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Original Article

Health Risk Assessment for Reused Backwash Water from Saveh Water Treatment Plant

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Abstract

Background: The increase in population growth, industries and living standards have caused an increasing need for drinking water in many countries. The reuse of treated water and wastewater is one of the most important options to deal with water shortage. To ensure the correctness of this work, it is necessary that the health risk assessment be reassessed during use so that consumers do not face serious problems. In this regard, the assessment of health risks assessment for the water recovered from the backwashing wastewater of the Saveh water treatment plant was investigated.

Methods: To reuse the backwash wastewater from the Saveh water treatment plant, the processes of primary sedimentation and coagulation (in the form of a test jar) were investigated. Metals and heavy metals like iron (Fe), aluminum (Al), lead (Pb), Arsenic (As) and cadmium (Cd) were examined to evaluate health risks. The initial settling time was 1 hour, the coagulant used was $FeCl_3$ made in Iran, and heavy metal contents were also measured with an Inductively coupled plasma (ICP) device.

Results: The value of HRIs for Al, Fe, As, Pb and Cd in the treated spent filter backwash water (SFBW) with primary sedimentation and coagulation was less than "1" and indicates the absence of risk.

Conclusion: The treated backwash wastewater treated with primary sedimentation and coagulation processes as well as raw water of the Saveh have no harmful effects in terms of heavy metals, and its reuse will not pose a risk to the health of the consumer.

Keywords: Backwash water, Saveh, Water treatment plant, Reuse, Health risks assessment

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Introduction

Today, various factors such as population growth, climate change, industrial expansion, increasing cultural levels, and uneven water distribution on the planet have posed significant challenges regarding water shortage for many countries and cities. On the other hand, the indiscriminate extraction of water for non-drinking purposes, inadequate water consumption management, and a low-consumption culture have exacerbated the issue in recent years.[1] Wastewater recovery and reuse have been practiced for an extensive period, and numerous countries employ this approach for a variety of purposes. These include using treated wastewater for irrigating crops, replenishing underground water sources, providing drinking water, fulfilling non-drinking needs such as street cleaning, recreational activities, firefighting, and various other applications.[2] When it comes to water consumption, agriculture and industry take the top two positions, while urban drinking consumption is ranked third in terms of usage. According to recent global policies, new approaches in the fields of agriculture and industry are being implemented or planned. In Iran, relatively good progress has been made or is underway in terms of wastewater reuse. However, water recycling from water treatment plants (WTPs) is still in its early stages, and unfortunately, not much work has been done in this area. Nonetheless, another significant and promising option for water recovery lies within the WTPs themselves. While WTPs serve as sources of water production, they also generate wastewater. By developing and implementing cohesive projects aimed at its recovery, it is possible to utilize the produced wastewater effectively and alleviate the pressures of water scarcity and excessive consumption.

In the past, a significant portion of the backwash water generated during water treatment processes was discharged into sewers. This practice resulted in several negative consequences, including an increase in raw water consumption, higher drainage costs, and reduced water production efficiency.[3] Various methods such as coagulation and flocculation, membrane processes and absorption have been used for backwash treatment.[4-7] The presence of natural organic matter (NOM) as well as its role as a precursor for disinfection byproducts, such as trihalomethanes, heavy metals, and microorganisms, is a significant concern when it comes to the quality of recycled water. This concern arises because during the reverse washing process, the accumulated impurities are separated from the filter. As a result, the backwash water contains colloidal pollutants, living organisms, NOM, and metals, particularly iron (Fe) and aluminum (Al).[8]

