

Assessment of Environmental and Health Hazards Arising from the Physical and Chemical Parameters Existing in Zayandehrood Water (2013–2015)

Maede Kamalinasab¹, Mohammad Mehdi Amin^{1,2,3}, Ali Fatehizadeh^{1,2,3}

¹Department of Environmental Management, Islamic Azad University, Najafabad Branch, Najafabad, Iran, ²Environment Research Center, Research Institute for Primordial Prevention of Noncommunicable Disease, Isfahan, Iran, ³Department of Environmental Health Engineering, School of Health, Isfahan University of Medical Sciences, Isfahan, Iran

Abstract

Aim: Zayandehrood River is an important drinking water source in Isfahan Province which has been exposed to contamination. The high variation of physical and chemical properties of water is an important factor influencing on the consumers' health and the recipient environment. This study aims to access the health and ecological hazards related to water quality-determining parameters. **Materials and Methods:** In present work, all the existing data on the physical and chemical quality of Zayandehrood water for two years (March 2013 to March 2015) were collected from Isfahan Province Regional Water Company. The collected data are including dissolved oxygen, turbidity, conductivity, nitrate, phosphate, ammonia, and heavy metals such as arsenic and cadmium. The environmental hazard were determined using the contamination indices such as heavy metal pollution index, positive index, and organic pollution index, and health hazards arising from the absorption of chemical parameters were assessed based on the Environmental Protection Agency model and the use of Rural Access Index. **Results:** The highest noncarcinogenic hazard due to the absorption of chemical parameters was for the children group, and the ratio of health hazard and the probability of exposure to each of the chemical compounds lies in the permissible limit. The hazard higher than 1 revealing the medium hazard was, however, found in the children age group. Assessment of environmental hazards accordingly shows that the quality of the water environment has low contamination. **Conclusion:** The contamination of Zayandehrood water with chemical compounds can play an important role in diseases due to the exposure of low-quality water. It is thus advised to properly treat water before drinking it, and in order to decrease the concentration of poisonous chemicals in Zayandehrood Lake water, appropriate actions should be taken to conserve it.

Keywords: Ratio and index of health hazard, water contamination index, Zayandehrood River

INTRODUCTION

Water is necessary for life sustainability on the Earth. Freshwater resources such as lakes, rivers, and ponds are the main source of daily supply of water for household, agriculture, and industrial uses. In the world, about 80% of freshwater resources include the lakes. However Yet, due to water stagnation and reduced water self-purification, than other waters, lake water is more exposed to contamination.^[1,2] In accordance with population growth and economic activity development in recent decades in Iran, continuous demand for water and food resources has thus increased. Exploitation of water resources due to the unfavorable climate changes in the fields of agriculture, industry, and drinking eventually results in the scarcity of water resources and hence a severe

decrease in water resources.^[3] The authors emphasize on the use of water resources as their research has shown a drastic decrease in the surface water resources especially in the

Address for correspondence: Prof. Mohammad Mehdi Amin, Department of Environmental Health Engineering, School of Health, Isfahan University of Medical Sciences, Isfahan, Iran. E-mail: mohammadmehdia@gmail.com

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case of rivers due to the increased use of water resources in the urban population in developing countries. Furthermore, due to economic and technological limitations, not adequate treatment by the existing systems is effected before discharge in which 0.2% of the urban population and 0.75% of the rural population on average lack freshwater.^[4] Therefore, increase in water contamination not only causes water quality decrease but also disorganizes the human health and aquatic ecosystems. From this point of view, physical and chemical properties in water are among the important parameters which play a vital role in the consumption of water health and consumers' level of satisfaction. It should be noted that due to no judgment with the bodily eyes, the study of chemical factors plays an important role in this study. Chemical contaminants in drinking water often have less priority, for which the harmful effects are generated due to long-term exposure to them. Yet, chemicals can also cause very serious problems.^[5] With a view to accomplishing the objective of the supply of water resources, we emphasize on the importance of drinking water supply for a few parts of Isfahan, Chaharmahal va Bakhtiari, and Yazd Provinces, the supply of agricultural water in Zayandehrood basin, and the generation of electricity in Zayandehrood Lake which is located in Zayandehrood watershed basin. It also plays an important role in the socioeconomic life due to vicinity with industrial, tourist, and large population poles.^[6] In the present study, we have comprehensively analyzed the lake water quality so as to estimate the environmental hazards and its consequential detrimental effects on the human health. Based on physical–chemical parameters such as chemical oxygen demand (COD), nitrates, and phosphates, we have also estimated the parameters of comprehensive pollution index, organic pollution index (OPI), and human health index.

