Evaluation of microbial water quality databases of Sulaimani city collected during 2018-2020

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ABSTRACT

Water is essential to support life and therefore preserving water quality is an effort that should be made. Due to the possible implications of waterborne illnesses, microbial pollution is currently regarded as the most serious risk factor affecting the quality of drinking water. This research is analyzing data of fecal coliform and *Escherichia coli* in drinking water of Sulaimani city from 2018 to 2020. Sample analysis was based on results that had more than double replications at least during a year. The samples collected (100 ml) from different points of distribution network (project stations, main store tanks, and domestic tanks) continuously along the year and then transferred to the lab. Samples analyzed at same day by multiple tube/ most probable number technique for FC (9221 E) and EC (9221 F) in the lab according to American public health association procedures. High contamination of drinking water by fecal coliform and *Escherichia coli* in main and domestic tanks was found in 2018 and 2019 with 6.82% and 15.22%, while 2020 had 0.82% and 3.10% respectively. The most probable number per 100 ml (MPN/100) of coliforms, thermotolerant and *Escherichia coli* ranged from 2.2 to more than 16.6. The percent of contamination by total coliform bacteria is different over the past three years. In 2018 nearly 14% of samples were contaminated by coliform bacteria, of which 4 samples was determined as EC contamination. In 2019 the contamination by total coliform decreased slightly, of which 3 samples we detected as EC. In 2020 out of 20% total coliform contamination only one sample detected as EC. Residual chlorine of drinking water during 2018, 2019 and 2020 was 0.0-1.2, 0.0-0.8 and 0.0-1.0 ml/gm, respectively. There was negative correlation between residual chlorine and coliform survivability. Most detected coliform and *Escherichia coli* was absent (0.0 ppm) of residual chlorine in water networks. Home tank spoilage in 2019 was greater by 25% compared to 2018 and 2020, which is the highest record among those three years.

Keywords: domestic storage tanks, drinking water quality, chlorine, MPN, Fecal coliform, *E. coli*

Introduction:

Water is necessary for life and exists, and as such, almost any effort should be taken to ensure the highest possible drinking water quality (1). The availability of clean drinking water is a major problem, especially in poor countries (2). Due to the possible repercussions of waterborne diseases, microbial pollution is currently regarded as the most serious risk factor affecting the quality of drinking water (3). On a global scale, drinking water has been identified as the main site of infection for diarrhea pathogens. Centrally treated drinking water distribution systems have almost eradicated outbreaks of waterborne illnesses (4). According to WHO in 2001, 1.1 billion people around the world lacked access to improved water supply and more than 2.4 billion lacked access to improved sanitation (5).

In general, testing water for every known waterborne pathogen to determine its safety for drinking is impractical. The World Health Organization (WHO) currently recommends *Escherichia coli* (EC) and/or thermotolerant ("fecal") coliforms (FC) as markers of water treatment efficiency and as indicator organisms for the presence of fecal contamination and waterborne pathogens. While EC are regarded the most appropriate early warning sign organism due to their sensitivity to fecal sources of contamination, FC are also recommended as an acceptable substitute; this recommendation is made despite the fact that the FC group includes coliform species of environmental origin and is thus unlikely to be fecal-specific (3).

Concerns about pathogenic related water diseases have prompted the adoption of stringent laws on microbiological contamination of water to ensure that drinking water, wastewater discharge, and water reuse meet acceptable requirements for public health and environmental protection (7, 2). Under these conditions, providers must create an action plan for limiting the spread of coliform bacteria across their distribution system in able to obtain the system back into conformity (7). As a result of these factors, specialized disinfection methods for water treatment must be devised in order to meet the goals of providing higher-quality water while maintaining technical dependability, economic viability, and environmental stewardship (2).

Chlorination is a technique that is used globally to treat and avoid contamination of water in order to avoid the spread of infectious illnesses via water, and is regarded to be a cost effective and efficient disinfectant (2). Chlorine effectively inhibits the most of organisms that cause diseases in humans, such as EC, which is decreased to 99 percent drop at 0.2 mg/l chlorine concentration for 3 minutes and 99 percent reduction at 0.5 mg/l chlorine concentration for 6 minutes (8).

