Environmental impact assessment of dams at construction and operation phases

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Abstract

Environmental impact assessment (EIA) in the projects of civil engineering, was not being considered by many countries until recent years. However, in recent decades of 20th century and after observing environmental impacts of some of the projects, it was stated that the environmental factors played a noticeable role in speeding and directing of projects. Dam construction as one of the important civil and developing projects have positive and negative effects on environment. The environmental impacts can be categorized based on different criteria e.g. short and long term, impacts on surface and the ecosystem of the region, upstream and downstream side of dam, and social and economic impacts. Whereas dams have positive effects, it is necessary to minimize the negative impacts of dams toward stable development. At the same time, it is known that the consequences and impacts are different during construction and operation period in terms of intensity, importance and extent. In this paper, at first, the effectible geophysical factors related to river and reservoir water, vegetation and animal, social, economic and cultural factors are studied. Then, as a case study, Gotvand dam for quantifying the environmental impacts using the Iranian matrix are presented.

Keywords: Environmental impact assessment, Earth dams, Environmental factors.

1. INTRODUCTION

The environmental considerations in the civil and developing projects were not taken in to account by most of the countries until recent years. The environmental consequences of some projects raised notices that environmental factors played an important role in the direction and speed of development in the last decades of 20th century. Nevertheless, development is not in contradiction to environment; but, exceeding extraction of natural resources leads to disturbance and contamination of environment. Development is stable and persistent when it is appropriate from environmental point of view in addition to technical, social and economic justification [1].

At the same time, it is known that the consequences and impacts during construction and operation period in term of intensity, importance and extent are different. In advance of any environmental impact assessment of the project, all other effects should be evaluated. It should be noted that environmental impact assessment depends on many factors e.g. existing records, collected data interpretation, statistics, sampling, and finally analysis of these subjects.

The environmental impacts of dam construction are shown in Fig.1 [1]. Also, the impacts of different environmental factors of dam construction is presented in following.

2. STUDY ON THE EFFECTIVE GEOPHYSICAL FACTORS

2.1. THE IMPACT OF TOPOGRAPHY

During construction period, the topography is subject to significant change due to rock and soil excavation, backfilling, road construction, temporary and permanent camps, borrow area excavation and etc. [10]. This impact is considered as a negative impact while it changes the region from its intact and natural condition. It would be intense, permanent and unavoidable. However, the impact would be on the ground shape and general view of the region during operation period.

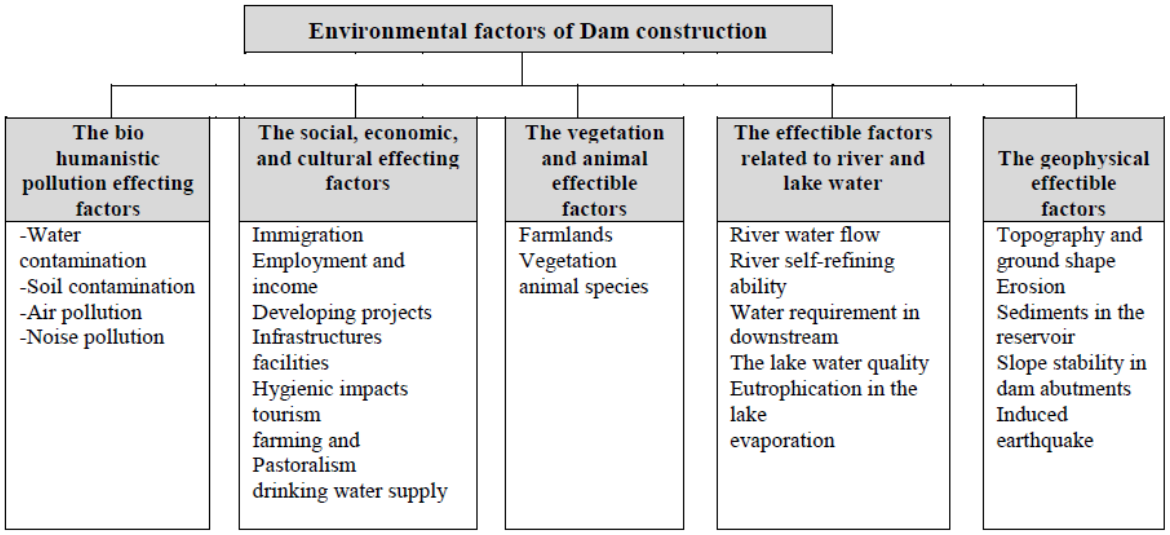

Fig.1- EIA diagram for dams

2.2. IMPACT ON SOIL EROSION

River diversion system, excavation and backfilling, removal of vegetation at the construction area, borrow area extraction and deposition, road and structures construction and machinery travelling are the factors that have intense effect on erosion during construction works.