MATERIALS AND METHODS

With an area of about 241,550 km², Zayandehrood watershed basin is the largest river in the Iranian Central Plateau covering Isfahan City. It starts from the mountain range of Zardkough and finally flows into Gavkhouni Wetland. This is a descriptive-analytical study which was conducted from March 21, 2013, to March 20, 2015, to determine the environmental and health hazards due to physical and chemical parameters in Zayandehrood water. For this purpose, all the available data on the abovementioned parameters in the abovementioned years were collected from Isfahan Province Regional Water Company. Health hazards due to the absorption of chemical parameters were assessed based on the Environmental Protection Agency (EPA) model and use of Rural Access Index. The environmental hazards were calculated based on the contamination indices such as heavy metal pollution index (HPI), OPI, and positive index. The average water quality parameters were analyzed during our study period in wet and dry seasons, for whole the lake, as shown from the results in Table 1. The regions surveyed in this study included the upstream of Zayandehrood dam reservoir at the lake input Ghalashahrokh station, the

dam reservoir including Zayandehrood developmental village, Zayandehrood dam crown, and the dam reservoir downstream including Zayandehrood dam outputs, Zaman and Chamasehan. The locations of all the stations and details of the sampling location are shown in Figure 1 and Table 2.

Environmental hazard assessment

Comprehensive pollution index

This index is assessed using the contamination measured with physiochemical parameters (C_i) including nitrate, ammonia, phosphate, dissolved oxygen (DO), electrical conductivity, turbidity, and COD at the permissible limits according to Iran's quality standard for quality situation classification of each parameter (S_i) and the parameters sum to determine the water quality and suitability for human consumption ($\sum P_i$).^[7] Indices used in assessing risk and pollution of water on lake are shown in Table 3.

Organic pollution index

This index is applied using the concentration measured with the parameters of nitrate, phosphate, COD, and the DO at the permissible limit according to Iran's water quality standard for classification of the organic charge or contamination due to organic compounds in water.^[8] Indices used in assessing risk and pollution of water on lake are shown in Table 3.



Figure 1: Sampling location

Table 1: Average water quality parameters analyzed during the study in wet and dry seasons

Station	Unit	Wet season	Dry season
DO	mg/L	14.11	18.62
EC	ms/m	534.50	810.06
Tur	NTU	8.37	6.75
NO ₃	mg/L	10.23	12.24
PO ₄	mg/L	0.31	0.15
Arsenic	mg/L	0.005	0.0003
Cadmium	mg/L	0.0001	0.013
COD	mg/L	27.71	30.64

DO: Dissolved oxygen, EC: Electrical conductivity, NTU: Normal thermal unit, COD: Chemical oxygen demand, Tur: Turbidity

Table 2: Details of sampling location

Sampling code	Latitude	Longitude
R1	50.459109	320,669,835
R2	50.544792	32.718886
R3	50.656662	32.731804
R4	50.731718	32.731804
R5	50.769402	32.724512
R6	50.899918	32.488215
R7	51.223013	32.375127

Table 3: Indices used in assessing risk and pollution of water on lake

Indices	Definition	Limit	Classification
CPI	Clean	0-0.2	1
	A little clean	0.2-0.4	2
	A little pollution	0.4-1	3
	Average	1.01	2
	High	Over 2	5
OPI	Good	0-1	1
	Start of pollution	1-2	2
	Low	2-3	3
	Average	3-4	4
HPI	No pollution	0-1	1
	Low pollution	1-2	2
	Medium	2-3	3
	High	Over 3	4
Health risk assessment	Low	0.1-1	1
	Medium	1-4	2
	High	Over 4	3

CPI: Comprehensive pollution index, OPI: Organic pollution index, HPI: Heavy metal pollution index

Heavy metal pollution index

Heavy metal contamination index is used for water components quality classification based on heavy metal concentration data. Metal concentration (arsenic, cadmium) is compared to its defined standard and is applied to reflect quality of the environment and assess the total contamination level relative to the existence of heavy metals in the water environment. Indices used in assessing risk and pollution of water on lake are shown in Table 3.

