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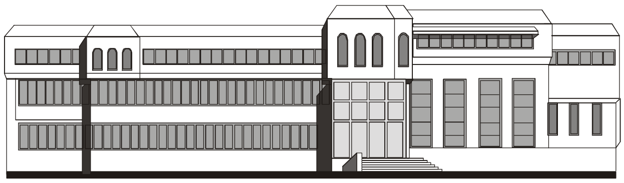

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Monitoring drinking water quality and safety in the Pelagonia region of Macedonia

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Abstract: Quality, but above all safe drinking water for every individual is the major problem of mankind in the 21st century because majority of the diseases are directly linked to the quality and safety of drinking water. Water and sanitation improvements, coupled with hygiene can have significant effects on the health of the population by reducing a variety of disease conditions. The purpose of our study was to determine whether drinking water from predetermined measuring points in the Pelagonia region is physicochemically and microbiologically safe. Total 18 fresh water samples were collected (9 each from urban and rural areas). Based on the results of the analysis, we can conclude that every consumer in the cities is supplied with hygienic and safe drinking water. However, in the rural areas nitrate concentrations were found to be higher, and a higher total bacterial count was observed at T = 22 °C; it did not include *Escherichia coli*, *Enterococci* and *Pseudomonas aeruginosa*. Nevertheless, values obtained did not exceed the limits, i.e., the drinking water was safe.

Key words: drinking water, physicochemical analysis, microbiological analysis, safety.

Introduction

Water is an ever-decreasing natural resource and its availability is a major social and economic problem (Vivar et al., 2019), and if its quality is not maintained it causes many adverse effects on children's health (most commonly diarrhea), chronic diseases and adverse reproductive outcomes among other health effects (Levallois and Villanueva, 2019). Urbanization of the environment leads to the creation of complex mixtures of chemicals that directly or indirectly find its way in water (BEI et al., 2019), making it difficult to establish a relationship between toxic compounds and suspicious contaminants (Shao et al., 2019). However, often the inadequate ratio of the chemicals (compounds) present in the drinking water results in changes in sensory properties, i.e. unacceptable taste, smell and appearance (Gutierrez-Capitan, 2019) and it becomes non-potable (WHO, 2011). The supply of microbiologically safe drinking water is based on the elimination of the causes of bacterial, viral and parasitic diseases (Bitton, 2014), most often the prevention of fecal contamination which is a major cause of water contamination with intestinal pathogens (Cabral, 2010).

Material and methods

The subject of our monitoring were 18 fresh water samples (9 samples from urban areas and 9 samples from rural areas) taken at the optimum temperature for water consumption (T=7-12°C), from predetermined measuring points in Pelagonia region, Macedonia, during the summer period, in order to get a general picture of the quality and safety of the water we consume daily.

Water samples for physicochemical analysis were taken in 500 mL glass bottles pre-rinsed with mili-Q water to investigate following parameters: turbidity (Lovibond Turbidimeter TB300 IR), active acidity (pH) and conductivity (EC) (JENWAY 3540 pH Meter), chlorine concentration (titration by Mohr method), residual chlorine and nitrates (comparatively, with Felliger comparator) and $KMnO_4$ consumption and oxidation (titration, by Kubel - Tiemann method).

Samples for microbiological analysis were taken in 500 mL sterile glass bottles and the total number of microorganisms (CFU/mL) were tested according to the method MKC EN ISO 6222, *Escherichia coli* (MKC EN ISO 9308-1), *Enterococci* (MKC EN ISO 7899-2) and *Pseudomonas aeruginosa* (MKC EN ISO 16266).

Results and discussion

Tables 1 and 2 show the average value obtained from the physicochemical and microbiological analysis of the water samples during the seven-day monitoring. Turbidity is an important indirect parameter for water pollution, i.e., its microbiological quality, because turbid water reduces the bactericidal ability of chlorine - one of the most commonly used disinfectants (WHO, 2017). In the context of the research of Huey and Meyer, (2010), we can observe that in the samples of water from the rural areas where we have partially increased turbidity (Table 1), there is an increase in the total number of bacteria (Table 2).

However, this water is safe to drink as there is no growth of pathogenic bacteria, *viz., E. coli, Enterococci* and *P.aeruginosa* and the total number of bacteria does not exceed the limits under the marketing authorization (Official Gazette of the Republic of Macedonia No. 183/2018).