Sulaimani City (Figure 1) is situated in northern Iraq and is one of the largest cities in Iraq (Kurdistan region), with a population of more than one million. The city is located between two mountains at Longitude 45.44312° and Latitude 35.55719°, with an average elevation of about 850 meters above sea level. Summers in the city are dry and warm, with an average temperature of 31.5°C, while winters are chilly and wet, with a mean temperature of 7.6°C (4, 5). Drinking water distribution system includes 3 main treatment centers (Sarchinar, Sherkozh and PWJ) with approximately 27 main storage tanks located on Circle Malik Mahmud Street. Main sources of drinking water are 1 and 2 lines of Dukan and a Karez in Sarchnar. These waters will treat in Sarchnar and Sherkozh treatment projects and then transferred to major large store tanks and in final transfers to household storage tanks. Water distribution system in Sulaimani city is interrupted and domestic storage tanks are used. The purpose of this study is to estimate the microbial quality and safety in drinking water of the Sulaimani city based on estimation of TC, FC and EC for three years periods (2018, 2019 and 2020).

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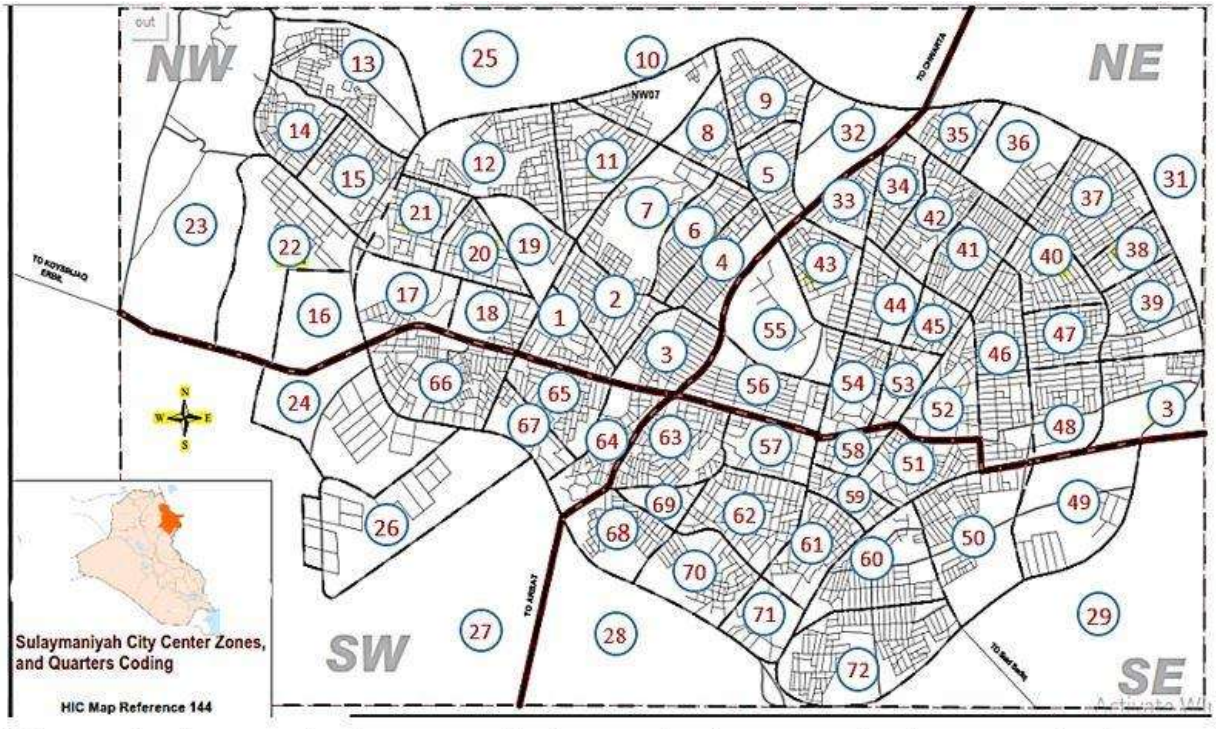

