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Assessment of water supply system and water quality of Lighvan village using water safety plan

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Abstract

Background: Continuous expansion of potable water pollution sources is one of the main concerns of water suppliers, therefore measures such as water safety plan (WSP), have been taken into account to control these sources of pollution. The aim of this study was to identify probable risks and threatening hazards to drinking water quality in Lighvan village along with assessment of bank filtration of the village.

Methods: In the present study all risks and probable hazards were identified and ranked. For each of these cases, practical suggestions for removing or controlling them were given. To assess potable water quality in Lighvan village, sampling was done from different parts of the village and physicochemical parameters were measured. To assess the efficiency of bank filtration system of the village, independent *t* test was used to compare average values of parameters in river and treated water.

Results: One of the probable sources of pollution in this study was domestic wastewater which threatens water quality. The results of this study show that bank filtration efficiency in water supply of the village is acceptable.

Conclusion: Although Bank filtration imposes fewer expenses on governments, it provides suitable water for drinking and other uses. However, it should be noted that application of these systems should be done after a thorough study of water pollution level, types of water pollutants, soil properties of the area, soil percolation and system distance from pollutant sources.

Keywords: Bank filtration, Lighvan, Risk ranking, Water safety plan, Water pollution

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Introduction

Safe drinking water is one of the necessities to sustain life and a satisfactory (adequate, safe and accessible) supply of water must be available for all peoples. Qualitative assessment of water leads to improvement in water quality and is an important factor in water treatment (1).

Although two-thirds of the earth is covered with water, available fresh water is rare. Along with water scarcity, water pollution is the other issue threatening fresh water resources (2,3).

Industrialization without considering sustainable development principles, population increase, modern and mechanized agriculture, etc have contributed to the pollution of water resources in recent years. This is much more significant especially in the case of developing countries (4,5).

In some villages in the country, domestic sewage flows through streets and open canals. This kind of wastewater collection leads to the contamination of surface and groundwater. Also, leachate with lots of nitrogen and microorganisms are the other source of pollution. Typically, these sources of pollutants are source of pathogenic contamination for drinking water.

Over time and with increased attention to the quality of drinking water during the last few years, different methods have been used to assess the quality of drinking water resources. Such measures over the last few years in relation to drinking water in the world is the implementation of water safety plans (WSPs). Given the importance of access to safe water, WSP since 2004 has been on the agenda of the World Health Organization (WHO) (4,6-8). Monitoring and evaluation of water from catchment to the

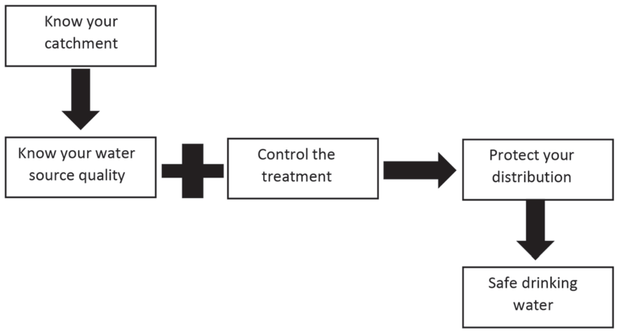

Figure 1. "Catchment to consumer" approach to risk management of the safety of the drinking water.

consumption point is taken into consideration, and study programming is reached as shown in Figure 1 (7).

The primary objectives of a WSP in ensuring good drinking-water supply practice are the prevention or minimization of contamination of source waters, the reduction or removal of contamination through treatment processes and the prevention of contamination during storage, distribution, and handling of drinking water. A WSP has three key components which are; system assessment, operational monitoring and management and communication plans (7).

Lighvan is a village in Meydan Chay rural district, in the central district of Tabriz county, East Azerbaijan province, Iran. At the 2011 census, its population was 5524, in 1553 families (9).

It is famous for its slight weather during summer time and cold weather in winter. The main occupation of the people is agriculture, dairy and gardening. Lighvan's traditional feta cheese is the most famous cheese all around Iran.

To our knowledge, there is no study about the quality of drinking water supply in Lighvan village and assessment of the village system performance. Therefore, the present study was aimed to identify risks and hazards threatening water quality and health of the villagers and to prioritize and monitor the risks and hazards. The performance of the river bank filtration (RBF) of the village was also investigated.

Methods

Before 2004, drinking water in Lighvan village was provided only from the spring. This spring was sanitized 20 years ago. The source of the water to this spring is provided from RBF. In recent years, the RBF system could not solely provide water for the village due to population increase in the village. In 2004, a well was drilled to a depth of 160 meters on the south side of the village. Well water after disinfection with chlorine along with RBF water are pumped to a storage tank on top of a mountain overlooking the village from where the water is injected to the water distribution network of the village.