During operation, it is possible that people, especially in the upstream side of dam, try to expand their farmlands due to providing the water supply. This can lead to increased soil erosion and sediment in dam reservoir. The soil erosion is very important because of sediment and suspended solids loading. Therefore, it is predicted that the project impact on the soil erosion during construction and operation periods is exposed in medium to high intensity.

2.3. SEDIMENTATION IMPACT ON THE RESERVOIR

One of the main issues in dam construction is sediment and deposition. When a dam is constructed, whether small or large, reservoir or regulatory, the river sediments are collected in the dam reservoir [2]. The impacts of deposition in the reservoir are reviewed from different aspects:

1. Reduction of dam service life: accumulation and combination of sedimentary materials lead to rapid increase of reservoir dead volume and thus, reduction of dam service life. This has a direct impact on economic of the project in form of losing national capital and social problems.
2. Reduction of the nutrients in the downstream side of dam: the river flow transmits a lot of amount of nutrients e.g. nitrogen, phosphorus and other required substances for plants to downstream. These materials divert to the farmlands, enrich the soil and so, the nutrient taken by plants from the soil would be compensated. Dam construction and water controlling change the natural pattern of deposition in the downstream side of the dam and reduction of suspended loads in the river leads to deposition decreasing in the farmlands located in the river trusses and the farmlands in the plains.

According to statistics, 50 billion cubic meters (1% of world reservoir capacity) accumulate in dams at all around the world each year. Sanmenxia dam on the Yellow river stored 50 billion tones sediment after dam impounding. The dam made 66000 hectare of the most fertile farmlands of the world went under the water. Kulekhani dam in Nepal was filled by sediment to 0.9 of its volume 12 years after construction. So, operation of the 114 m dam with predicted 100-year service life was finished. [3]

2.4. THE IMPACT ON INDUCED EARTHQUAKE

Dam construction and making a big reservoir of water, several millions or even billions of new load impose on the dam and foundation where haven't been experienced such a load at the area. There are lots of evidences of earthquake due to dam impounding [2]. The research has done on the 20 big dams of the world about induced earthquake and the results show that induced earthquake with different intensities while impounding has occurred. Based on past experiences, after dam impounding some induced earthquakes with low or micro

intensities occur and their frequencies and intensities increase by water depth till it reaches a fixed amount. Water impact on the lake base or the connate water weight in the reservoir make the fault movement that causes earthquake. When the water height is above 100 meters or the reservoir volume is about 1 billion cubic meter, a more intense earthquake occurs with 3-5 Richter magnitude or rarely more than 5 Richter. Then, less intense earthquakes occur till it ended.

Today, the relation between earthquakes and dam reservoirs has been proved in more than 70 dams. For example, Koyna dam with 103 m height caused a 6.3 Richter earthquake and Koynangar village in Maharashtra state was destroyed on 1967, Dec.11 [4]. Vaiont dam in Italy with 261 m height was constructed in 1960 and the earthquakes occurred immediately after impounding [5]. In 19663, when the dam height reached to 180 m, 60 shakings were recorded and on October 9th the Longarone city destroyed and all people were killed.

2.5. THE IMPACT ON FLOOD AND SLOPE STABILITY OF THE RESERVOIR ABUTMENTS

Flood control is one of the side purposes of dam construction due to damaging impact of river floods [6]. One of the natural processes after dam construction is water penetration in to the surrounded ground layers of the dam. In case of inappropriate bedding e.g. Marnstone, Conglomerate, limestone and etc. and when the bedding has the steep slope toward the reservoir, water penetration causes less friction between rock layers and the natural slop stability ruined and landslide of soil and rocks happens. Inappropriate extraction of borrow areas near to the reservoir and making slopes of abutment steeper can cause the slope instability.