Heavy metals possess certain characteristics that make them a significant concern. They have the potential to accumulate in materials and the food chain, exhibit high toxicity to vital organs in the body, and are associated with carcinogenicity, malformation, mutation, and dysfunctions in organs such as the kidney, heart, digestive system, brain, and bones. Notable heavy metals include cadmium (Cd), lead (Pb), nickel, chromium, mercury, and arsenic (As).[9-12] The content of heavy metals in water resources holds significant importance in terms of hygiene. These substances are highly hazardous, and when present in elevated concentrations, they can have severe effects on consumer health. This issue becomes even more critical when water and wastewater recovery and reuse programs are being considered.[13] Numerous studies have been conducted in the field of backwash reuse from WTPs. The primary objective of these studies is to recover water and utilize it for various urban purposes.[14-17] While there have been several investigations into the contamination of drinking water with heavy metals through various studies, there is a lack of research specifically focused on health risk assessments related to backwash recovered from WTPs.[18-20] The quantitative chemical risk assessment (QCRA), hazard quotient (HQ), accumulation index, hazard index (HI), and quantitative microbial risk assessment (QMRA) are the main risk assessment methodologies that can be used for drinking water. Moreover, to investigate the amount of heavy metals in source water, the QCRA is a suitable index.[21] Therefore, the aim of this study was to investigate the amount of heavy metals in the reused spent filter backwash water (SFBW) and its potential health risk assessment.

Materials and Methods

Description of Study Area

Saveh WTP with an area of about 8 hectares is located in the northeast of Al-Qadeer Dam with longitude (x or E) and latitude (N or y) X = 422151.69 m and Y = 3863158.67 m (Figure 1). The maximum flow rate to the Saveh WTP is 650 l/S in summer and 400 l/S in winter. Also, the nominal capacity of the treatment plant is 575 l/S.

Sampling

In this study, sampling was done from the backwash effluent of the sand filters of the Saveh WTP in the summer season. For homogenous and uniform sampling, the samples were taken from a specific filter with a 24-hour working period at different times. After completing the reverse washing steps, the backwash effluent is entered the recovery pond in the treatment plant. After 15 min, the outlet of the recovery pond was opened and sampling was done by a bucket from the outlet. The samples in 20-L containers were quickly transferred to the laboratory of Saveh University of Medical Sciences in less than 45 minutes and used to perform the necessary tests.

Experiment Procedure

In this study, a jar test device was used to determine the optimal dosage and pH. After adding a certain amount of the coagulant, the samples were subjected to rapid mixing as 120 rpm for 2 minutes and flocculation as 40 rpm for 10 minutes. To perform the primary sedimentation, the raw backwash water was left in a large container for 1 hour.

Chemical Analysis

Inductively coupled plasma (ICP) was utilized for analyzing Fe, Al, Pb, Cd and Arsenic (As).

Chemical and Reagents

In this study, $FeCl_3.6H_2O$ was used as the coagulant, manufactured in Iran. The coagulant stock solution was prepared by dissolving 1.6615 g of ferric chloride in 1 L of distilled water. To adjust pH, hydrochloric acid and 0.1 N sodium hydroxide were employed.

Figure 1. Geographical location of Saveh WTP

Human Health Risk Assessment

The USEPA QCRA and HQ methodologies[22] were used for health risk assessment. This index calculates the chronic daily intake (CDI) dose via special exposure pathways like dermal contact, inhalation or ingestion. Moreover, daily intake dose was calculated and compared with reference allowed dose (RfD). Also, HQ index was obtained by dividing the daily intake dose to RfD. HQ less than 1 means the risk is acceptable.

CDI Calculation

The CDI for water ingestion was calculated by using the equation 1:

$$CDI = C \times DI = BW \quad (1)$$

Where, BW is body weight (72 kg for adults and 32.7 for children), DI is average daily intake rate (2 L/day for adults and 1 for children), and C is the concentration of metals in water (µg/L).

Calculation of HQ

Equation 2 was used to calculate the HQ for non-carcinogenic risk:

$$HQ = CDI / RfD \quad (2)$$

The amount of RfD has been presented in Table 1.