No.	Quarter	No.	Quarter	No.	Quarter	No.	Quarter	No.	Quarter	No.	Quarter	No.	Quarter
1	Andazyaran	11	Besarany	21	Bakhtyary Nuwe	31	Saleem Bag	41	Tooy Malik	51	Dargazen, Sabunkaran	61	Julakan
2	Baranan	12	Zargata	22	Harawaz (Grdi Sarchnar)	32	Dabashan	42	Majid Bag	52	Malkandi	62	Chwar Bakh
3	Ali Naji	13	Kani Speeka	23	Qilyasan	33	Mamostayan	43	Qazi Muhamad	53	Shekhan	63	Shekh Muhedin
4	Ashti	14	Sarchinar	24	Lala Zar	34	Majid Bag	44	Sulaymaniyah Nuwe	54	Kane Askan	64	Mushirawa
5	Kareza Wshk	15	Sarchinar	25	Zargatai kon	35	Hawari Taza	45	Girdi Joga	55	Rapareen	65	Rizgary
	Ashti	16	Chwar Chira	26	Kargakan	36	Azmar	46	Darogha, Gwezha	56	Shorish	66	Rizgari
7	bakhan	17	Bakhtyary	27	Zargatay Kon, Sardaw	37	Hawara Barza	47	Shahidan	57	Wayss	67	Ablakh
8	Kareza Wshk	18	Handren	28	Qalawa Flats	38	Goizhay Nuwe	48	Azadi	58	Bazrgani	68	Awbareek
9	Suren	19	Sherwana	29	Zerenok	39	Azadi	49	Mama Yara, Rozhalat	59	Sarshaqam	69	Garmiyan
10	Badinan	20	Hakary	30		40	Ali Kamal	50	Sawan, Rozhalat	60	Khabat	70	Sharawany
71	Julakan	72	Tanjaro, Zmnako										

Figure 1. Sulaimani city center map by Humanitarian Information Centre (HIC) (9).

Methodology:

This research is carried out by collecting and analyzing data of coliform contamination (fecal coliform, and *Escherichia coli* bacteria) in drinking water of Sulaimani city for 3 years period (2018, 2019 and 2020). During the study 3531 data samples were collected and total percentage of contamination was calculated. The analysis was based on results that had more than double replications at least during a year. The samples collected (100 ml) from different points of distribution network (project stations, main store tanks, and domestic tanks) continuously along the year and then transferred in cooling bag to lab. Samples analyzed at same day by multiple tube/ most probable number technic for FC (9221 E) and EC (9221 F) in the lab according to American public health association procedures (10).

Result and discussion:

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Contamination of water by coliform is an essential trait that sometimes occurs in water and make changes in quality of water (8). Contamination happens due to cross connection, insufficient treatment, or a failure to maintain a disinfectant residual in distributed water and it travels via pipes, open reservoirs, standpipes, and storage tanks (7, 11). Figure 1 addresses the contamination percentages of distribution systems network (total project stations, main tanks and household storage tanks). In general, there were decrease in ratio of detection through the consecutive years. Results explained that contamination by coliform at project stations is in low level but the ratio increases as it travels via the pipelines in distribution system to get in the end points (domestic tanks). Generally, 2019 recorded highest portion of contamination in main and domestic storage tanks with 6.82% and 15.22%, respectively, while 2020 recorded the lowest ratio of contamination with 0.82% and 3.10% respectively.