In some valleys of Iran, especially north parts due to bedding, landslide makes limitations. In general, instability of abutments can cause potential dangers in dams and bring important issues. Like:

- The long waves on the reservoir surface, make the risk of overtopping and high pressure to dam body that cause dam failure and destroying all the facilities and therefore, lots of human and financial damages.
- Reduction of dam useful volume due to soil and rock failure in to dam causes water resources management and investment get ruined. So, social, political and economic damages will happen.
- The intake systems, gates and trash racks will be broken and cause the operational system to be out of function.

3. THE EFFECTIBLE FACTORS RELATED TO RIVER AND RESERVOIR WATER

3.1. THERMAL STRATIFICATION IN DAM RESERVOIR

In general, the quality of the reservoir water alters each season. Usually, lake in mild regions have 2 yearly turnovers in spring and fall. They have thermal layering in summers and reverse thermal layering in winters. Most of lakes in the world have this situation that is very important for gas exchanges and nutrient distribution. According to these studies it could be known the elevation of gates installation. [6]

Stratification is a thermal process and is a function of different factors like reservoir volume, morphology and depth, geographic conditions of the environment, the ratio of inflow to reservoir and the ratio of reservoir depth to length. It is because of layering and making two or three layers of water that the conditions of above layer and under layer are different. It is possible that the dissolve oxygen reduces or even anaerobes conditions happen. This may lead to gas production and the organic matters of dam bed float on the reservoir surface. The layering phenomena is one of the most common in the lakes and reservoirs and makes the most important impact on the hydraulic and thermal features of the dam. It is layers of fluid that are created due to differences in density or temperature or dissolve or suspended substances.

3.2. STUDY THE PROBABILITY OF EUTROPHICATION IN THE RESERVOIR

The base of eutrophication phenomena in dam reservoir, is accumulation of organic matters and sediments in the reservoir. Therefore, the phenomena mean enrichment of water with nutrients e.g. Nitrogen, phosphorus and consequently, algae and other aquatic plants will grow more in the reservoir.

Increasing and accumulation of the materials in dam reservoir may lead to eutrophication in lake and reduction of the quality of water. Considering the effectible factors for the phenomena in the catchment area, it is expected that this happens after impounding.

The other factor for this phenomena is still water. The more time, the algae grow more.

For reducing the eutrophication, considering the above mentioned issues, some treatments would be done during the dam and related structures operation period.

3.3. THE IMPACT ON EVAPORATION

Evaporation of the lakes depends on some factors e.g. lake surface, its depth, region's climate, wind. Evaporation of the lake has a direct relation with area of the lake and reverse relation with its depth. In other word, if the lake surface expands the yearly evaporation will increase accordingly.

In dry and semi-dry climate, the evaporation increases and in humid climate it decreases. Therefore, the most evaporation happens in dry regions when the wind takes away the vapor and the lake surface would expose to evaporation again.

It should be noted evaporation from natural and artificial lakes is complicated and billions cubic meters of fresh water that are collected and stored with high costs will return to atmosphere due to this process.

The evaporation from the lakes are much larger than rivers and the dam reservoir water would be salted consequently. For example, Colorado salted water made farming and crops less efficient.

In addition to the above mentioned effects, other important impacts as following should be considered in environmental assessment impact:

The impact on surface water quality (river)

The river self-refining

The impact on quality and quantity of underground water

4. THE VEGETATION AND ANIMAL EFFECTIBLE FACTORS

This includes the impact on plants species that are near to extinction and on vegetation inside dam reservoir. The impact on animal species divides to aquatic and terrestrial animal categories. With dam water supply, the wild animal would have access to water during summers and this could lead to their population growth. For aquatic animals, dam lakes could lead to more fishing.

5. THE SOCIAL, ECONOMIC, AND CULTURAL EFFECTING FACTORS

The social, economic and cultural effects of dam construction include knowledge, employment and income, houses and resettlement, hygiene and diseases, and tourism [2] and [7]. All these effects would be positive. During dam construction, the employment makes the immigration less and population of the area more. During dam operation, the tourism and increased value of the properties makes long term positive effects.

