SEASONAL VARIATION OF BACTERIOLOGICAL AND CHEMICAL QUALITY OF DRINKING WATER: A CASE STUDY IN A PALESTINIAN DISTRICT

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ABSTRACT

Evaluation of drinking water quality for Jenin district in Palestine was carried out for the years 1997, 1998, and 1999, respectively. Only 53.1%, 85.4% and 69.6% of the drinking water samples tested for free chlorine residual, total coliforms and faecal coliforms, respectively are within the limits of the Palestinian and International standards. The seasonal variation of bacteriological and chemical quality of drinking water was investigated. It was found out that the summer season has the best quality and the winter has the worst. There remains some ignorance in testing the drinking water in the villages and towns in Jenin district. Huge efforts are required to improve the drinking water quality in Jenin district, as well as other Palestinian districts, through public awareness, training of governmental inspectors, in addition to a strict monitoring system for water quality.

Key words: ***faecal coliforms; total coliforms; free chlorine residual;Jenin district; and Palestine.***

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INTRODUCTION

Water is an indispensable commodity, which should be easily accessible, adequate in quantity, free of contamination, safe, inexpensive and readily available throughout the year in order to sustain life. According to the World Health Organization ,WHO[1] , and others[2,3,4,5], protection of water supplies from contamination is the first line of defence.

According to the Palestine Standards Institution, PSI[6], in order to have acceptable drinking water, we have to examine the water continuously to make sure that it is free from bacteria and should have the concentrations of substances such as free chlorine residual based on the guideline value. One must distinguish clearly between the examination of chlorinated and unchlorinated water supplies. If one is examining a chlorinated water supply one knows that, if the chlorination process is working correctly, all coliform organisms will have been killed[7,8].

Most of the time, the source water usually meets hygiene standards. However, free chlorine residual concentration rapidly declines in the distribution system, as there is little protection against secondary microbiological contamination of water in pipelines, and rechlorination is not practiced. This situation results in very low free chlorine residual at taps, and therefore gastrointestinal morbidity might appear[9].

The majority of the population in the Jenin district construct their own cisterns to collect rain water from the roofs of their houses during the winter seasons and utilize it for their domestic consumption. Approximately 60% of the wastewater generated from households in the Jenin City is collected by sewer networks. Unfortunately, the cesspits or cesspools are the main methods of wastewater disposal in the Jenin district. Approximately 13% of the population in the Jenin district is connected with the sewage network. Another serious problem in the Jenin district is that water pipelines are laid adjacent to sewage lines causing, in many cases, wastewater infiltration to the drinking water[10]. According to Al-Kahah[11] and Othman [12] there are 76 communities in Jenin district, out of which only 34 communities are connected to public water networks.

This study was performed to ascertain the bacteriological quality of the drinking water in Jenin district, in Palestine, in addition to some of its chemical characteristics. The aim of this

research is to determine if the drinking water throughout Jenin district is suitable for drinking and does not constitute a health hazard to the population. In this study, the distribution of total and faecal coliforms and free chlorine residual in the drinking water in Jenin district will be examined and analysed. This will include all the water samples which were collected by the team of environmental health inspectors from MoH and tested in the public health laboratory of the MoH during the years of 1997-1999.

MATERIALS AND METHODS

During January 1997 until 26 December 1999, 1964 drinking water samples were collected from different locations (wells, houses, restaurants, springs, schools etc.) from the villages, towns, a city, and a refugee camp in Jenin district in the West Bank of Palestine. The samples were collected by the Environmental Health Department of the Palestinian Ministry of Health for inspection purposes. One thousand nine hundred and thirteen samples were examined for total coliforms (247 for faecal coliforms). One thousand and sixty-nine samples were examined for free chlorine residual, to ensure the chemical quality of the drinking water. The samples were taken during the day time, normally in the early morning, but no specific time was indicated for this purpose. A quantitative descriptive design, describing the microbiological and chemical quality of drinking water available in records, has been used. Total coliforms and faecal coliforms were enumerated by the Most Probale Number , MPN, method inoculating series of five tubes, using Lactose Broth- Brilliant Green Bile Broth respectively[13].