Health risk assessment

According to the US EPA, there are techniques to assess the chemical parameters hazards which we can determine under the following conditions. This hazard can be assessed under the condition of everyday water consumption throughout the human life or in a specific period. In this technique, ingestion rate is the average consumed drinking water equals 2 l for children of 1–10 years' age group and 3.45 l for the 10–70 years' age group because of the reference.^[9] The dosage of each of the chemicals is thus calculated regarding the amount of water every individual drinks every day and other items presented in Table 1. The parameters used to show the average daily

absorption included the mean concentration of physical and chemical parameters which is indicated by the symbol C and the durations of exposure to the parameters in years scientifically denoted by exposure duration (ED) and considered equaling 10 years for each children's age group and equaling 50 years for adults. The frequency of exposure to the parameters in days/years is also denoted by exposure frequency equaling 365 days for both age groups, and the duration of exposure to the parameters in days on average, denoted by Average time, is calculated via multiplying ED by 365. In the end, the average body weight of the person exposed to chemical compounds is calculated weight 60 and 25 kg, respectively, for adults and children, and noncarcinogenic hazard digestive exposure to each of the compounds and the compounds sum relatives to their reference levels (reference dose) which equal 1.6, 0.057, 0.97, 0.3, and 0.5, respectively, for the chemical compounds including nitrate, phosphate, ammonia, arsenic, and cadmium. Finally, health ratio (quotient ratio) is obtained by dividing the average daily dose of adsorption by its reference level. And health index from the total values obtained from the risk ratio, each of the chemical compounds is obtained. This mathematical relation is expressed in Table 3.^[10,11]

RESULTS

The measured concentration of the water quality parameters was studied from March 21, 2013, to March 20, 2015, in two dry and wet seasons and was compared to water quality permissible concentration for drinking water defined by Iran's water quality standard relevant to the bureau of human Environment Deputy Office, Iranian Department of Environment.^[12] The result from the comparison of physico-chemical parameters and water heavy metals to the drinking standard (2nd group) shows that except for cadmium and (biological oxygen demand [BOD]) which are 19° and 5° higher than the standard limit, respectively, the remaining parameters are at the standard level. In order to study the assessment of human health hazard and the lake water quality situation, the data measured using consumer price index, OPI, HPI, and H1 indices were used. The results from water comprehensive contamination index in the dry season showed that all the amounts are in the 0–0.2 range, and in the wet season, all the amounts are higher than 0.2 lying, respectively, in the "a little clean" and "clean" range of water quality situation. The organic contamination index lies in both seasons at all the sampling station in the >1 range with no contamination. The result from water comprehensive and organic contamination indices shows water quality acceptable and satisfactory information. Yet, none of the two indices includes any data on heavy metals including arsenic and cadmium. For this reason, the HPI index was used to show water contamination with heavy metals, whose results showed that in the dry season, all the amounts at the sampling stations are over 3, whereas in the wet season, all the amounts are <1. They are thus highly contaminated and no contaminated, respectively. According to the descriptions in the tables, it was shown that Zayandehrood River is chemically contaminated

in this region. In order to assess its effects on human health in terms of ratio and index of health hazard, depending on exposure to contaminants, an important tool for health hazard calculation, the results of which are listed in Table 4. The average ratio of noncarcinogenic hazard due to the chemical compounds via water drinking in both children age groups in both dry and wet seasons is lower than 1 and higher than 0.01, as shown in Figure 2, while the index of health hazard due to the sum of health hazard ratios of chemical compounds (nitrate, phosphate, arsenic, and cadmium) at all sampling locations in the dry and wet seasons in the children age group are the minimum and maximum of the amounts in the 1.42–2.16 and 1–1.46 range, respectively, and in the adults' age group are in the 0.70–1.12 and 0.53–1.12 range. All the amounts in the children age group are higher than 1 and have the average effect, as shown in Table 4.

DISCUSSION

Based on the results of the present study, physical parameters; Chemical and heavy metals measured in the water show that all values are higher in the dry and hot seasons of the year. The main contamination variations occur at stations 1 and 2 which are more contaminated in both dry and wet seasons. As a result, they have a lower quality than the other sampling stations suggesting the fact that the greatest amount of contamination in the lake enters it through this part. These results resemble