In this study (conducted in 2014), the first step was to identify the hazards and potential risks in different parts of the water distribution network and prioritize them. A variety of different semi-quantitative and qualitative approaches have been proposed for ranking risks. In this study the ranking proposed by the WHO was used. The semi-quantitative approach used in the present study is shown in Table 1 (9).

The study identifies and prioritize the risks in accordance with the above matrix and then strategies to modify or reduce the risks were also presented.

Lighvan river originates from the northern slopes of Sahand mountain. Several springs and rivers join to form the Lighvan river. The river flows from south to north and irrigates downstream lands. This river flows in relatively deep valley in the downside of the village.

In this study, 3 water samples from different parts of the river flowing through the village were taken. The samples were taken from entrance, middle (next to RBF system), and the lower course of the river in village. Parameters including pH, electric conductivity (EC), hardness, major cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and major anions (HCO_3^{-}, SO_4^{2-}, Cl^{-}, F^{-} and NO_3^{2-}) were measured. All the analyses were done according to standard methods for examination of water and wastewater (10).

Since the water to the village is supplied from two separate sources (well and RBF system), sampling was also done from these points. The samples were collected in acid-washed polyethylene terephthalate (PET) bottles after 5 minutes discharge of the current and 3 times after washing of the bottles. To evaluate the water quality at the point of use, 3 samples were taken from different parts of the network (Figure 2).

Table 1. Scoring matrix for ranking risks[a]

Likelihood	Severity of consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	5	10	15	20	25
Likely	4	8	12	16	20
Moderately likely	3	6	9	12	15
Unlikely	2	4	6	8	10
Rare	1	2	3	4	5

[a]Risk rating: Low, <6; Medium, 6-9; High, 10-15; Very high, >15.

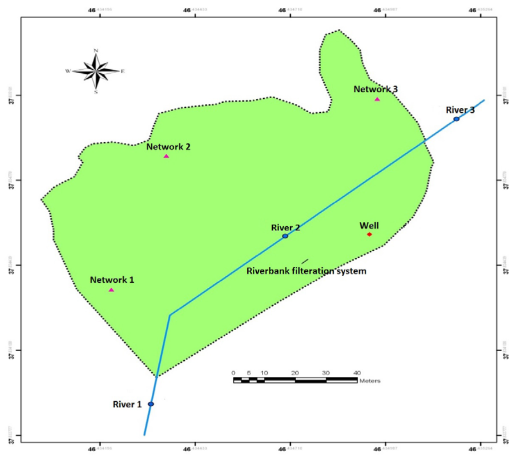

Figure 2. Sampling points and RBF system of the village.

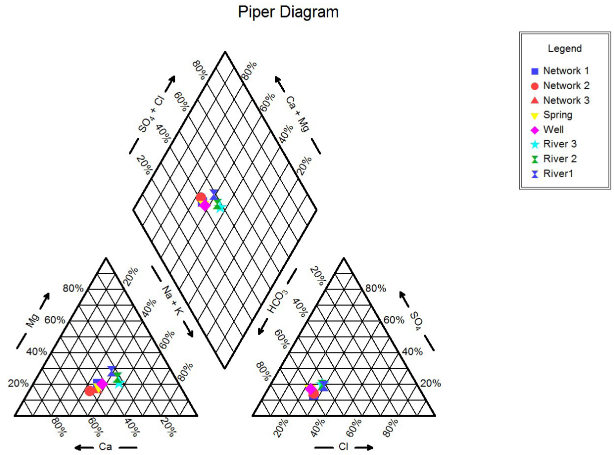

Figure 3. Piper diagram for the analyzed samples.

In order to study the performance of the filtration system of the village and impact of the river water on the treated water by RBF, statistical analysis was used. To assess the normality of the variables in spring and summer seasons, Kolmogorov–Smirnov test was used and confirmed. For the comparison of mean values of the indices, independent *t* test was used. $P < 0.05$ was considered significant.

Results

Potential hazards

All potential risks of water quality of Lighvan village are shown in Table 2. Likelihood and severity of each of the risks was determined by 3 environmental health experts and finally the extent of these risks was ranked.

As indicated in the table, the sanitary wastewater of the village is one of the main potential source of pollution. This is particularly important in the case of RBF.