6. THE EFFECTING FACTORS DUE TO POLLUTION MADE BY HUMAN

6.1. WATER QUALITY

The environmental consequences may happen by not considering water quality until the investment will rather or completely ruins and reaching to dam goals would be impossible [6]. One important factor on water quality is the organic matters. The allowable limits of organic matters differ with the kind of water usage (farming, drinking etc.). In addition, if the reservoir gets empty and full yearly and water would be just for farming, the environmental impacts are low and even the sediments of water would help to the soil to get fertile. But, if the water is for drinking or industrial usage, the high and out of standard organic matters make the project out of function. The sources of organic matters in dam reservoir are: jungles and grasslands, Manure, waste water of factories, animal trapping production, organic fertilizers etc.

6.2. SOIL POLLUTION

As agricultural works develops and farmers use fertilizers and pest repellent poisons for gaining more corps, the penetration of chemical substances to soil and water resources due to farming drainages is possible in long term. This issue makes soil pollution in areas with high underground water level because one of factors of soil pollution (except rare factors due to radioactivity and oil pollution) is losing soil substances due to going underwater. Therefore, the project impact on soil pollution as a negative factor, is considerable with average intensity.

The other issue related to soil pollution is tourism or other industries in the region that can make more trashes and this is the secondary and indirect impact of the project.

6.3. AIR AND NOISE POLLUTION

The different preparation and construction works e.g. rock and soil excavation, road construction, blasting, exploration drill holes, upstream and downstream cofferdams, temporary and permanent camps, equipment transportation, borrow area extraction and machineries make dust, particulates, smoke from heavy machineries and therefore, this lead to air and noise pollution [5]. Some treatments could make the negative impacts less however, this phenomenon is an unavoidable impact that is temporary in construction site and around of it.

During operation period, and after this works have done, no air and noise pollution is expectable.

7. CASE STUDY: GOTVAND DAM

It this part, Gotvand dam with considerable environmental impacts are reviewed Based on above mentioned impacts. The upper Gotvand Dam is the highest earth dam in Iran which is located on Karoon River about 10 km from Gotvand city. Regarding to the geology, it was investigated that Gachsaran salted formation in the reservoir made the reservoir water and consequently Karoon River salty [8]. According to studies, the nearby salt mine and salty Gachsaran formation weren't considered in study phase of the dam. The mine with 5 km distance from the dam made it (with hundreds of millions of tones reserves) completely drowned in the water after dam impounding and therefore the salt amount of Karoon River reaches to the highest level [9]. After dam construction, and before impounding, a clay blanket was constructed on the formation, but only 3 days after impounding the clay was cracked and it didn't work and not prevented salting the water.

Therefore, the quality reduction of water in the reservoir due to salt dome dissolving lead to huge environmental damage in the downstream. The Iranian matrix is used for indicating the impacts of the project works on environmental parameters and quantity studying. In this method, the impacts of a work are studied based on intensity, importance, amount and weight.). The sum of these factors will define the general impact of the project. When an impact is helping to balance the environment it is positive otherwise negative.

Considering the effective factors mentioned in parts 2-6, the environmental impact assessment (EIA) of Gotvand dam during construction and operation phases was done as a case study. The results are presented in table (1).

