

Comparison of hardness of drinking water and morbidity of population consuming water from infiltration water intake

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Abstract. The link between the total hardness of drinking water and the primary and total population turnover in polyclinics of the city, located on the territory supplied with drinking water from the infiltration water intake, for some diseases (malignant neoplasms, blood diseases, endocrine diseases, diseases of the circulatory system, respiratory diseases, digestive diseases, skin diseases, diseases of the musculoskeletal apparatus, diseases of the genitourinary system, congenital deformities) was searched. Different manifestations of links between diseases of the population and the available level of water hardness of the infiltration water intake zone were revealed.

1 Introduction

In order for drinking water to be safe and harmless to humans, various hygienic requirements are imposed on its chemical composition [1]. However, despite this, various chemical substances in drinking water, which are either within the permissible limits or below the definition level, can affect human health [2].

It is believed that drinking hard water is not harmful to human health [3, 4], but there is evidence of negative health effects of both hard drinking water [3-10] and soft drinking water [11- 15]. Therefore, water hardness is an important indicator of water quality for water use conditions [16-19].

2 Characterization of research objects and research methodology

We searched for the relationship between drinking water hardness and the number of visits (primary and total) of the population to polyclinics of the city (P1, P2, P3, P4), which are located in the zone of drinking water supply from the infiltration water intake. The initial data were daily determined concentrations of hardness in clean water tanks (CWT 1, CWT 2, CWT 3) of the water intake, and average annual values of the number of visits per 1000 visits per shift for the following diseases: Malignant neoplasms (MN), blood diseases (BD), endocrine diseases (ED), circulatory system diseases (CSD), respiratory diseases (RD), digestive diseases (DD),

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skin diseases (SD), musculoskeletal diseases(MD), genitourinary system diseases (GSD), congenital deformities (CD) for the period from 2002 to 2014.

The CWT water hardness values used in the correlation analysis were obtained by adding the daily hardness concentrations of the respective year and dividing the resulting sum by the number of readings. The calculation was performed using correlation and regression analysis.

A weak relationship (Cheddock scale - 0.0-0.3 [20]) showing minimal relationship between the indicator in drinking water and diseases recorded in the studied health facilities would not be appropriate to consider.

3 Results and discussion

"High" and "Very high" (Cheddock scale: high 0.7-0.9, very high 0.9-0.99) associations between infiltration drinking water hardness and health facility diseases were not found (Table 1).

Despite the fact that the greatest number of positive and negative correlation coefficients (162 coefficients: 95 positive, 67 negative) falls on the "weak" relationship (Table 1), for further analysis it is not appropriate to consider it, in view of the fact that it reflects a minimal relationship between the hardness of drinking water of infiltration water intake and the studied diseases.

For further analysis, the obtained correlation coefficients were grouped according to the occurrence of moderate and marked relationships for primary and general referrals, taking into account positive and negative values of correlation coefficients (Table 2). Analysis of the data on the correlation between water hardness and morbidity shows that in 72 cases out of 234, there are "moderate" and "marked" relationships, with 49 of them having positive values and 23 having negative values. The correlation coefficients characterising the "moderate" relationship occur 48 times and the correlation coefficients of the "noticeable" relationship occur 24 times (Table 2).

For P1 there are only two correlation coefficients with a "noticeable" relationship, they are for the total incidence of CSD. Other diseases are characterised by "moderate" correlation. On primary treatment, the largest number of negative correlation coefficients of "moderate" relationship is for MD and GSD, and ED have the maximum number of positive correlation coefficients of "moderate" relationship. In terms of total turnover, BDs have correlation coefficients characterising "moderate" relationship (Table 1, Table 2).

In P2, diseases such as MD, DD, CSD are noted, with maximum number of correlation coefficients with "marked" and "moderate" relationships for both referrals. SD have maximum number of negative correlation coefficients of both links in both circulations. RD and BD have correlation coefficients of "noticeable" relationship for total turnover (Table 1).

For P3, the total turnover by CD is characterised by correlation coefficients of "moderate" relationship. It is also noted that RD and ED have the highest number of correlation coefficients of "moderate" and "noticeable" relationship for both turnover (Table 1).