Results and Discussion

Raw and Treated Backwash Water Characteristics

In terms of the amount of heavy metals, the quality of the raw water was suitable (Table 2) and their amount was less than the standard values, except for the amount of Al. Also, compared to the raw water, the SFBW had more concentration of heavy metals. During the water treatment, metals or heavy metals were trapped on filter beds. The contents of metals and heavy metal in the SFBW were found as follows: Fe > Al > Pb > As > Cd. Similar results have also been observed in the investigation of the chemical quality of the SFBW of the Isfahan WTP in Iran.[24]

After the primary sedimentation, the amounts of Fe, Al, Pb, As and Cd were 0.657 mg/L, 2.3 mg/L, 8 µg/L, 1 µg/L and 0.05 µg/L, respectively. Meanwhile, the concentration of Fe and Al was higher than the standard. Also, the optimum pH and dose was 7.8 and 20 mg/L. After coagulation in optimum pH and dose, the amounts of Fe (mg/L), Al (mg/L), Pb (µg/L), As (µg/L) and Cd (µg/L) were 0.438 mg/L, 1.1 mg/L, 4 µg/L, 1 µg/L and 0.05 µg/L, respectively. Here, the concentrations of Fe and Al were higher than the standard.

Figures 2 and 3 show the results of mixing settled backwash water and coagulated backwash water with raw water entered into the WTP. In these calculations, the backwash water flow rate is 1500 m^3/d and the raw water flow rate entered to the WTP is assumed to be about 43200 m^3/d. Equation 3 was also used to calculate the parameters after the mixing process:

$$C_{mix} = \frac{(Q_{raw} \times C_{raw}) + (Q_{bw} \times C_{bw})}{(Q_{raw} + Q_{bw})} \quad (3)$$

Where, C_{mix} = pollutant concentration after mixing; Q_{raw} = raw water's flow rate; C_{raw} = pollutant concentration in raw water; Q_{bw} = flow rate of backwash water after primary settling; C_{bw} = pollutant concentration in the backwash water after primary sedimentation

As seen, after mixing settled backwash water with inlet raw water to the WTP. Al, Fe, Pb, As and Cd value were, 0.96 mg/L, 0.22 mg/L, 6 µg/L, 1 µg/L and 0.05 µg/L, respectively. In comparison with the initial concentration in the backwash, it decreased noticeably and also caused very little changes in raw water quality.

Meanwhile, after mixing coagulated backwash water with inlet raw water to the WTP, the contents of Fe, Al, Pb, As and Cd were 0.22 mg/L, 0.92 mg/L, 5.9 µg/L, 1 µg/L and 0.05 µg/L, respectively. Compared to the initial concentration in the backwash, it decreased greatly and also caused very little changes in raw water quality. Similar results were reported by other researchers that worked on the SFBW reuse.[8,17]

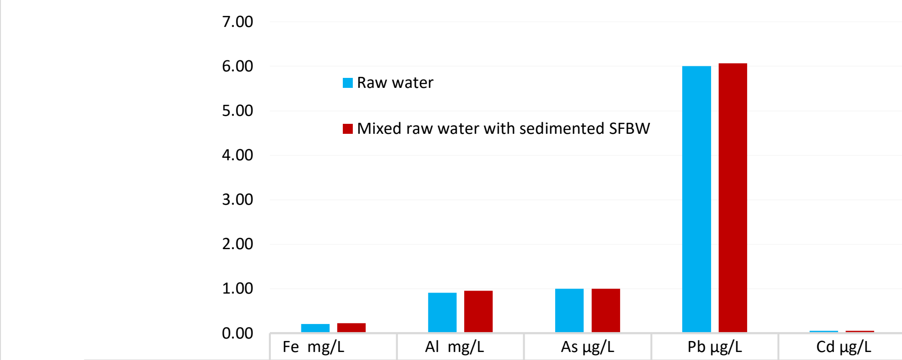
Table 1. Rfd Value for Metals and Heavy Metals in Water as Oral Consumption

Parameters	Oral RfD (µg/(kg.day))
Pb	3.5
Al*	7000
Cr	3
As	0.3
Cd	1
Cu	0.4
Ni	0.02
Fe	700

* FAO and WHO proposed these values.[23]