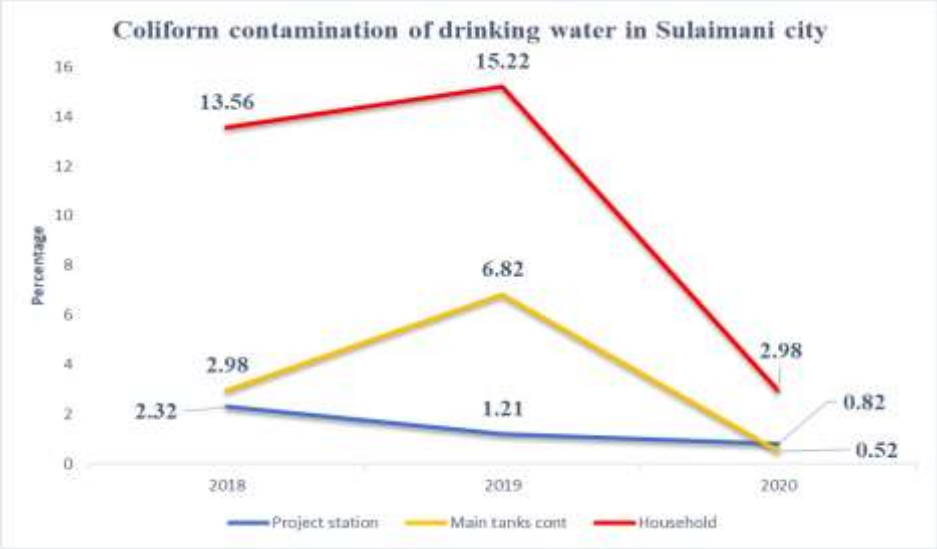

Figure 1. Total coliform contamination percentage in drinking water for project stations, main and household storage tanks of Sulaimani city for 2018, 2019 and 2020.

The contamination of stations decreased by a factor of two in the years that followed. These findings argue that the government is taking more sanitary actions and is being more precise in the treatment of drinking water in order to provide safe water to people. In general, the government follows the rules and recommendations set by WHO to enhance water quality. According to WHO and Iraqi standard specification (No. 10/2270: 2014, first edition), drinking water must contain any FC and EC. There was a positive correlation in contamination by coliform among main and household tanks in the period three years. The contamination in home tanks were raised as contamination in main tanks increased and vice versa. The coliform transferred through pipes to main tanks and then to homes.

Household store tanks had high levels of contamination by several times when compared to project and main tank points. Contamination in domestic storage tank water is about 6 to 10 times more than source (projects) and 2 to 6 times than main tanks distribution system. It clearly demonstrates the fact that spoilage of drinking water increases during the distribution process in pipelines from major source to storage tanks. Bacteria can infiltrate the distribution system due to a failure to sanitize water or maintain an appropriate disinfectant residual, low pipeline water pressure,

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discontinuous service, are many leakages, part corrosion, and insufficient sewage disposal (11).

In Sulaimani, the distribution system does not supply complete and uninterrupted water and therefore people use storage tanks in order to make water available. Storage of drinking water always means a change in its quality, since chemical, physical and microbiological processes take place during its residence in systems (12). Storage tanks in Iraqi-Kurdistan and in Sulaimani city are located on the roof which makes it more susceptible to enter dust. As well as, because of the water shortages, difficulty of cleaning and low consciousness, tanks do not clean on a regular basis, resulting in increased accumulation, sediment, and turbidity in tanks. Turbidity has the potential

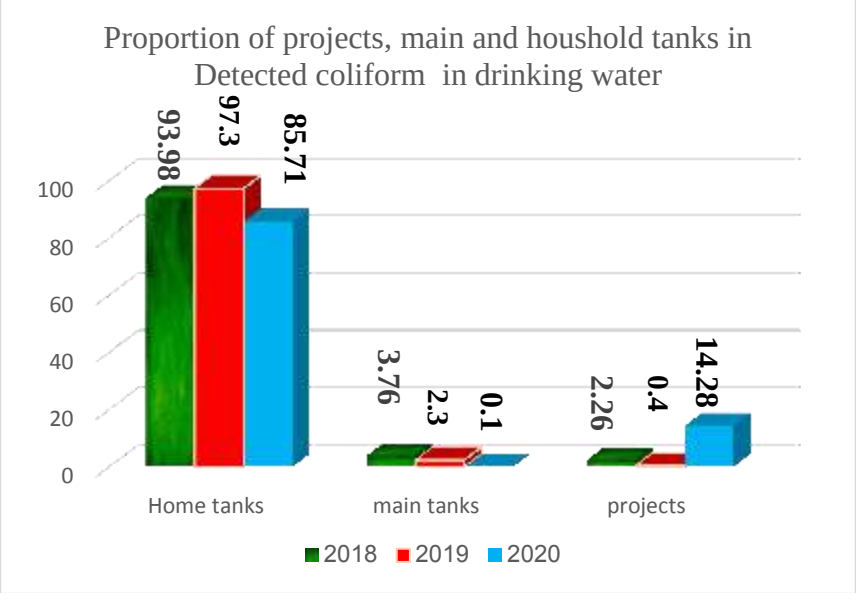


Figure2. Proportion of project, main and household storage tank from detected total coliform in drinking water.