In P4 for total turnover, a "noticeable" relationship is observed for MD, and a "moderate" relationship for CSD and CD. GSD, MN and RD have correlation coefficients of "moderate" association with negative values, and SD is noted with negative correlation coefficients of "moderate" and "noticeable" association (Table 1).

It should be noted that relatively high values of correlation coefficients are not evidence of a high risk of a particular disease, but indicate only the presence of a relationship between these indicators.

Table 1. Correlation coefficients showing the relationship between water hardness of infiltration water intake and disease incidence.

Incidence	Primary turnover (PT)			Total turnover (TT)			Primary turnover (PT)			Total turnover (TT)		
	CWT 1	CWT 2	CWT 3	CWT 1	CWT 2	CWT 3	CWT 1	CWT 2	CWT 3	CWT 1	CWT 2	CWT 3
	P1						P2					
MN	0.09	0.06	-0.01	0.16	-0.01	0.03	-0.22	-0.25	-0.35	-0.27	-0.27	-0.3
BD	-0.37	-0.2	-0.22	0.28	0.39	0.34	-0.21	-0.07	0.07	0.27	0.51	0.63
ED	0.17	0.39	0.45	0.02	0.06	0.05	0.31	-0.04	-0.09	0.03	-0.08	-0.17
CSD	-0.06	-0.22	-0.25	0.45	0.62	0.64	0.14	0.38	0.45	0.13	0.24	0.34
RD	-0.4	-0.23	-0.2	-0.27	0.19	0.17	0.01	0.2	0.16	0.16	0.63	0.61
DD	-0.25	-0.01	0	-0.27	0.19	0.17	0.17	0.54	0.62	0.17	0.54	0.62
SD	-0.06	-0.21	-0.28	0.14	0.34	0.26	-0.45	-0.56	-0.59	-0.45	-0.56	-0.59
MD	-0.17	-0.32	-0.3	0.19	0	0.06	0.5	0.32	0.43	0.5	0.32	0.43
GSD	-0.13	-0.4	-0.38	-0.07	0.28	0.21	-0.02	-0.01	-0.05	-0.02	-0.01	-0.05
CD	0.48	0.22	0.07	-0.18	-0.08	-0.21	0.41	0.21	0.02	0.41	0.21	0.02
Incidence	P3						P4					
MN	0.33	0	0.08	0.1	0.17	0.15	0.01	-0.32	-0.32	0.09	-0.14	-0.11
BD	-0.09	-0.27	-0.29	0.1	-0.01	0.01	0.1	-0.13	-0.21	0.12	-0.18	-0.18
ED	0.61	0.27	0.31	0.52	0.21	0.25	0.1	-0.13	-0.21	0.28	0.17	0.21
CSD	0.2	-0.05	-0.08	0.2	0.23	0.31	-0.14	-0.25	-0.31	0.42	0.37	0.41
RD	0.11	0.45	0.47	0.11	0.52	0.54	-0.14	-0.32	-0.46	0.06	0.22	0.25
DD	0.21	0.03	0.11	0.24	0.2	0.23	0.1	0.23	0.16	0.19	-0.07	-0.01
SD	0.16	-0.05	-0.03	0.21	0.01	0.05	-0.07	-0.54	-0.44	0.17	-0.05	0.05
MD	0.07	0.07	0.12	0.13	0.12	0.17	0.09	0.29	0.21	0.54	0.55	0.55
GSD	0.18	0.02	0.05	0.16	-0.03	-0.04	-0.08	-0.14	-0.13	-0.08	-0.35	-0.4
CD	*	*	*	0.38	0.3	0.31	*	*	*	0.14	0.39	0.42
* there was no circulation registered												

Table 2. Results of grouping of correlation coefficients characterising moderate and marked relationships between infiltration water hardness and morbidity.