The data was coded and entered into the computer and analyzed using the statistical analytical system SPSS (Statistical Package for Social Sciences). It was found that there were some limitations for this research, as many missing items were found in the sampling form results, many samples were not labelled well and the location was not identified, and not all the samples were tested for free chlorine residual.

RESULTS

The values of all microbiological and chemical parameters are shown in Table 1. Out of the tested 1069 samples for free chlorine residual, 488 (45.7%) of the samples have a concentration less than 0.2 ppm (0-0.1), 568 (53.1%) of the samples between 0.2-0.8 ppm and 13 samples more than 0.8 ppm. According to the WHO[5] and PSI[7] guidelines for drinking water quality, for effective disinfection of drinking water, the concentration of free chlorine residual should be 0.2 ppm and not more than 0.8 ppm when water reaches the consumer. This means that only 53.1% of the drinking water available in Jenin District is acceptable for drinking within the limits of standards. This result directly reflects the presence of microbiological contamination of the drinking water.

According to the WHO[3] and Al-Qahah[11] (2001) classification of total coliforms, out of the 1913, 85% of samples are free of contamination (zero degree of contamination), while 7.8% and 6.8% of samples are in the second and third degrees of contamination respectively. None of the examined water samples were within the third dergree of contamination. Out of 247 samples tested for faecal coliforms, 172 (69.6%) were of good quality and had no risk, while 21 (8.5%) of the samples had low risk, 33 (13.4%) of the samples had an intermediate risk level, 21 (8.5%) of the water samples showed high risk level, and none of these samples showed very high risk level. This classification of risk is recommended by WHO[3].

Table 1. Range Values, Frequencies and Valid Percentages of Free Chlorine Residual (FCR), Total Coliforms and Faecal Coliforms (TC-FC)

Range Values, Frequencies and Percentages								
Free Chlorine Residual (ppm)			TC (n/100ml)			FC (n/100ml)		
0-0.1	488	45.7	0-3	1633	85.4	0	172	69.6
0.2-0.8	568	53.1	4-50	150	7.8	1-10	21	8.5
>0.8	13	1.2	51-50,000	130	6.8	11-100	33	13.4
			>50,000	-	-	101-1000	21	8.5
						>1000	-	-
Total	1069	100.0		1913	100.0		247	100.0

Table 2 shows the results of sampling location versus annual distribution of population[14], sample size, and sampling density per 1000 of population cross tabulations. The total number of samples shown in this table are 1570 out of 1964 tested, due to the limitations of the study. Nine hundred and fifty-two (60.6%) of the total samples were collected from the city of Jenin during the three years of 1997, 1998, and 1999; while 124 (7.9%) were from Jenin Refugee Camp. Four hundred and ninety-four (31.5%) of the samples were collected from the different villages and towns of Jenin District. The range of annual sampling densities in the City of Jenin, Jenin Refugee Camp and the villages and towns of Jenin district are between 10.3 -13.0, 3.9-5.1 and 2.4-3.0 samples per 1000 population respectively.

DISCUSSION

In order to see the effect of the concentration of free chlorine residual on the biological indicators, many cross tabulations have been performed. The final summary is presented in Table 3. As it is clearly seen from this table, there is an inverse relationship between presence of TC and FC and the concentration of free chlorine residual. Most of the contaminated samples with faecal coliforms have a free chlorine residual less than 0.2 ppm. Only one sample tested for

Table 2. Sampling Location Versus Annual Distribution of Population, Sample Size (Pop, N), and Sampling Density (1000 N/ Pop)

	Sampling Year								
	1997			1998			1999		
Sampling Location	Pop*	N	(1000 N/ Pop)	Pop*	N	(1000 N/ Pop)	Pop*	N	(1000N/ Pop)
Jenin City	26332	272	10.3	27329	354	13.0	28394	326	11.5
Jenin Refugee Camp	8991	35	3.9	9331	48	5.1	9695	41	4.2
Villages And Towns	157420	165	1.0	163381	203	1.2	169748	126	0.7
Total	192743	472	2.4	200041	605	3.0	207837	493	2.4

*PCPS[14]

Table 3. Effect of Free Chlorine Residual Concentration (FCR) on Total Coliforms and Faecal Coliforms (TC, FC) and the Degree of Contamination Risk.