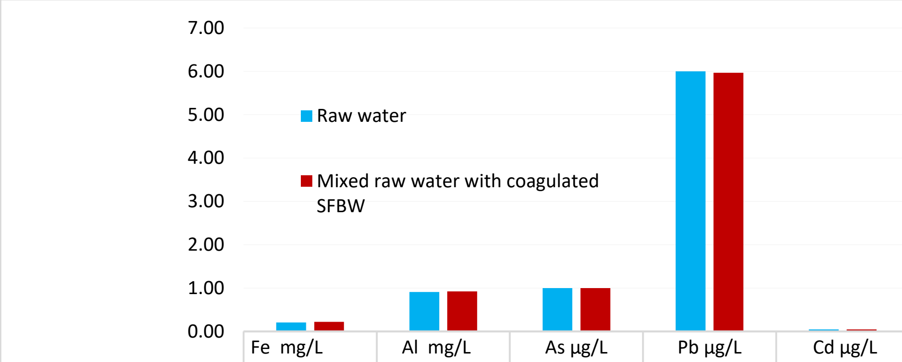
Table 2. The Quality of the Raw Water and SFBW

Parameters	Raw WATER	Raw SFBW	Treated SFBW by Sedimentation	Treated SFBW by Coagulation and Flocculation	(EPA, 2012) (MCL)
As (µg/L)	1 (±0.2)	1 (±0.05)	1 (±0.05)	1 (±0.05)	10
Al (mg/L)	0.91 (±.08)	2.7 (±0.1)	2.3 (±0.11)	1.1 (±0.08)	0.05-0.2
Cd (µg/L)	0.05 (±0.01)	0.05 (±0.01)	0.05 (±0.01)	0.05 (±0.01)	5
Fe (mg/L)	0.21 (±.03)	1.1 (±0.14)	0.65 7 (±0.09)	0.438 (±0.07)	0.3
Pb (µg/L)	6 (±1.41)	9 (±0.5)	8 (±0.4)	4 (±0.2)	10



	Fe mg/L	Al mg/L	As µg/L	Pb µg/L	Cd µg/L
Raw water	0.21	0.91	1.00	6.00	0.05
Mixed raw water with sedimented SFBW	0.22	0.96	1.00	6.07	0.05

Figure 2. Mixing Settled SFBW With Raw Water Entering the WTP



	Fe mg/L	Al mg/L	As µg/L	Pb µg/L	Cd µg/L
Raw water	0.21	0.91	1.00	6.00	0.05
Mixed raw water with coagulated SFBW	0.22	0.92	1.00	5.97	0.05

Figure 3. Mixing the Coagulated SFBW With Raw Water Entering the WTP

Health Risk Assessment

The amount of HRI and CDI for metals and heavy metals of raw water and treated SFBW are presented in Tables 3 and 4. An HRI value of less than 1 indicates a healthy water quality for the consumer.[25]

It was observed that CDI values of Iron, Al, Pb, As and Cd for the raw water were 5.83, 25.28, 0.17, 0.03 and 0 µg/kg-day, respectively for adults and, for children, they these figures were 6.4, 27.8, 0.18, 0.03 and 0.002 µg/kg-day, respectively. Additionally, in the settled backwash water, CDI values for adults were 18, 63, 0.22, 0.02, and 0.001 µg/kg-day, respectively, while for children, the values were 19, 70, 0.24, 0.03, and 0.002 µg/kg-day. In the coagulated backwash water, the CDI values for adults were 12, 30, 0.11, 0.02, and 0.001 µg/kg-day, respectively, and for children, the values were 13, 33, 0.12, 0.03, and 0.002 µg/kg-day. The CDIs value for metals and heavy metals in treated SFBW with primary sedimentation and coagulation were determined in the following order: Fe > Al > Pb > As > Cd. These findings align with similar results observed in a study conducted in Isfahan.[24] It was founded that the treated SFBW by sedimentation had greater CDI values than the treated SFBW by coagulation.

The amount of HRIs values Fe, Al, Pb, As and Cd for raw water were, respectively, 0.008, 0.004, 0.004, 0.09 and 0.003 for adults. The results demonstrated that the raw water had low heavy metals; hence, the value of H index was less than 1, illustrating the absence of danger for the consumers. In addition, the observations for children's water consumption were similar to adults (Table 4).