Table 1. Physicochemical analysis of water samples from urban and rural areas

Parameters (N=18)	Turbidity	pH	EC	Cl	rez Cl	NO_3	$KmnO_4$	O_2
Values according to regulations	1.5 NTU units	6,5-9,5	2500 µS/cm	250 mg/L	0,5 mg/L	50 mg/L	8 mg/L	5 mg/L
Number of samples	Rural areas							
1	1,02	6,92	364	29	0,00	30	3,1	1,0
2	0,58	8,00	196	6	0,00	10	2,2	0,7
3	0,30	7,33	568	23	0,00	30	2,5	0,6
4	0,46	7,99	195	6	0,39	10	1,9	0,7
5	0,62	7,98	192	6	0,40	20	2,0	0,6
6	0,60	7,97	201	6	0,40	2	2,5	0,9
7	0,69	8,00	200	7	0,40	2	2,1	0,8
8	0,83	8,00	193	5	0,40	20	1,9	0,6
9	1,27	8,00	193	6	0,40	1	1,8	0,6
$\bar{x}$	0,71	7,80	256	10	0,27	14	2,2	0,7
	Urban areas							
1	0,37	8,00	197	6	0,00	1	2,2	0,7
2	0,39	8,00	194	6	0,00	1	2,2	0,8
3	0,39	7,99	196	5	0,00	1	1,9	0,6
4	0,45	8,00	194	6	0,39	1	2,2	0,6
5	0,46	8,00	193	5	0,38	1	1,9	0,6
6	0,53	7,99	194	6	0,38	1	1,9	0,6
7	0,23	7,97	196	5	0,00	0	1,7	0,7
8	0,37	7,21	194	5	0,00	0	1,9	0,7
9	0,93	8,00	195	6	0,40	1	1,7	0,6
$\bar{x}$	0,46	7,91	195	6	0,17	1	2,0	0,7

*pH-active acidity; EC- electrical conductivity, Cl-chlorine, rez Cl-residual chlorine; NO3-nitrates; KMnO4-potassium permanganate; O2-oxygen.

In both measurement ranges, the pH values are in the appropriate range, i.e., the environment is neutral to slightly alkaline and is not a cause for additional water contamination (Hao et al., 2015). Correlated with water safety is electrical conductivity (EC) - a proportional indicator of water purity, i.e., contaminated water results in increased values for this parameter (RA-SAS, 2004). On the other hand, water samples that had high values for conductivity also contain significantly higher concentrations of chlorine than others (Gichevska and Hristovski, 2013). Owing to absence of residual chlorine in the drinking water as an indicator of bacterial contamination (Yoon et al., 2017), an increased total number of bacterial counts in rural areas compared to urban areas (Table 2) was also expected.

Table 2. Microbiological analyzes of water samples from urban areas and rural areas

Parameters (N=18)	CFU/mL	CFU/mL	*Escherichia coli*	*Enterpcocci*	*Pseudomonas aeruginosa*
Values according to regulations	(100/mL) T=22°C	(20/mL) T=37°C	(0/100mL)	(0/250mL)	(0/250mL)
Number of samples	Rural areas				
1	67	14	0	0	0
2	12	0	0	0	0
3	83	18	0	0	0
4	10	0	0	0	0
5	15	0	0	0	0
6	13	0	0	0	0
7	26	3	0	0	0
8	54	8	0	0	0
9	14	0	0	0	0
x̄	33	5	0	0	0
	Urban areas				
1	4	0	0	0	0
2	20	2	0	0	0
3	18	1	0	0	0
4	22	1	0	0	0
5	7	0	0	0	0
6	6	0	0	0	0
7	21	2	0	0	0
8	19	1	0	0	0
9	5	0	0	0	0
x̄	14	1	0	0	0

The presence of nitrates in significantly higher concentrations of water from rural areas compared to urban areas is a result of insufficient urbanization and inadequate construction of water networks (Manassaram et al., 2005). The best way to eliminate it is to purify the water with reverse osmosis (Harter and Lund,

2012) which should be done as soon as possible so that the nitrate values do not exceed the maximum residual level (MRL) and no more serious public health problems occur (WHO, 2011). Consumption of KMnO4 and oxidizability are within the permissible interval according to the marketing authorization (Official Gazette of the Republic of Macedonia No.183/2018), and the presence of organic matter in the water samples could be due to different anthropogenic impacts and natural processes (James et al., 2004).

It can be observed that some of the physicochemical parameters (turbidity, electrical conductivity (EC), residual chlorine - Table 1) have an impact on the total number of microorganisms (Bitton, 2014) in both investigated areas. On the other hand, no growth developments were noticed of the pathogenic bacteria *Escherichia coli*, *Enterococci* and *Pseudomonas aeruginosa* (Table 2).

Conclusion

After comparing the results of our monitoring, we can conclude that drinking water from rural areas has slightly lower quality than that from urban areas. The plausible factors for the same could be due to insufficient urbanization of rural water supply networks. Nevertheless, all water samples taken from measuring points were found to be sanitized properly and were safe for drinking as the obtained values were in accordance to the set standards.

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