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Evaluation of Physico-Chemical Quality of Drinking Water with Drinking Water Quality Index in Kumanova City, Macedonia

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Abstract: *Water is the most essential product that is consumed by humans, which must be prevented from deterioration in quality. The quality of drinking water becomes even more important as water borne diseases spread through water. For this purpose, we assess the quality of drinking water in the city of Kumanova with some physico-chemical parameters, which have a significant role in determining the potability of drinking water. The obtained results were compared with Macedonian standards as well as with those set by the WHO and the EU. In this research, parameters such as temperature, turbidity, RC, pH, EC, TRAE, TDS, COD, nitrites, nitrates, ammonia and chlorides were found to be within the permissible limits, while residual chlorine in one case were found to be below lower than the recommended limit. Finally, the Drinking Water Quality Index (DWQI) developed by Canadian Council of Ministers of the Environment for five sample points is calculated. It has been found that drinking water in the 2011 spring season was of a Excellent category (average value of DWQI = 95.21) and suitable for drinking. We recommend that the relevant municipal authorities make regular and proper amount disinfection of drinking water, as there is no compromise that can be made when it comes to the drinking water.*

Keywords:- *Public Health, DWQI, Physico-Chemical Parameters, Drinking Water Quality.*

1. INTRODUCTION

Environmental pollution and especially the contamination of water sources is a problem our society is facing today. The increasing urbanization, industrialization, the modernization of agriculture, the increase in traffic all contribute to global pollution, which in turn requires accurate monitoring and information about the quality of water resources. Water is a crucial natural resource, a basic human need and a precious natural asset. Concerns for the quality of water come from the global social trends, population growth and development activities, which have been the cause of pollution. Moreover, in adequate management of water systems can cause serious problems in the water availability and quality of water [1]. Hence, it is necessary to evaluate the quality of the drinking water.

Water is the main factor for the existence of life in our planet. It is used for various purposes, such as drinking, cooking, maintaining proper hygiene etc., thus controlling the water quality is necessary in order to gather information about the level of contamination. Drinking water should be of high quality; it should meet the standards for daily usage and should not bear the po-tential of health risk. Water with such qualities is often limited, thus water is used from lakes, underground waters as well as artificially accumulated waters that initially must undergo treatment.

The treatment process of drinking water used in house-holds consists of: accumulation of water in water reservoirs, water aeration, coagulation, flocculation, precipitation, filtration and disinfection [2]. During usage, water in households and industry is contaminated with inorganic, organic and other contaminants, and as such it returns to our environment. Furthermore, water is also contaminated by the usage of agricultural practices.

Today, water that is considered drinkable should be subject to physical and chemical analysis; this also includes water from natural sources, such as wells. Treatment is done with physical and chemical methods such as: filtration, disinfection with chemicals and ultraviolet radiation. These methods have significantly increased the amount of accessible drinkable water for human consumption and at the same time have managed to reduce potential diseases. In order to eliminate bacteria, viruses and microorganisms that can cause various diseases amongst humans and animals, drinking water is treated with chlorine or similar disinfectants [3].

The drinking water quality directly affects human health. The impacts reflect the level of contamination of the whole drinking water supply system (raw water, treatment facilities and the distribution network to consumers) [4]. Drinking water is an essential environmental constituent and the quality of drinking water is an issue of primary interest for the residents of the European Union [5].

The assessment of water quality is done in various ways. A very powerful tool for this purpose is the Drinking Water Quality Index (DWQI). The objective of an index is to turn multifaceted water quality data into simple information that is comprehensible and useable by the public [6]. The DWQI represents a simple number from 0 - 100 where a highest value indicates the best water quality and vice versa [7], [8], [9].

The aim of the article is to assess the physical-chemical quality of the drinking water of Kumanova city during the spring season 2011, in order to conclude the quality of the drinking water and its impact on the health of the population living in this region. This is done by comparing the valuesof the measured parameters with drinking water guidelines of Macedonia, the WHO and the EU. Categorization of drinking water is done with DWQI.

2. MATERIAL AND METHODS

2.1. Drinking Water in the City of Kumanova

The city of Kumanova and the Likova municipality are supplied with water from the Likova dam, which is the oldest dam in the entire territory of the Republic of Macedonia. Likova dam was built in 1958 and its located 2 miles west of the same village, at an altitude of 478 m. River Likova is rich in water and its basin surface is 110 km^2, while the altitude ranges from 450 to 1350 m, with an average altitude of 1070 m.River Likova's greater flow is during the spring season, where as the flow levels drop during summer and autumn when the region needs irrigation of arable land and potable water supply in the region.