Table 1- EIA of Gotvand dam

Activities / Impacts		Construction Period Major Activities								Operation Period Major Activities				Algebraic Sum of Construction Period	Algebraic Sum of Operation Period	Algebraic Sum of Total Activities
		Diversion System Cons.	Excavation & Embankment	Access Road	Dam & Relevant structures	Powerhouse cavern & Tunnelling	Equipment Transport	Borrow Area Excavation	Blasting	Reservoir Impounding	Hydropower Energy	Installations Operation	Environmentally Water need			
Geophysical factors	topography and ground shape	-2	-3	-3	-5	-1	-1	-2	0	0	0	0	0	-17	0	-17
	sedimentation in reservoir	-1	-2	0	0	0	0	-1	0	-3	0	0	0	-8	-3	-7
	tability of the reservoir abutm	-1	-1	-1	2	-1	0	0	-2	-4	0	0	0	-6	-4	-8
	flood impact	-2	0	0	0	0	0	0	0	5	0	0	2	-10	7	5
river and reservoir impacts	water river quality	-1	-2	0	-1	-2	0	-1	-1	-5	-2	0	1	-11	-6	-14
	reservoir water quality	-1	-1	0	0	0	-1	0	0	-5	1	0	3	-3	-1	-4
	Eutrophication	0	0	0	-1	0	0	0	0	-4	0	0	0	-2	-4	-5
	evaporation	-1	0	0	0	0	0	0	0	-5	1	0	2	-4	-2	-3
vegetation and animal factors	agricultural land	0	-1	0	0	0	-1	-1	0	-4	0	0	1	-3	-3	-6
	plants species & land	0	0	-1	-1	-1	0	-2	-1	-2	0	0	-1	-17	-3	-9
	animal species	-1	-1	0	-2	0	-1	-2	-4	2	0	0	-1	-11	1	-10
social, economic & cultural factors	employment and income	2	1	1	3	2	3	3	0	-2	2	1	0	18	1	16
	developments planings	0	0	0	1	1	1	0	0	1	4	0	0	5	5	8
	infrastructures	0	0	0	2	0	0	0	0	2	3	1	0	2	6	8
	tourism	0	0	0	-2	-2	0	0	-1	4	4	0	1	-5	9	4
	drinking water secure	0	-1	0	-1	0	0	0	0	-5	0	0	1	-9	-4	-6
bio-humanistic pollution factors	water quality	-1	-1	0	-2	-1	0	0	-2	-3	1	0	1	-27	-1	-8
	noise pollution	-2	-2	-1	-3	-4	-1	-2	-5	0	0	0	0	-22	0	-20
	soil pollution	0	0	0	0	0	0	0	-2	-2	0	0	0	-13	-2	-4
	Air pollution	-1	-2	-1	-2	-1	-1	-2	-1	1	0	0	0	11	1	-10
Algebraic Sum of positive impacts		2	1	1	8	3	4	3	0	15	16	2	12	51	30	41
Algebraic Sum of negative impacts		-14	-17	-7	-20	-13	-6	-13	-19	-44	-2	0	-2	-186	-33	-131
Algebraic Sum of impacts		-12	-16	-6	-12	-10	-2	-10	-19	-29	14	2	10	-135	-3	-90

8. SUMMERY AND CONCLUSIONS

According to this study, the general conclusions about EIA are as following:

- The experience from construction and impounding of Gotvand dam and other dams in Iran demonstrates that environmental impact assessment (EIA) prior to dam construction could prevent the environmental hazardous consequences.

- The positive impacts of dam construction projects are more than negative impacts considering social, economic and cultural parameters. For negative impacts, whereas they are long-term, the suitable environmental treatments should be planned and make it minimum (environmental management planning).

- Dams have hazardous and positive impacts. The negative impacts of construction period due to improper geophysical, biological and hygienic changes are much more than operational period. However, this is unavoidable considering the civil projects nature.

- The undesirable consequences of dam construction are as: reducing bio diversity in downstream, destroying the farmlands, gardens, grasslands near to river after impounding, destroying the houses and residential areas near the river, resettlement of people in the neighborhood and etc. therefore, the environmental management program is necessary for dam study and construction.

- The environmental management program (EMP) includes solutions for reducing important negative environmental impacts and also, make positive effects of the project more. This program has the stable development goal and considers solution for controlling the negative impact of environment and plans are made to reduce hazardous environmental impacts, supervise the treatments and reduce the negative impacts by survey and test the environment.

- In dams located south of Iran, thermal layering exists due to low elevation above the sea, rather high evaporation of the lake, organic matters, rural wastewater and chemical fertilizers and this lead to decreasing lake water quality. In dam reservoirs salted water collects in lower layers because of more weights and they mix very slowly with the reservoir water. Therefore, the salted water, made from dissolution, influences lower layers. The amount

of EC starts from less than 1000 μ mho in the above layers and reaches to more than 1800 μ mho (4 times more salted than Persian Gulf) in the lower layers.

The lower bottom outlet can be used to take out this improper water and also, water intakes in different levels can be utilized for the better quality water.

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