Physicochemical analysis of water samples

Results of the physicochemical analysis are presented in Table 3. In terms of hardness, water is grouped as soft water (<75 mg/L $CaCO_3$), medium hard (75–150 mg/L $CaCO_3$), hard water (150–300 mg/L $CaCO_3$) and very hard water (>300 mg/L $CaCO_3$). As specified in the table, the range of total hardness in the network water samples was 124-136 mg/L $CaCO_3$, indicating that the studied wa-

Table 2. Potential pollution risks ranking

Event	Likelihood	Severity	Risk ranking
Contamination of drinking water by sanitary wastewater discharged to river	5	4	20
Drinking water contamination by sewage from dairy products canters, especially in the months of January through the end of July	3	3	9
Drinking water contamination by animal waste	4	2	8
Drinking water contamination by agricultural drainage	3	2	6
The risk of secondary contamination due to lack of residual chlorine in the network	2	2	4
Contamination of drinking water by the wastewater from nearby school	2	1	2

Table 3. Mean values of physicochemical analysis of water samples

Sample	pH	EC µs/cm	TDS mg/l	Turbidity NTU	F mg/l	Cl mg/l	SO_4 mg/l	NO_3 mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Hardness mg/l	Alkalinity mg/l
Network 1	7.20	320	208.0	0.21	0.6	36	23.8	9.4	35.2	9.7	30.0	4.2	128	112
Network 2	7.02	315	204.8	0.34	0.6	36	25.5	7.4	41.6	7.8	28.9	4.1	136	112
Network 3	7.12	318	206.7	0.39	0.6	36	26.1	7.2	36.8	7.8	31.2	4.2	124	112
RBF	7.03	310	201.5	0.26	0.6	32	32.5	8.5	35.2	8.7	31.2	3.9	124	116
Well	7.02	340	221.0	1.16	0.6	36	35.2	7.3	36.8	10.7	35.8	4.1	136	128
River 3	7.35	360	234.0	20.40	0.6	44	41.1	6.9	30.4	11.7	47.3	4.2	124	112
River 2	7.60	335	217.8	12.60	0.6	42	38.9	4.2	27.2	12.6	41.5	3.5	120	108
River 1	7.90	326	211.9	4.10	0.6	40	33.9	3.1	24.0	12.6	31.2	3.3	112	96

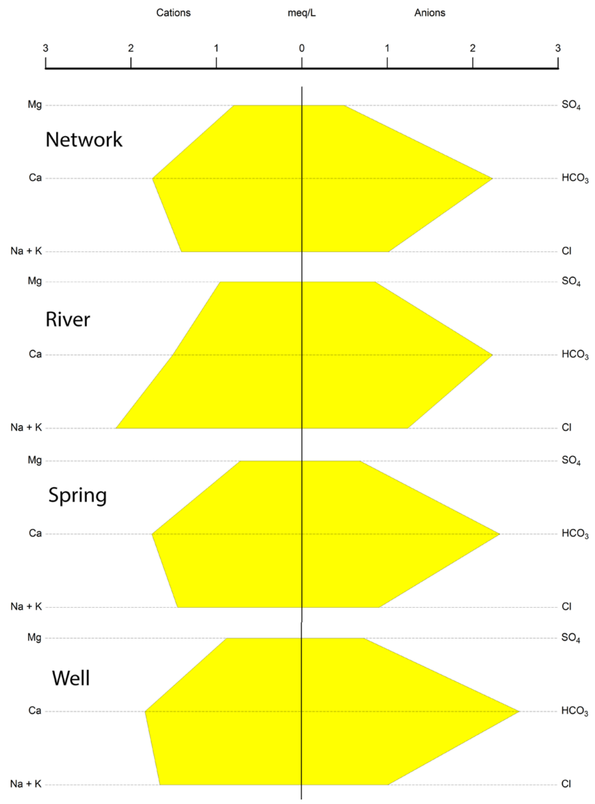

Figure 4. Stiff diagram for the analyzed samples.

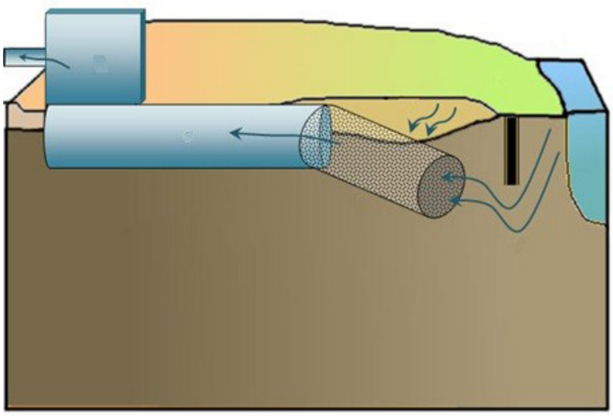

Figure 5. Schematic of RBF system.

ter samples could be grouped as medium hard water. Electrical conductivity was almost same in different parts of the water distribution network, indicating that there is no change in dissolved solids.

As shown in Table 3, the amount of dissolved solids in the RBF is less compared to the well.