		TC (n/100ml)			FC (n/100ml)			
		0-3 no risk	4-50 low risk	51-50,000 intermediate risk	0 no risk	1-10 low risk	11-100 intermediate risk	101-1000 high risk
Free Chlorine Residual (ppm)	0-0.1	453	25	9	23	3	1	-
	0.2-0.8	525	23	20	21	1	1	1
	> 0.8	12	1	-	6	-	-	-
Total		990	49	29	50	4	2	1

faecal coliform and has a high risk effect. Fourty-nine samples tested for TC and two samples tested for FC are found to be within the degree of intermediate risk.

Table 4 summarizes the sampling location versus range values and frequencies of FCR, TC, FC, respectively. It is noticed that most of the samples are tested in Jenin city even though its population consists of only 13.7% of the total population of Jenin District. There is some attention given to drinking water sampling in Jenin Refugee Camp, but most of the samples tested for FCR have a concentration less than 0.2 ppm, which is the minimum concentration recommended by PSI[6] and WHO[4]. It is clearly seen that there is some ignorance in testing the drinking water in the villages and towns in Jenin district even though their population consists of 81.7% of the total population, and most of the contaminated samples with TC are in the villages and towns.

From the cross tabulations as shown in Table 5, it was obvious that there is a significant statistical relationship between the sampling year and the contamination of drinking water with FC (Chi square = 19.834, p= 0.001) and the free chlorine residual concentration (Chi square = 44.967, p= 0.000) respectively. Table 5 shows that in 1997 and 1998, 83.1% of the samples tested for FC had no risk. This situation was improved in 1999 where 90.5% of the samples had no risk of contamination. In 1997, 47.4% of the samples tested for FCR concentration were within the limits of standards (0.2-0.8 ppm). The situation improved in 1998, as 64.5% of the tested samples were found to have FCR concentration within the limits of standards, but this trend had changed in 1999 with only 43.9% of the samples within the limits of standards.

Regarding the FC, there is no siginficant relationship between the sampling year and degree of contamination, and this is clear in Table 5. For example, in 1997, 70.5% of the samples tested for FC showed no risk of contamination, while

Table 4. Sampling Location Versus Range Values and Frequencies of Free Chlorine Residual (FCR), Faecal Coliforms and Total Coliforms (TC, FC).

	Range values and frequencies									
	FCR (ppm)			TC (n/100ml)			FC (n/100ml)			
Sampling Location	0.0-0.1	0.2-0.8	>0.8	0-3	4-50	51-50,000	0	1-10	11-100	101-1000
Jenin City	286	355	7	875	41	34	18	-	-	-
Jenin Refugee Camp	94	7	1	115	7	2	1	1		
Villages and Towns	34	157	-	432	47	12	9	1	2	-
Total	414	519	8	1422	95	48	28	2	2	

Note: the numbers in the body of the table are the number of samples

Table 5. Cross Tabulations of Sampling Year versus Range Values, Frequencies and Valid Percentages of Free Chlorine Residual (FCR), Total Coliforms and Faecal Coliforms (TC -FC) .

Range Values, Frequencies and Percentages												
Sampling Year	Free Chlorine Residual (ppm)			TC (n/100ml)				FC (n/100ml)				
	0-0.1	0.2-0.8	>0.8	0-3	4-50	51-50,000	>50,000	0	1-10	11-100	101-1000	>1000
1997	119	108	1	507	50	53	-	67	8	9	11	-
	52.2	47.4	0.4	83.1	8.2	8.7		70.5	8.4	9.5	11.6	
1998	149	285	8	599	69	53	-	54	7	15	2	-
	33.7	64.5	1.8	83.1	9.6	7.4		69.2	9.0	19.2	2.6	
1999	220	175	4	527	31	24	-	51	6	9	8	-
	55.1	43.9	1.0	90.5	5.3	4.1		68.9	8.1	12.2	10.8	
Total	448	568	13	1633	150	130	-	172	21	33	21	-
	45.7	53.1	1.2	85.4	7.8	6.8		69.6	8.5	13.4	8.5	

Table 6. Cross Tabulations of Sampling Season versus Range Values, Frequencies and Valid Percentages of Free Chlorine Residual (FCR), Total Coliforms and Faecal Coliforms (TC -FC).