The HRI values for Fe, Al, Pb, As, and Cd in the treated SFBW with primary sedimentation were as follows: 0.02, 0.009, 0.06, 0.09, and 0.002, respectively, for adults, and 0.028, 0.01, 0.06, 0.1, and 0.003, respectively, for children. Similarly, in the treated SFBW with the coagulation process, the HRI values were 0.01, 0.004, 0.03, 0.09, and 0.003, respectively, for adults, and 0.01, 0.005, 0.03, 0.1, and 0.003, respectively, for children. The HRIs values for metals and heavy metals in treated SFBW with primary sedimentation and coagulation were below "1," indicating no risk for consumers. Comparing the water quality produced, the treated SFBW with the coagulation process exhibited lower HRI values than the treated SFBW with primary sedimentation. Both treated SFBW with primary sedimentation and coagulation met the drinking water standards as per EPA guidelines, except for elevated levels of Fe and Al. However, after blending the treated SFBW with the incoming raw water at the WTP, the concentration of all heavy metals decreased and returned to the level of the raw water, with the exception of Al, which remained

Table 3. The Calculated CDIs, μg/(kg·d) for Metals and Heavy Metals in Treated SFBW

Parameter	Individuals	Raw Water	Treated SFBW by Sedimentation	Treated SFBW by Coagulation and Flocculation
As	Adults	0.03	0.028	0.028
	Children	0.031	0.031	0.031
Al	Adults	25.28	63.889	30.556
	Children	27.829	70.336	33.639
Cd	Adults	0	0.001	0.001
	Children	0.002	0.002	0.002
Pb	Adults	0.17	0.222	0.111
	Children	0.183	0.245	0.122
Fe	Adults	5.83	18.056	12.167
	Children	6.422	19.878	13.394

Table 4. Calculated Health Risk Indexes of Metals and Heavy Metals in the Treated SFBW

Parameter	Individuals	Raw Water	Treated SFBW by Sedimentation	Treated SFBW by Coagulation and Flocculation
As	Adults	0.093	0.092	0.093
	Children	0.102	0.101	0.102
Al	Adults	0.004	0.009	0.004
	Children	0.004	0.010	0.005
Cd	Adults	0.003	0.002	0.003
	Children	0.003	0.003	0.003
Pb	Adults	0.048	0.063	0.032
	Children	0.052	0.069	0.035
Fe	Adults	0.008	0.025	0.017
	Children	0.009	0.028	0.019

high in the raw water. Alidadi's results in Iran showed that the HQ value of As was lower than 1 for adults, but it was more than 1 for children.[18] Furthermore, Amin's study on investigation of potentially toxic elements in drinking water revealed that Hg, Pb, Fe, and Mg showed there were not any harmful health risk for children and adults.[20] the carcinogenic and non-carcinogenic risk assessment of heavy metals in the water resources was conducted by Sadeghi. He concluded that the consumption of water endangered all consumer.[26]

Conclusion

- The concentrations of metals and heavy metals in the treated SFBW with primary sedimentation and coagulation processes were generally low, meeting EPA standards, except for Fe and Al. Following the blending of the treated SFBW with the incoming raw water at the WTP, the levels of heavy metals decreased and returned to the levels found in the raw water, except for the concentration of Al. Overall, the treated SFBW with primary sedimentation and coagulation processes maintained low concentrations of metals and heavy metals.
- The coagulation process exhibited a higher removal efficiency compared to primary sedimentation.
- The calculated HRIs in the treated SFBW with primary sedimentation and coagulation processes were less than "1," indicating the absence of danger in water consumption.
- The raw water from the Saveh city treatment plant, as well as the backwash wastewater treated with primary sedimentation and coagulation processes, showed no harmful effects in terms of heavy metals. Therefore, the reuse of this treated water is not expected to pose a risk to consumer health.

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Competing Interests

The authors declare that they have no conflict of interests.

Ethical Approval

Not Applicable.

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