Table 1: *Some data in regards to the Likova accumulation*

Volume	*Used Volume*	*Length*	*Width*
1 500 000 m^3	1 300 000 m^3	1 480 m	120 m

Due to the high demand for quality water, 14 years later a second dam was built about 5 km west of Lake Likova, Gllazhnja locality. The length of the dam is 344 m concrete wall with a width of 4 m and a height of 84 m. The Gllazhnja reservoir supplies water to 13 settlements and a part to the city of Kumanova.

Table 2: *Some data in regards to the Gllazhnja accumulation*

Volume	*Used Volume*	*Length*	*Width*	*Surface*
24 075 870 m^3	22 160 000 m^3	3 162 m	320 m	96.5 ha

2.2. Working Methodology

The methodology involves collecting samples, their preparation and measuring. Experimental measurements were performed at the laboratories of the State University of Tetova and Institute for Health Protection in Kumanova.

2.3. Water Sampling

The sampling method has a great impact on the results of the analysis obtained. Thus sampling is defined by international recommendations. Water samples are placed in clean glass containers, which are initially rinsed 2-3 times with the water that is about to be tested. The container is closed with glass lid. In order not to confuse the samples, all the containers are labeled with date, the type of water, sample site, time and the name of the person collecting the sample. Prior to collecting the sample of water needs to flow for about 10 min.

The time from collecting the sample and analyzing it should be as short as possible. Samples with high pollution should be analyzed within 12 hours, the ones with lower pollution within 24 hours, while non-polluted waters within 72 hours. During this time, the samples should be stored in a dark place and at a temperature of 3-4 °C to avoid possible changes as a result of the activity of microorganisms present in water.

2.4. Sampling Points, Instruments and Reagents

Samples were collected from five sampling points of Kumanova city: K1 (Sinan Tatar Pasha Mosque), K2 (Fontana city center), K3 (Str. Dr. Ribar), K4 (Cafeteria Elib) and K5 (Str. Boris Kidriç). The present study was carried out in the months March, April and May 2011. Drinking water samples from five sampling points are analyzed each week in the months for the determination of physical-chemical parameters of the drinking water.

The water samples were collected from five sample points selected in the city of Kumanova (K1 – K5) in clean polyethylene and glass containers of 1.5 litres. The water temperature, residual chlorine (RC), pH, electrical conductivity (EC) and total dissolved solids (TDS) of water samples were recorded at the sampling points.

All other physical-chemical parameters such as turbidity, the total residue after evaporation (TRAE), chemical oxygen demand (COD), nitrites, nitrates, ammonia and chlorides were analysed using standard methods [10]. Chlorides were determined by titration method, while nitrites, nitrates and ammonia were analysed by spectrophotometric method. To realize the measurements were used these instruments: UV-VIS spectrophotometer HACH, MA conductometer 5964

WTW, pH-meter MA 9507 WTW, MA colorimeter 9507, analytical balance, water bath etc. Various different chemicals with pro-analysis and Suprapur® were used. For evaluating the physical-chemical quality of drinking water the Canadian Council of Ministers of the Environment Drinking Water Quality Index was used [11], which is widely used index. According to this index the drinking water quality is ranked in the following five categories: *Excellent* (DWQI values 95–100), *Good* (DWQI values 80–94), *Fair* (DWQI values 60–79), *Marginal* (DWQI values 45–59) and *Poor* (DWQI values 0–44).

3. RESULTS AND DISCUSSIONS

The results are presentedinFigures1 – 7. A comparison of the various physical-chemical characteristics of the studied water samples has been made with the Macedonian [12], WHO [13] and EU standards.

3.1. Water Temperature

The temperature plays a crucial role in physical-chemical and biological behavior of aquatic system [14]. Chemical reactions depend on the water temperature and it controls the metabolic and reproductive processes of aquatic species. The recorded temperature of drinking water was more or less similar in all sample points and slightly differed in months and the spring season (Fig. 1). Water temperature in months was found to vary from 10.60 to 11.60 °C. The highest temperature was observed in K2 and K3 (April and May) and the lowest was recorded during March in K2. Seasonal average with standard deviation was 11.20±0.33°C and was under state recommended value.

3.2. Turbidity

Turbidity is a measurement of the amount of suspended material in the water. Higher turbidity increases water temperatures because suspended particles absorb more heat. Clean waters are generally associated with low turbidity, but there is a high degree of natural variability involved. Rain events can increase turbidity in surface waters by flushing sediment, organic matter and other materials into the water. All samples are likely to show no significant difference. Range of turbidity was from 0.3 to 0.9 NTU unit (Fig. 2). Monthly averages in March, April and May were 0.42, 0.62 and 0.62 respectively, while the seasonal average with standard deviation was 0.55±0.18 NTU and was below the state recommended value. The consumption of highly turbid water may constitute a health risk as excessive turbidity can protect pathogenic microorganisms from the effects of disinfectants, and also stimulate the growth of bacteria during storage [15].

