-1	low	medium	low	low	low	low
Iran	IR-2	low	low	low	low	high	high
Iran	IR-3	low	low	low	low	low	low
Iran	IR-4	low	low	low	medium	low	low
Iran	IR-5	low	low	low	medium	low	low
Afghanistan	AF-1	low	low	low	low	low	low
Afghanistan	AF-2	low	low	low	low	low	low
Afghanistan	AF-3	low	low	low	low	low	low
Afghanistan	AF-4	medium	low	low	low	low	low
Afghanistan	AF-5	medium	low	low	low	low	low
Afghanistan	AF-6	medium	low	low	low	low	low
Afghanistan	AF-7	low	low	low	low	low	low
Afghanistan-Turkmenistan	AF-8	medium	medium	low	high	medium	low

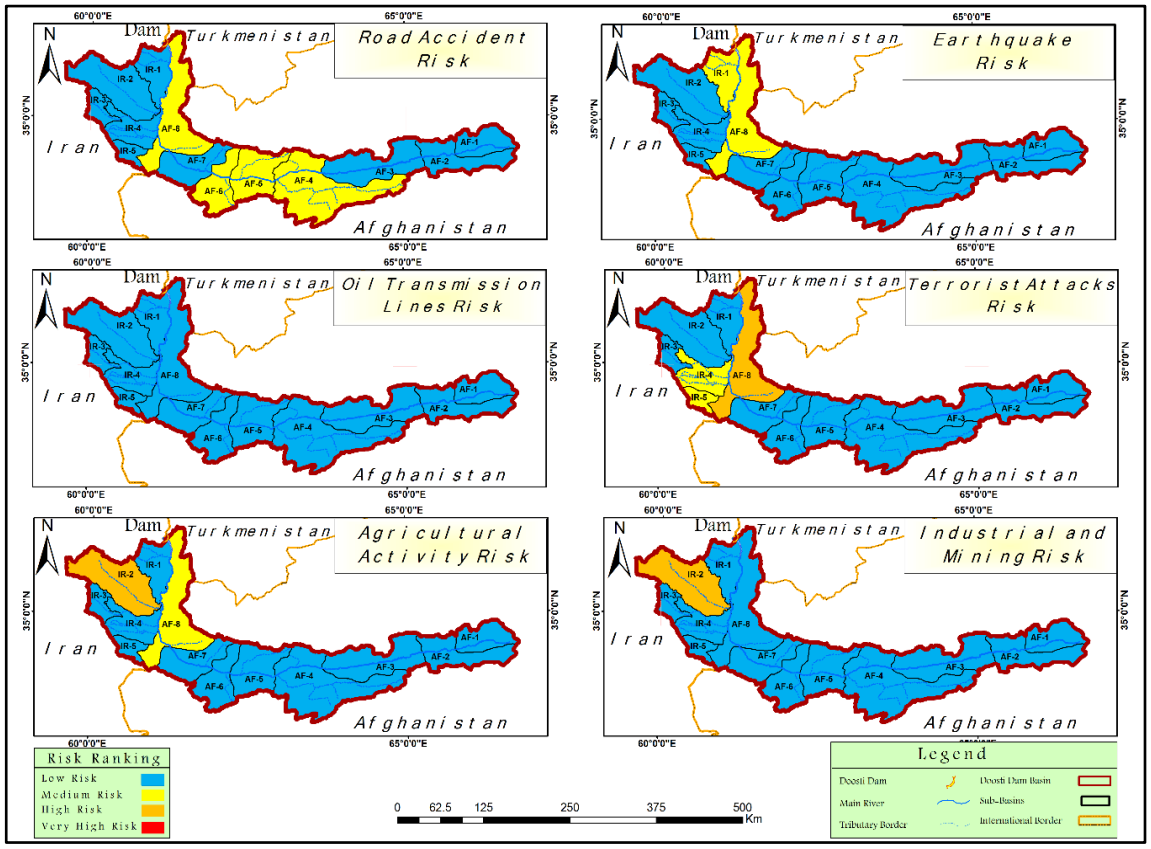

Figure 2. Map of risk assessment result in Doosti basin

5. ACKNOWLEDGMENT

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6. REFERENCES

1. Liu, H.D.X, Zhang. J, Zhijun. T, Ji. M. (2018), "*The Spatial Distributions and Variations of Water Environmental Risk in Yinma River Basin, China*"International Journal of Environmental research and public health.

