ORIGINAL ARTICLE

Correlation of bacteriological quality of drinking water and sewage disposal in Zenica-Doboj Canton

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ABSTRACT

Aim To determine the bacteriological quality of drinking water samples analyzed in the period between 1 January 2007 and 30 June 2012 in Zenica-Doboj Canton, Bosnia and Herzegovina.

Methods The data were extracted from the Protocols of the Laboratory for Sanitary and Clinical Microbiology (Cantonal Public Health Institute Zenica). A total number of coliform bacteria, thermotolerant *E. coli* and aerobic mesophilic bacteria were determined. Membrane filtration method (MFM) was used for the analysis the samples of drinking water. The analyses were performed according to standards and legal regulations.

Results A total number of 14932 samples were analyzed, of which 2276 (15.2%) samples did not meet the standards. The trend of drinking water quality was slightly increasing. The highest number of unsatisfactory samples was from wells, 2863 (83.1%) samples, from which 46.1% of the Canton population is supplied. There was a statistically significant correlation between bacteriological quality of water and quality of sewage sanitation systems in rural regions (Pearson correlation coefficients of 0.449).

Conclusion Poor sewage sanitation systems in rural regions is a cause of a high number of unsatisfactory samples of drinking water. Preventive activities and more frequent water sampling are necessary measures.

Key words: coliform bacteria, thermotolerant *E. coli*, aerobic mesophilic bacteria, chlorinated water, wells, springs.

INTRODUCTION

According to the World Health Organization sources, 80% of all diseases worldwide are caused by inadequate sanitation, polluted water and lack of access to drinking water (1). Three of five people in developing countries have no access to safe drinking water (1), and only one of four people have some sort of water sanitation (1). Only 15-20% of the world's population have access to drinking water (treated, chlorinated or uncontaminated water) (1). Daily consumption is about 300 liters of water per person in cities with modern drinking water supply systems, while only 25 liters in developing countries (1). Around 1.1 billion world population depend on unsafe sources of drinking water (1).

Quality water has no taste, odor, color, fecal contamination and chemical impurities in the quantity that is harmful to human body (1-3). The objective of this study was to determine the bacteriological quality of drinking water in Zenica-Doboj Canton. The purpose of this paper is to point out the importance of safe drinking water supply.

MATERIAL AND METHODS

The data for this retrospective study were extracted from the Protocol of the water analyses from the Laboratory for Sanitary and Clinical Microbiology of Cantonal Public Health Institute of Zenica in the period between 1 January 2007 and 30 June 2012.

A total number of 14 932 water samples was analyzed during this period and included in the study.

The Zenica-Doboj Canton has 6484 public water sources supplying 438 877 inhabitants with drinking water: 2.5% of the population using springs, 46.1% using wells, and 51.4% using municipal water supplies (chlorinated water). Continuous surveillance of sewage disposal and possibility of well water contamination (e.g. geology, location if neighboring wells) are responsibility of the Environmental Health Department in the Cantonal Public Health Institute Zenica. Sewage sanitation systems were designated as standard (centralized treatment and disposal), substandard (cesspool, septic tank), or absent (pouring into or near a stream/river).

Microbiological analysis of water is performed routinely at the Laboratory for Sanitary and Clinical Microbiology (Cantonal Public Health Institute Zenica) according to the standards and legal regulations of the Republic/Federation of Bosnia and Herzegovina.

Water samples (100 mL) were analysed for total and faecal coliforms by filtration through 0.45-μM cellulose nitrate membrane filters (Saratorius, Geottingen, Germany), placed on Endo agar plates (Oxoid, Basingstoke, UK), and incubated at either 37°C or 42°C for 48 h. The quality of the water sample was considered to be acceptable if thermotolerant *E. coli* was not isolated and the total coliform number was $0 \leq 10$ or ≤ 100 in chlorinated water, wells and springs, respectively.

Descriptive statistic methods were used for processing the data related to the analyzed water samples. Pearson correlation was used to calculate correlation between bacteriological quality of water and quality of sewage sanitation systems in rural regions.