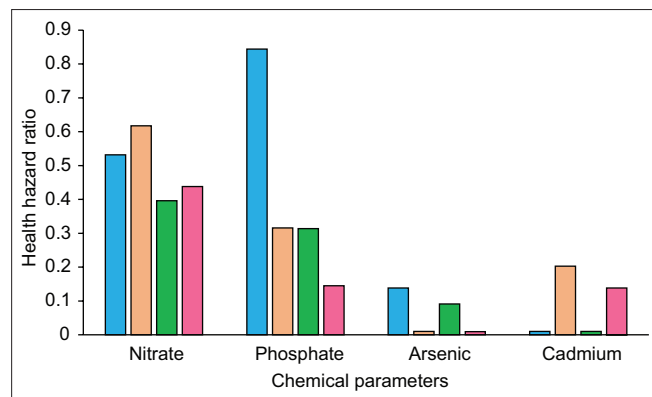


Figure 2: Average health risk ratio of chemical parameters

the results of a similar research conducted by Samarghandi MR *et al.* on Karkheh Reservoir Dam,^[13] in which an increase at the contamination level has been reported in the dry season than in the wet season. This may be due to the fact that regarding Zayandehrood Lake surrounding lands use map, a vast spread of the upstream regions is allocated to agriculture. In addition, it can be predicted that the increase in nutrient load (nitrate and phosphate) in the water is due to the entry of contamination due to the use of phosphate and nitrogen fertilizers in the upstream region. In the dry season accordingly, the lake water decreases. As a result, a decrease occurs in contaminant dilution that reduced the self sustained, carrying or assimilative capacity of the lake. In researches, Mishra *et al.*, Barnwal *et al.*, and Yadav *et al.* calculated, as in the present study, water contamination index in two relevant dry and wet seasons. Their results showed that contamination amounts are higher in the dry season than in the wet season. In those studies, It indicates that the lake receives more amount of wastewater in the dry season In those studies, decrease in precipitation and as a consequence decrease in contaminants dilution It have also been the main and important causes complying with our results.^[14-16] Besides, the chemicals' health hazard has also been assessed in Table 4 using (hazard index [HI]) at all the stations. Its values have been observed in all places in the range of more than 1 for the age group of children, which indicates the unacceptable risk of carcinogenicity to human health if the lake water is used in that age group. Also, based on the present results, the amount and proportion of health risk through swallowing path for children is more than adults in both seasons, so it can be said that children are considered as a sensitive society to adults. (While the risk of carcinogenesis is calculated from the average daily absorption rate in the carcinogenic risk index for each element.) Based on the present results, the amount of health hazard ratio and index is higher for children than for adults in both seasons through ingestion, one of whose probable causes can be said to be due to the fact that children are considered the sensitive members of society compared to adults. In the study of Rahman *et al.*, health hazard due to some heavy metals and nitrates in the groundwater has been reported to be 9.94 for children and 4.97 for adults. These amounts that involve high hazards are considered higher for children as the sensitive and vulnerable population, and comply with the present results.^[17] From the

Table 4: Indices values to classify the risk pollution of Zayandehrood river

Station	Wet season					Dry season				
	CPI	OPI	HPI	HI (child)	HI (adult)	CPI	OPI	HPI	HI (child)	HI (adult)
1	0.17	0.53	0.09	1.46	1.12	0.23	0.68	0.86	2.16	2.12
2	0.18	0.54	0.06	1.33	0.76	0.29	0.61	3.8	1.42	0.85
3	0.16	0.48	0.10	1.11	0.59	0.27	0.66	3.92	1.36	0.85
4	0.15	0.43	0.03	1.07	0.53	0.21	0.47	3.71	1.17	0.70
5	0.17	0.51	0.05	1.15	0.62	0.25	0.49	3.84	1.26	0.74
6	0.20	0.58	0.02	2.38	2.04	0.27	0.56	3.77	2.41	0.74
7	0.16	0.44	0.05	1	0.55	0.28	0.59	3.69	1.62	0.88
Mean	0.17	0.50	0.061	1.35	0.88	0.25	0.58	3.37	1.62	0.84

conclusions of the study of Fe-quan *et al.*, the noncarcinogenic risk of chemical compounds in drinking water resources was found to be higher than the standard in a number of high-risk sampling stations, and the risk of carcinogenicity is acceptable; therefore, the noncarcinogenic risk of compounds (nitrate, fluoride, chromium, and iron) in the 5 points that have the highest amount can increase the overall health risk. And because the level of contamination is also higher in the dry season than in wet season for the mentioned reasons, so health hazard is, as a result in case of using the lake water, also higher in this season than in the wet season. In the researches of Dalakoti *et al.* and Chaudhary, it has been concluded that the rate of contamination in the dry season is higher than that in the wet season compared to our study results.^[1,8]

CONCLUSION

Isfahan Province Zayandehrood water quality was analyzed in the dry and wet seasons from March 21, 2013, to March 20, 2015. The results suggest that the quality of the river water as the raw water input to Isfahan drinking water treatment plant is not potable and that water comprehensive contamination index at all of the studied stations is lower than 1 and has low contamination. However, in the dry season, water heavy metals contamination index at all of the stations is higher than 3 and has high contamination. It is accordingly observed that water quality in the wet season is better than the quality in the dry season. The amounts from all of the stations, (HI) are higher than 1 in the children age group, while (HI) for adults at all stations <1. Thus, it is suggested to purify water for the nutrients concentration balance before its use for drinking and bathing purposes. “(if water is used for drinking directly, prior treatment).”

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Conflicts of interest

There are no conflicts of interest.

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