2. Iran Ministry of Energy, (2013). *"Draft Guidelines for the Management of Pollution Disaster Risk in Surface and Groundwater Resources"*. Publication No. 407.a. (in Farsi)

3. Chen, S.Q.; Chen, B.; Fath, B.D. (2013). "*Ecological risk assessment on the system scale: A review of state-of-the-art models and future perspectives*". Ecol. Model. 250, 25–33.

4. Kiriscioglu, T.; Hassenzahl, D.M.; Turan, B.(2013)."*Urban and rural perceptions of ecological risks to water environments in southern and eastern Nevada"*. J. Environ. Psychol. 2013, 33, 86–95.

5. Li, Y.L.; Liu, J.L.; Gao, Z.G.; Lin, C.; Yang, Z.F. (2010). "*Spatial distribution and health risk of heavy metals and polycyclic hydrocarbons(PAHs) in the water of Luanhe River Basin, China"*. Environ. Monit. Assess. 163, 1-13.

6. Wei, Y.H.; Tang, D.S.; Meng, Z.Z.(2015).*"Analysis on the Relation of Water Environment and Economic Development"*.Appl. Mech. Mater 737, 941–944

7. Marianne, S.; Dan, L.; Emily, C.; Hart, A.(2012)."*Review of risk from potential emerging contaminants in UK groundwater"*. Sci. Total Environ. 416, 1–21. 23. Huang, P.C.; Tong, L.I.; Chang, W.W.; Yeh, W.C. A two

8. Sadeh, N. Rezaian, S. (2017), "*Risk Management and Control of Dams Based on Integrating TOPSIS and RAM-D Techniques (Case Study: Paveh Rood Dam,Iran)*",Environmental Energy and Economic Research. 1(4): 363-372.

9. Rezaian, S. Jozi, S, A. Zaredar, N. (2016), "*Environmental risk assessment of a dam during construction phase*", Global J. Environ. Sci. Manage., 2(4): 345-356.

10. Hoshyari, E. Hassanzadeh, N. Khodabakhshi, M. (2019),"*Risk Assessment of Water Supply System Safety Based on Water Safety Plan (WSP) Implementation in Hamadan, Iran*", Arch HygSci;8(1):46-55.

11. Page, D., Gonzalez, D., Dillon P., Vanderzalm, J., Vadakattu, G., Toze, S., Sidhu, J., Miotlinski, K., Torkzaban,S., and Barry, K. (2013), "*Managed Aquifer Recharge Stormwater Use Options: Public Health and Environmental Risk Assessment Final Report*", Goyder Institute for Water Research Technical Report 13/17.

12. Bartram, J., Corrales, L., Davison, A., Deere, D., Drury, D., Gordon, B., Howard, G., Rinehold, A. and Stevens, M. (2009). "*Water safety plan manual: step-by-step risk management for drinking-water suppliers*". World Health Organization. Geneva, 2009.

13. NHMRC–NRMMC (2011). "*Australian Drinking Water Guidelines(NWQMS Document 6)".* National Health and Medical Research Council and Natural Resource Management Ministerial Council,Canberra,Australia. http://www.environment.gov.au/water/publications/quality/ (17/6/2013).

14. NRMMC–EPHC–AHMC (2006). "*Australian Guidelines for Water Recycling: Managing Health andEnvironmental Risks (Phase 1). (NWQMS Document 21)".* Natural Resource Management Ministerial Council, Environment Protection and Heritage Council, and Australian Health Ministers' Conference, Canberra, Australia. http://www.environment.gov.au/water/publications/quality/ (17/6/2013)

15. Chen, Y. Chen, H, Zhang, L. Jiang, Y. Gin, K, Y, H. He, Y. (2018);"*Occurrence, Distribution, and Risk Assessment of Antibiotics in a Subtropical River-Reservoir System". Water, 10,104; doi: 10.3390/w10020104.*

16. SINGOVSZKÁ, E. BÁLINTOVÁ, M. (2009); *"Methods of Environmental Risk Assessment in Water Management"*. POLLACK PERIODICA, Vol. 4, No. 1, pp. 105–113.