to have a major impact on the microbiological quality of drinking water. Studies showed that an increase in turbidity was associated with an increase in the number of coliforms. According to the results of the experiments, the binding of bacteria to surfaces resulted in the largest rise in disinfectant resistance. In addition to age of the biofilm and bacteria encapsulation, other factors that enhanced disinfection resistance were prior growth circumstances (for example, growth medium and growth temperature) in the laboratory (8).

The MPN/100 coliforms, FC and EC ranged from 2.2 to more than 16.6. If two coliform organisms are detected in 40 samples collected each month by a water system, the system may be in breach of the Total Coliform Regulation (7). According to present WHO recommendations, safe drinking water should include no detected EC or FC in any 100 ml sample (9). To avoid the need to categorize exposures, previous WHO guidelines categorized disease threat water related according to the types of indicator organism counts found in 100 ml water samples as a replacement for classifying exposures.: 0 EC or FC is considered safe; 1–10 EC or FC is considered moderate risk; 11–100 EC or FC is considered intermediate risk; 101–1000 EC or FC is considered high risk; and1000 EC or FC is considered very high risk (3). Under these recommendations and under special situations, countries make editions on the guidelines.

Based on Iraqi standard specification in (No. 10/2270: 2014, first edition), drinking water must be absent from FC and EC, while, according to Indian drinking water specification (IS 10500:2012), less than 50 MPN/100 ml CF is permitted but FC must be undetectable (13). Despite widespread use of EC and FC to determine the microbiological safety of drinking water, no evidence linking any of these particular markers to waterborne disease has been established (3).

Figure 2 demonstrates the proportion of project stations, main and domestic tanks in detected whole coliform. Significant proportion was recorded for domestic storage tanks that take more than 94% of total detected coliform in 2018 and 2019. Nevertheless, in 2020 the risk slightly decreases by 9%.

As it can be seen in figure 3. The percent of contamination by total coliform bacteria was slightly changed between these three years. In 2018 nearly 14% of samples were contaminated by coliform bacteria, of which 4 samples was determined as EC contamination. In 2019 the contamination by total coliform increased slightly, of which 3 samples we detected as EC. In 2020 out of 20% total coliform contamination only one sample detected as EC.

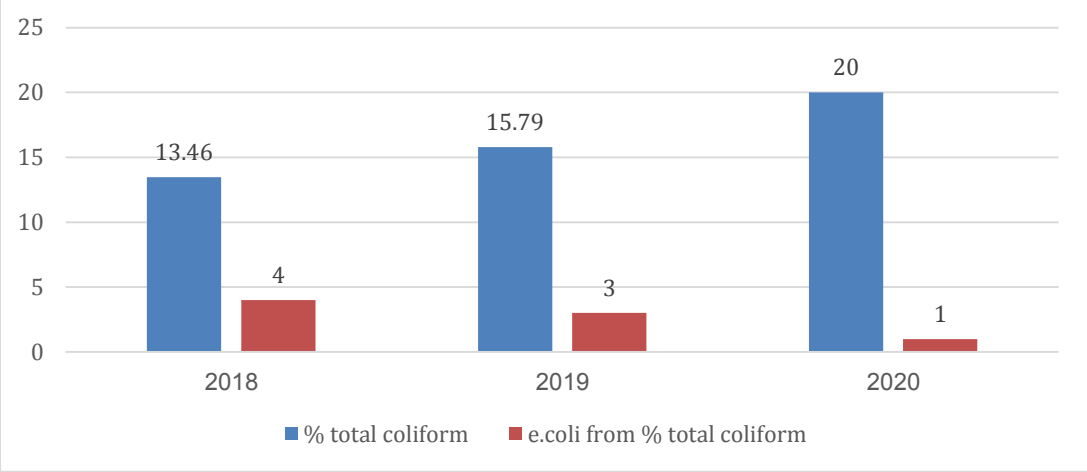


Figure 3. The percentage of coliform bacteria including recognized *E. coli* in drinking water in Sulaimani city for 3 years period.