			"Moderate."0.3-0.5	"Notable."0.5-0.7	Total
P1	PT	+	3	0	3
		-	6	0	6
	TT	+	4	2	6
		-	0	0	0
P2	PT	+	6	3	9
		-	2	2	4
	TT	+	4	7	11
		-	2	2	4
P3	PT	+	4	1	5
		-	0	0	0
	TT	+	4	3	7
		-	0	0	0
P4	PT	+	0	0	0
		-	6	1	7
	TT	+	5	3	8
		-	2	0	2
Total		+	30	19	49
		-	18	5	23

Further analysis made it possible to determine the incidence of diseases that are identified by analysing the "moderate" and "noticeable" relationships for the zone of influence of the infiltration water intake. For this purpose, the obtained correlation coefficients were grouped by occurrence for each disease for primary and general circulation, taking into account positive and negative values of the coefficients (Table 3).

Table 3. Results of grouping of correlation coefficients characterising moderate, marked and high relationships between infiltration water hardness and morbidity.

Liaison		Incidence									
		MN	BD	ED	CSD	RD	DD	SD	MD	GSD	CD
Moderate	+	1	2	4	8	2	-	1	4	-	8
	-	4	1	-	1	3	-	3	2	4	-
Notable	+	-	2	2	2	4	4	-	5	-	-
	-	-	-	-	-	-	-	5	-	-	-
Total	+	1	4	6	10	6	4	1	9	-	8
	-	4	1	-	1	3	-	8	2	4	-

The majority of correlation coefficients characterising moderate and marked relationships between water hardness and disease incidence for ED, CSD, RD, MD and CD have positive values, and the number of occurrences of correlation coefficients for these diseases indicates the possibility of manifestation of these diseases (Table 3). For ED, CSD and CD, the

majority of correlation coefficients obtained correspond to a moderate association, while for RD and MD - to a marked association (Table 1).

It is interesting to note that most of the correlation coefficients indicating marked and moderate relationships between water hardness and SD have negative values (Table 1, Table 3). That is, it can be assumed that the existing level of water hardness in drinking water of the CWT has, to some extent, a favourable impact on the population consuming water from a particular water source, reducing the risk of skin diseases.

For the remaining diseases (MN, BD, DD, GSD), correlation coefficients characterising moderate and marked relationships are sporadic.

Comparison of correlation coefficients defining the relationship between indicators and diseases showed that correlation coefficients can have different signs (Table 4).

Table 4. Occurrence of correlation coefficients characterising moderate, marked and high associations between infiltration water hardness and morbidity.

Zone		Incidence									
		MN	BD	ED	CSD	RD	DD	SD	MD	GSD	CD
Infiltration water intake	+	1	4	6	10	6	4	1	9	-	8
	-	4	1	-	1	3	-	8	2	4	-

4 Conclusion

A moderate relationship with positive correlation coefficients was found between water hardness of infiltration water intake and CD. Negative coefficients of moderate correlation are characteristic for GSD, moreover, GSD have minimal (in comparison with other diseases) occurrence of coefficients and are not considered as possible diseases. For the infiltration water intake area, RDs with maximum positive coefficients of marked association are distinguished. Moderate, appreciable and high correlations are established between water hardness and CSD. Correlation coefficients for ED correspond to moderate and marked. MN have minimal occurrence and are not considered as possible diseases.

Differences in correlation coefficients showing the relationship between water hardness of infiltration water intake and morbidity show that the existing level of water hardness in this zone influences the possibility of manifestation of any disease. Among all diseases, diseases of musculoskeletal apparatus with the maximum number of positive correlation coefficients stand out.

It should be noted that correlation coefficients showing moderate, marked and high correlations between drinking water hardness and population morbidity are not evidence of a high risk of a particular disease, but indicate only the presence of a relationship between these indicators. The obtained data indicate that in most cases it is difficult to establish a pronounced relationship, perhaps this is due to migration of the population, changes in the records of diagnosis of diseases, consumption of bottled water by the population, nevertheless, the obtained data can be considered as an opportunity to determine the positive and negative impact of total water hardness on such diseases as malignant neoplasms, diseases of the circulatory system, respiratory diseases, diseases of the digestive system, diseases of the musculoskeletal system.

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