Figure 3 shows the piper diagram for samples taken from the Lighvan village. As shown, samples taken from drinking water contains higher bicarbonate ions compared to samples taken from the river.

Figure 4 shows the stiff diagram of the water samples for network, river, spring and well. As shown in the figure, sodium and chloride in the river water is higher than in drinking water. The type of river water is sodium-bicarbonate, while it is calcium-bicarbonate for drinking water.

Evaluation of river bank filtration system performance

RBF is a type of filtration that works by passing water to be purified for use as drinking water through the banks of a river. Schematic diagram of Lighvan village RBF is illustrated in Figure 5. As shown in the figure, water passes through river bank and then, the purified water is taken for drinking purpose. After passing the river water through the RBF, reduction was observed in pH, turbidity, total dissolved solids (TDS), magnesium, sodium, sulfate and chloride. However, there was a slight increase in bicarbonate, potassium, nitrate, calcium and hardness.

The results of *P* value between the mean values of the physicochemical parameters of the river and RBF system shows that there is only significant correlation between chloride ($P=0.049$) and magnesium ($P=0.032$).

Discussion

One of the main problems that threaten the safety of the village water is sanitary wastewater and the wastewater discharged to the river from dairy production centers. Considering that a large population inhabits the village, thus a large amount of wastewater is produced. The intrusion of wastewater to the river and passage through the RBF could threaten public health of the villagers. It is strongly suggested to modify the wastewater collection network of the village and to channel the collected wastewater downstream of the village. Then it could be treated by natural wastewater treatment systems, and after being purified up to an accepted level it could be discharged to the river. Minimal corrective action which could be given should be that discharge of wastewater to the river from the upstream of the RBF should be stopped.

About the case of animal wastes, which could be the main reason for an increase in nitrate concentration of the RBF effluent, it is suggested to allocate some sites out of the village for waste storage.

It is suggested to construct special canals for collecting agricultural drainage particularly near the well and RBF system.

About the case of river water quality, due to the intrusion of wastewater, the amount of dissolved solid increases in the river water on passing through the village. As previously mentioned, there are lots of diary production centers in the village, these centers also discharge their wastewater, which contains high amount of salt (salt is used for preservation of cheese) into the river.

According to the lithology maps of the studied area, geological structure of the village is made of volcanic and sedimentary rocks. Based on the results of the present study, bicarbonate and calcium of the water increase after passing through the RBF. This could be attributed to the geological structure of the study area which is made up of volcanic and sedimentary rocks (Eq. 1) (11).

$CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2HCO_3$ (1)

As shown in Table 3, potassium was also increased in the water on passing through the RBF system, which was also observed in groundwater. This could be due to the presence of potassium-feldspar minerals in the geological structure of the area. Potassium-feldspar can react with carbonic acid and generate potassium and increase alkalinity as shown in Eq. 2 (12).

$$H_2CO_3 + KAlSi_3O_8 + H_2O \rightarrow K^+ + HCO_3^- + 2H_4SiO_4 \quad (2)$$

Subsurface water storage systems have the advantages of natural capacity of water and soil therefore, in addition to little cost to governments, it can generate high quality water (13-15). In this study some chemical parameters such as hardness, alkalinity, nitrate, potassium and calcium increased after treatment which is similar to the findings of a study conducted in Egypt on the Nile River filtration system. However, the amounts of magnesium, sodium, sulfate and chloride decreased which contrasts the findings of the Nile River study. In addition, similar to the study in Egypt, turbidity and amount of suspended solids reduced significantly (16).

Although nitrate was low, it increased after passing through the filtration system. This could be due to accumulation of animal waste near the RBF system which leads to the filtration of nitrogen from animal waste into treated water.

In general, in the construction of these kinds of systems, there should be much emphasis on water pollution, type of pollutant, soil type, soil permeability and the distance of the system from pollution sources. While this method is recommended for use in different parts of Iran, comprehensive studies in this field is also proposed for accurate and continuous monitoring of water for chemical and biological parameters before and after construction of the system and during its operation.

Conclusion

Many risks and hazards of pollution could be controlled by implementation of rural WSP. Therefore, implementation of these kinds of programs, especially in rural communities is recommended.

Although bank filtration imposes fewer expenses on governments, it provides suitable water for drinking and other uses. However, it should be noted that application of these systems should be done after a thorough study of water pollution level, types of water pollutants, soil properties of the area, soil percolation and system distance from pollutant sources.

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Ethical issues

It is confirmed that this manuscript is the original work of the authors and has not been published or under review in another refereed journal, and is not being submitted for publication elsewhere.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors contributed equally and participated in the data collection, analysis and interpretation. All authors critically reviewed, refined and approved the manuscript.

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