The identification of EC gives conclusive proof of fecal contamination; however, in practice, the detection of thermotolerant (fecal) coliform bacteria is an adequate substitute (11). Table 1. shows the coliform and EC percentage that founded in drinking water according to the amount of residual chlorine (ppm). In total, residual chlorine of drinking water during 2018, 2019 and 2020 was 0.0-1.2, 0.0-0.8 and 0.0-1.0 ppm, respectively. For biofilm development to be prevented and water quality degradation to be prevented, WHO recommended a minimum amount of 2 ppm total chlorine residue must be present. However most home drinking water contains 0.1-1.0 ppm in chlorine. Concentration of the residual effects by pH, temperature and total dissolved solid (14).

Results clearly explain the effect of chlorine concentration on availability of fecal coliform and *E. coli*. There was negative correlation between residual chlorine and coliform survivability. Most detected coliform and EC were in absent (0.0 ppm) of residual chlorine in water networks. Present the chlorine significantly decreased the ratio of contamination. As concentration increased, the

concentration of biofilm decreased and vice versa.

The presence of chlorine residuals in drinking water has long been regarded as an effective indication for assessing water quality in the distribution infrastructure. Microorganisms in the distribution network will be recovered at high quantities if there is no disinfectant residue present.

Table 1. Detected Coliform and *E. Coli* percentage in drinking water of Sulaimani according availability of Chlorine.

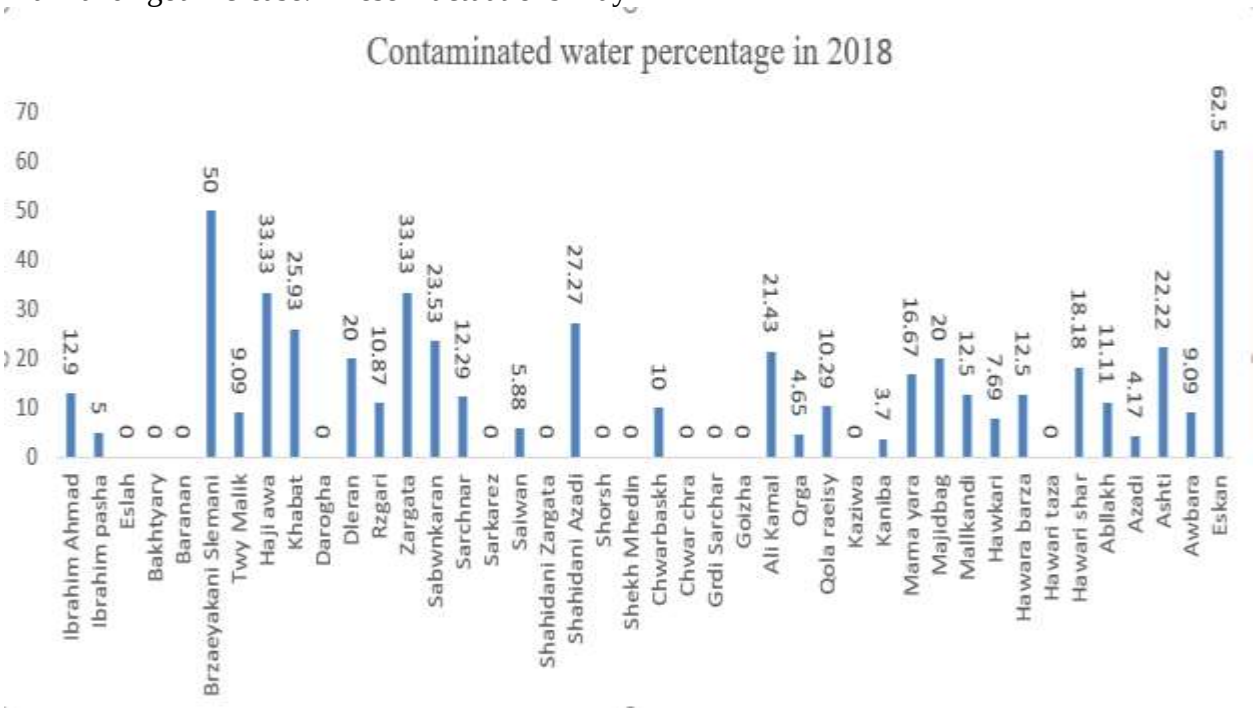
Chlorine (ppm)	2018		2019		2020	
	Coliform %	*E. Coli* %	Coliform %	*E. Coli* %	Coliform %	*E. Coli* %
0.0	58.06	66.67	62.09	66.1	45.46	0.00
0.1	8.87	11.9	6.27	3.39	13.64	0.00
0.2	7.26	4.76	5.08	4.08	4.55	25.00
0.3	7.26	7.15	6.87	10.17	9.09	0.00
0.4	4.03	2.38	4.78	1.70	9.09	25.00
0.5	3.23	2.38	5.37	4.08	4.55	0.00
0.6	2.42	0.00	4.78	3.39	0.00	0.00
0.7	0.00	2.38	2.39	0.00	0.00	0.00
0.8	4.84	2.38	2.39	4.08	4.55	25.00
0.9	0.00	0.00	0.00	0.00	0.00	0.00
1.0	2.42	0.00	0.00	0.00	9.09	25.00
1.2	1.61	0.00	0.00	0.00	0.00	0.00