Range Values, Frequencies and Percentages												
Sampling Season	Free Chlorine residual (ppm)			TC (n/100ml)				FC (n/100ml)				
	0-0.1	0.2-0.8	>0.8	0-3	4-50	51-50,000	>50,000	0	1-10	11-100	101-1000	>1000
Summer	155	181	9	442	47	44	-	63	5	14	4	-
	31.8	31.9	69.2	27.1	31.3	33.8		36.6	23.8	42.4	19.0	
Autumn	108	140	-	374	29	29	-	36	3	6	3	-
	22.1	24.6		22.9	19.3	22.3		20.9	14.3	18.2	14.3	
Winter	129	105	-	388	43	25	-	9	4	3	3	-
	26.4	18.5		23.7	28.7	19.2		5.2	19.0	9.1	14.3	
Spring	96	142	4	429	31	32	-	64	9	10	11	-
	19.7	25.0	30.8	26.3	20.7	24.6		37.2	42.9	30.3	52.4	
Total	488	568	13	1633	150	130	-	172	21	33	21	-
	100.0	100.0	100.0	100.0	100.0	100.0		100.0	100.0	100.0	100.0	

in 1998 and 1999, 69.2% and 68.9% of the samples tested for FC showed no risk of contamination, respectively. This means that the quality of drinking water has not improved over the years.

In order to see the seasonal variation of sampling and water quality, many cross tabulations have been performed. The final summary is presented in Table 6. As is clearly seen from this table, the summer season is the best for FCR concentration since 31.9% of the samples that are within the limitation of the PSI[6,15] and WHO[4] standards are in this season. The worst quality was in the winter season, since only 23.7% of the samples are within the limitation of the standards. It can be concluded also that the the summer season is the best from the point of view of bacteriological quality of the tested samples (see Table 6). The samples tested for TC in the summer, with zero degree of risk, consists of 27.1% of the 1633 samples tested for TC. In winter only 23.7% of the 1633 samples tested for TC are of zero degree of risk. The same result can be concluded for FC. That means there is a strong realtionship between the disinfection of drinking water and its bacteriological quality. More investigation is required to know the reasons for the bad quality of drinking water mainly in winter.

It was noticed that none of the samples were examined for faecal streptococci or sulphite-reducing clostridia, as recommended by PSI[6] when samples are contaminated with faecal coliform. According to WHO[8] and PSI[6] it is recommended that the drinking water should not contain enteric viruses, three of the intestinal protozoa that are pathogenic for man and can be transmitted by drinking water: Entamoeba histolytica, Giardia Spp. and Balantidium coli - all helminthes that can be infective to man and free-living organisms, including plankton and macro invertebrates. It was noticed that none of the samples were examined for any of the above mentioned indicators.

CONCLUSIONS

From the analysis of the results the following conclusions can be drawn:

1. The Ministry of Health in Jenin district focussed attention on the city more than other areas in the same district, such as the camp, the villages and the towns.

2. The range of annual sampling densities in the City of Jenin, Jenin Refugee Camp and the villages and towns of Jenin District, are between 10.3 -13.0, 3.9-5.1 and 2.4-3.0 samples per 1000 population, respectively.

3. There is a significant statistical reltionship between the sampling year and the contamination of drinking water with FC and the free chlorine residual concentration.

4. The seasonal variation of sampling indicated that the summer season is the best for water quality and the worst quality was in the winter season.

5. There is a strong realtionship between the disinfection of drinking water and its bacteriological quality.

The following recommendation can be made as a result of the previous analysis:

1. More attention should be paid for sampling of drinking water in the villages and towns in Jenin district.

2. Adequate monitoring network should be established.

3. A time schedual for the biological and chemical examination of drinking water should be followed.

4. Public awareness about safety of drinking water and its impact on health should be emphasized.

5. Intersectoral collaborations between the Ministry of Health, the Ministry of Education and other related leaders should be established for planning a national strategy for providing safety water and improving the quality of water in Palestine.

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