Table 1. Distribution of contaminated drinking water samples in twelve municipalities of Zenica-Doboj Canton in the period 2007 - 2012

Municipality (No of samples)	No (%) of unsatisfactory samples						
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**Total**
Visoko (1349)	66 (22.9)	64 (24.8)	24 (10.4)	31 (13.8)	29 (10.9)	6 (7.3)	220 (16.3)
Kakanj (1606)	63 (28.1)	115(36.9)	57 (17.3)	56 (17.2)	54 (16.8)	14 (14.9)	359 (22.4)
Tešanj (3520)	48 (11.1)	138(19.7)	99 (13.5)	98 (12.4)	66 (9.7)	6 (3.2)	455 (12.9)
Zavidovići (1762)	50 (18.1)	67 (19.7)	16 (4.9)	32 (10.3)	23 (6.3)	6 (4.3)	194 (11.0)
Zenica (2406)	67 (16.3)	76 (18.1)	22 (5.5)	39 (8.6)	44(10.6)	36 (11.9)	284 (11.8)
Vareš (801)	23 (18.5)	26 (17.1)	6 (3.7)	15 (9.3)	13 (9.2)	3 (4.9)	86 (10.7)
Žepče (618)	18 (21.4)	31 (28.4)	22 (18.0)	29 (22.3)	3 (3.4)	2 (2.3)	105 (17.0)
Breza (676)	16 (17.6)	34 (28.1)	22 (17.9)	35 (27.3)	15 (12.3)	3 (3.3)	125 (18.5)
Doboj Jug (291)	2 (41)	9 (16.4)	1 (1.9)	7 (13.5)	2 (5.7)	0	21 (7.2)
Maglaj (1174)	52 (24.8)	56 (24.2)	48 (20.3)	57 (24.8)	46 (23.0)	19 (28.8)	278 (23.7)
Olovo (312)	3 (12.0)	28 (53.8)	9 (14.5)	21 (35.0)	22 (31.0)	5 (11.9)	88 (28.2)
Usora (417)	3 (20.0)	13 (34.2)	12 (12.6)	15 (15.3)	14 (15.0)	3 (3.9)	60 (14.4)
Total (14932)	**411 (18.4)**	**657 (23.5)**	**338 (11.8)**	**435 (14.7)**	**331 (11.8)**	**104 (8.2)**	**2276 (15.2)**

RESULTS

A total number of 14 932 water samples were analyzed in the period between 1 January 2007 and 30 June 2012. The highest number of analyzed samples were from the municipality of Tešanj, 3520 (23.6%), and the lowest number was from the municipality of Doboj Jug, 291 (1.9%) (Table 1).

A total number of 2276 (out of 14 932, 15.2%) samples did not satisfy the standards (Table 1). There were samples positive for two or three analyzed parameters. The highest number of unsatisfactory samples were from the municipality of Olovo, 88 (28.2%), and the lowest one was from the municipality of Doboj Jug, 21 (7.2%) (Table 1).

Of the total number of the samples positive for coliform bacteria the highest number was from the wells, 1317 (87.9%) (Table 2). The highest number of coliform bacteria in chlorinated water was in 2011, 18 (14.5%), in the wells in 2008, 507 (91.7%) samples, and in the springs in 2007, 20 (6.2%) samples (data not shown).

Of the total number of positive samples for thermotolerant *E. coli*, the highest number was also from the wells, 808 (88.3%) (Table 2). The highest number of thermotolerant *E. coli* in chlorinated water was in 2011, 12 (11.8%), in the wells in 2008, 300 (92.0%), and in the springs in 2009, 5 (6.2%) samples (data not shown).

Of the total number of positive samples for aerobic mesophilic bacteria the highest number was from the wells again, 738 (71.5%) (Table 2).

The highest number of aerobic mesophilic bacteria in chlorinated water was noted in 2011, 12 (11.8%); in wells 150 (75.8%) samples in 2011, and in springs 5 (6.2%) samples in 2009 (data not shown).

The curve had an ascending path between 2007 and 2008 and between 2009 and 2010, and then it continuously declined towards 2012 (Figure 1).
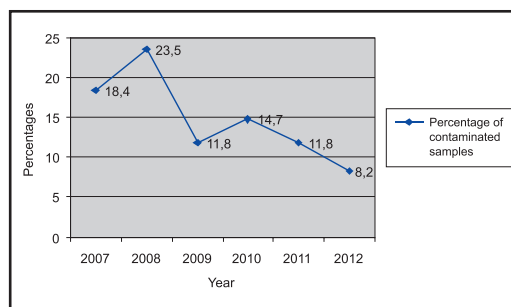
There was statistically significant correlation

Figure 1. Trend of unsatisfactory samples of drinking water in Zenica-Doboj Canton in the period 2007 - 2012

between bacteriological quality of water and quality of sewage sanitation systems in rural regions (Pearson correlation coefficients of 0.449) (Table 3).