The presence of any disinfectant residue lowers the number of microorganisms present and the frequency with which they appear at the consumer's faucet. Maintaining a specific level of residual chlorine in tap water is effective not only in improving sanitary conditions, but it is also effective in suppressing the regeneration of microorganisms and inhibit the onset of biofilms on the internal surface of distribution pipelines, among other things (8, 14).

Many studies discovered a negative connection between turbidity and chlorination efficiency. A developed model projected that an increase in turbidity from 1.0 to 10.0 NTU would result in an eight-fold reduction in disinfection effectiveness at a given chlorine dosage when the chlorine concentration was held constant. Studies on the effectiveness of disinfection at NTU turbidites of 1.0 and 5.0 showed that viruses and coliforms adhering to organic materials were more resistant to disinfection than those adhering to inorganic material like. Disinfectant-resistant organisms were found to be five times lower in organic particles when turbidity was decreased from 5.0 to 1.0 NTU (8).

Figure 4 explains the ratio of contamination in home tanks in some quarters in Sulaimani city. Results showed that level of contamination are in high level. Generally, the percentage of quarter home tank spoilage in 2019 was more than 2018 and 2020 recorded the lowest percent of contamination when compared to others. Eskan recorded highest percent of infection in both 2018 and 2019 with 62.5 and 41.18% respectively. There was fluctuation in contamination in quarters which some quarters had the same ratio in spoilage in 2018 and 2019

and some others raised. There was no change in level of Twimalik and Ashti quarter stay constant in level of contamination while Rzgari, Khabat, Srachnar declined and Ibrahim pasha, Ibrahim Ahmad, Sabwnkaran, Qrga and Mallkandi got increase. These fluctuations may be referred to sampling position and sanitary treatment of tanks by owners in quarters and allies. Rzgari, Zargata, Majid bag and Shahidani Azadi decreased continuously in period of three years.