DISCUSSION

Since 1914 the determination of the total number of coliform bacteria as indicators of faecal contamination is used as a criterion for determining the microbiological quality of drinking water (4). Bosnia and Herzegovina is one of the few countries in Europe and worldwide, which has significant resources of safe drinking water (4). In the Federation of Bosnia and Herzegovina 73.2% of the population is connected to a central water supply system (4). The bacteriological analysis of drinking water is mandatory in Zenica-Doboj Canton according to the standards and legal regulations of the Republic/Federation of Bosnia and Herzegovina. In Zenica-Doboj Canton, 51.4% of the population use water from municipal water supply systems for drinking as well as for personal hygiene (5). In other parts of the world there are countries where a large number of inhabitants is connected to public water supply systems, such as the U.S. - 85% of the population, Germany - 97.8%, UK - 99%, Monaco - 100% (6). Still, Portugal is the country with the similar situation, where only 58% of the population is connected to water supply systems (6).

Previous studies in Zenica-Doboj Canton have

Table 2. Characteristics of unsatisfactory water samples in Zenica-Doboj Canton in the period 2007 – 2012

Unsatisfactory finding	No (%) of samples			
	Chlorinated water	Wells	Springs	Total
Total coliform bacteria	132 (8.8)	1317 (87.9)	50 (3.3)	1499
Thermotolerant E. coli	73 (8.0)	808 (88.3)	34 (3.7)	915
Aerobic mesophilic bacteria	278 (26.9)	738 (71.5)	16 (1.6)	1032
Total	**483 (14.0%)**	**2863 (83.1%)**	**100 (2.9%)**	**3446**

Table 3. Bacteriological quality of drinking water and quality of sewage sanitation systems in the Zenica-Doboj Canton in period 2007 - 2012

Zenica-Doboj Canton municipalities (population)	Bacteriological analysis of water		Sewage sanitation system	
	No of samples examined	No (%) of unsatisfactory samples	No of rural regions	No of regions with absent or substandard systems
Visoko (42 171)	1349	220 (16.3)	88	71 (80.7)
Kakanj (45 764)	1606	359 (22.4)	116	71 (61.2)
Tešanj (52 104)	3520	455 (12.9)	34	30 (88.2)
Zavidovići (46 229)	1762	194 (11.0)	82	82 (100)
Zenica (143 193)	2406	284 (11.8)	76	62 (81.6)
Vareš (10 364)	801	86 (10.7)	10	1 (10)
Žepče (30 621)	618	105 (17.0)	40	40 (100)
Breza (15 516)	676	125 (18.5)	27	27 (100)
Doboj Jug (5534)	291	21 (7.2)	4	4 (100)
Maglaj (26 804)	1174	278 (23.7)	23	20 (87.0)
Olovo (13 581)	312	88 (28.2)	46	46 (100)
Usora (6996)	417	60 (14.4)	9	9 (100)
Total (438 877)	**14932**	**2276 (15.2)**	**555**	**454 (81.8)**

shown an incidence rate of 252/100,000 population of hepatitis A virus (HAV) infections, with 90.1% cases occurring in nine community-wide outbreaks (5). An analysis of water supplies showed that 19.1% samples contained coliforms, including 50.8% that were contaminated with thermotolerant *E. coli* (5). The high incidence of HAV infection did not correlate with the quality of the drinking water supply in the region, although the results of environmental and epidemiological investigations suggested that well were the source of infection in two outbreaks (5).

The greatest number of samples of drinking water positive for thermotolerant *E. coli* in this study were from individual local water supply facilities (wells), where chlorination is often not done.

Comparing the number of contaminated water samples from this study (15.2%) with data obtained in Serbia (from 1997 to 2007), a far lower percentage of contaminated samples of drinking water was observed in Serbia (5.94 %) (7). The reason for this situation probably lies in the fact that in Serbia there was no devastation of water supply facilities during the recent war, outflow of skilled personnel and lack of equipment necessary for quality monitoring of water safety (7).

In Zagreb city (Croatia) (in 2003) 5% of citizens were not connected to the water supply system, more than half (61.8%) of samples from the wells were contaminated (8), which is lower than in this study. Total coliform bacteria and fecal coliforms were found in 47.0% and 50.0% of the samples, respectively (in this study 87.9% and 88.3%, respectively) (8). Proportion of contaminated samples of chlorinated water from the supply systems in Zagreb city were 1.5% of in 2002, in Croatia as a whole 8.2% (8), compared to 15.2% in this study.

Most dumps of communal waste in the FB&H do not satisfy the hygiene standards, which is a risk for the occurrence and spreading of infectious diseases. European requirements for sanitary dumps are partially satisfactory in Zenica city (9).

The present study showed that the high number of unsatisfactory samples of water correlate with the quality of sewage sanitation systems in rural regions. Inadequate sewage disposal, substandard or absent sanitation and personal hygiene are most important environmental risk factors for unacceptable counts of coliforms and thermotolerant *E. coli* in water (5).

The necessity of bacteriological analysis of drinking water and other surface waters is imposed for the purpose of systematic monitoring of their bacteriological quality (9-13). For this purpose it is necessary to increase the frequency of water sampling for bacteriological analysis (9-13). Improved reporting and monitoring of diseases caused by polluted water, monitoring of hygiene and sanitary conditions (properly remove liquid waste), and the daily cooperation of microbiologists, epidemiologists and ecologists are important measures for the implementation of preventive measures in order to reduce morbidity from these diseases (9).

The measures for the prevention of water contamination include preventing the devastation of forests and land, especially in the catchment

areas, construction of systems for purification of municipal and industrial water, promotion and proper construction of hygienic septic tanks in the villages, provision of sanitary protection zones around water sources, improving sanitary and technical conditions of water facilities (9-13). In Zenica-Doboj Canton there are 81.8% rural households with absent or substandard sewage sanitation system (5), which coincides with HAV infection (9).

The prevention of diseases caused by contaminated water is simple and inexpensive (5), but many people persistently ignore the application of the basic principles of sanitation. The main cause of infection from contaminated water is avoidance of implementation of these principles (5), because of lack of staff, the attitude of individuals in the community or lack of funds (9). Adequate sanitation is not only the responsibility of individuals but also of entire communities (9). Maintaining personal hygiene is an insufficient measure (10). The maintenance of good sanitary conditions and quality of drinking water is only possible if the persons are familiar with information and the financial support of the responsible institution (10). Only well-educated population can prevent the destruction of the environment and protect water.

The fact is that only 3.5% of worldwide water is suitable for drinking, so water control according to the standards and legal regulations must be taken daily (1). In order to preserve resources and quality of drinking water and improve sanitation, legal regulations in the field of water must be harmonized with the European Union, and the Protocol on Water and Health (inter-state agreement of the European region) must be strictly implemented (4).

FUNDING

TRANSPARENCY DECLARATION

Competing interests: None to declare.

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Korelacija bakteriološke ispravnosti vode za piće i sanitacije u Zeničko-dobojskom kantonu

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SAŽETAK

Cilj Istražiti bakteriološku ispravnost analiziranih uzoraka vode za piće, u periodu od 01. 01. 2007. do 30. 06. 2012. godine u Zeničko-dobojskom kantonu (Bosna i Hercegovina).

Metode Korišteni su protokoli Laboratorija za sanitarnu i kliničku mikrobiologiju Kantonalnog zavoda za javno zdravstvo u Zenici. Određeni su ukupan broj koliformnih bakterija, termotolerantne *E. coli* i aerobnih mezofilnih bakterija. Uzorci vode za piće analizirani su metodom membranske filtracije (MMF). Analize su provedene prema odgovarajućim standardima i zakonskim regulativama.

Rezultati Od ukupno 14932 analizirana uzorka, 2276 (15,2%) uzoraka nisu zadovoljavali odgovarajuće standarde. Trend kretanja ispravnosti vode za piće bio je u blagom poboljšanju. Najveći broj neispravnih uzoraka bio je iz zatvorenih izvorišta, 2863 (83,1%) uzorka, iz kojih se inače snabdijeva 46,1% populacije kantona. Ustanovljena je statistički značajna korelacija između bakteriološke kvalitete vode i kvalitete sanitacije u ruralnim područjima (Pearson koeficijent korelacije 0,449).

Zaključak Loši sanitarni kanalizacijski sistemi u ruralnim područjima uzrok su velikog broja bakteriološki nezadovoljavajućih uzoraka vode za piće. Preventivne aktivnosti i češće uzimanje uzoraka vode su neophodne mjere.

Ključne riječi: koliformne bakterije, termotolerantna *E. coli*, aerobne mezofilne bakterije, hlorisana voda, zatvorena izvorišta, otvorena izvorišta.