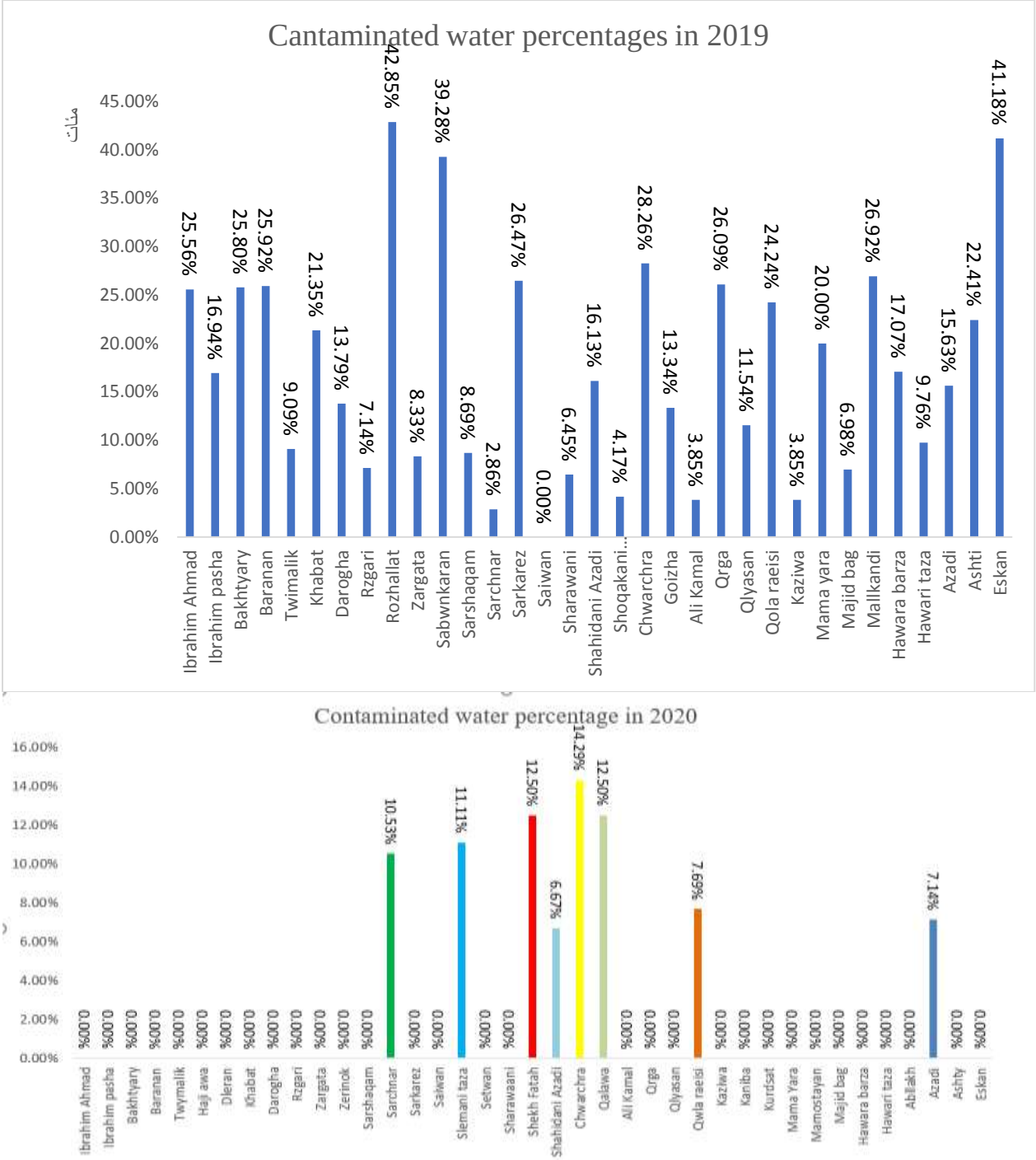


Figure 4. Contamination in household tanks in some quarters in Sulaimani city during 2018, 2019 and 2020.

The degradation in water quality happens as a result of the regrowth of bacteria in biofilms that develop on the inner surfaces of water pipes, or as a result of the back siphonage of polluted water into the distribution system. The amount of biological activity in biofilms is regulated by the amount of nutrients in the water, the temperature, and the amount of residual chlorine

(16). Based on the survival study of EC in the environment, we can bracket its survival in water containing a moderate microflora at a temperature of 15-18°C of between 4 and 12 weeks (17). It is essential to do frequent testing to ensure that there is still a sufficient quantity of free residual chlorine in the potable water. Maintaining a suitable amount of chlorine residue is required at all points in the distribution system where chlorine is employed as a disinfectant. Maintaining a specific amount of residual chlorine in tap water is beneficial not only in improving sanitary conditions, but also in inhibiting microorganism renewal and avoiding the development of biofilms on the interior surface of distribution pipes (18). The turbidity and the acidity (pH) of the water have a significant effect on the efficiency of chlorine as a disinfectant. The turbidity should be < 5NTU and the pH level between 7.2 and 6.8. For normal domestic use, residual chlorine levels at the point where the consumer collects water should be between 0.2 and 0.5 mg/l (19).

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