3.3. Residual Chlorine

Residual chlorine (RC) has great significance in the presence or absence of microorganisms. The presence of RC in drinking water indicates that a sufficient amount of chlorine was added initially to the water to inactivate the bacteria and some viruses that cause diarrheal disease and the water is protected from recontamination during storage. The presence of free RC in drinking water is correlated with the absence of disease-causing organisms, and thus is a measure of the portability of water. Seasonal variation of RC in the spring season are presented in Figure 3, where it can be seen that the RC values in K1 (May) was below the state recommended value. RC during spring season was found to vary from 0.18 to 0.27 mg/L. The highest value was observed in K3 (May) and the lowest was recorded in K1 (May) which is lower valuesthan the state recommended values. Monthly averages in March, April and May were 0.2340, 0.2320 and 0.2340 respectively, while the seasonal average with standard deviation was 0.233 ±0.024 mg/L.

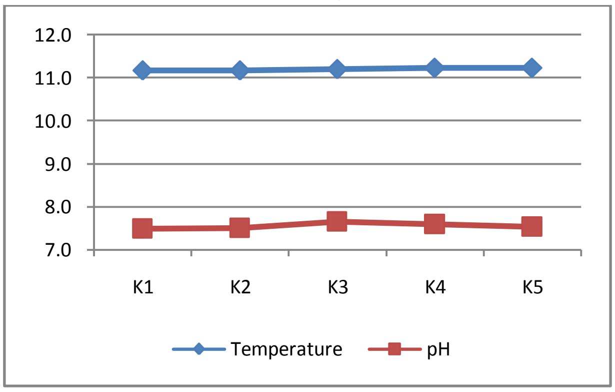

Fig 1: *Seasonal variation of average values of temperature and pH*

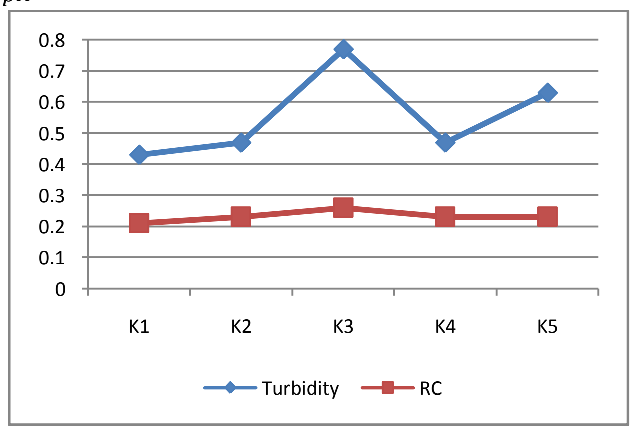

Fig 2: *Seasonal variation of average values of turbidity and residual chlorine*

3.4. pH Value

pH is a measure of hydrogen ion activity in water, or, water acidity. pH classified as a secondary drinking water contaminant whose impact is considered aesthetic. Water with a low pH can be acidic, naturally soft and corrosive. It can also damage metal pipes and cause aesthetic problems. Drinking water with a pH level above 8.5 indicates that a high level of alkalinity minerals is present. The recorded water pH was more or less similar in all sample points as well as season (Fig. 1). The pH for the water samples varied between 7.05 in K1 (March) to 7.91 in K3 (May), while average values for three months were 7.14, 7.69 and 7.85 respectively. The seasonal average with standard deviation was 7.56 ±0.32 and was under state recommended value.

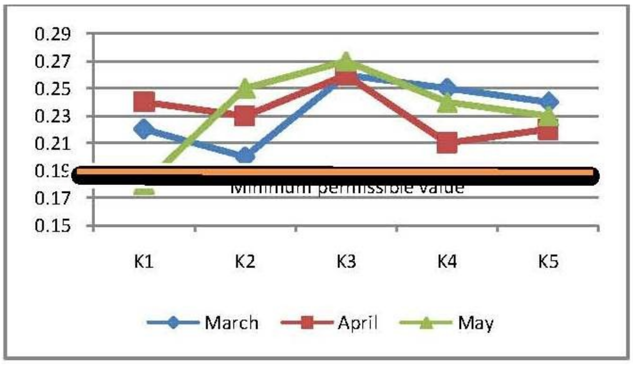

Fig 3: *Seasonal variation of residual chlorine in the spring season*

3.5. Electrical Conductivity

Electrical conductivity (EC) is a measure of the ability of water to conduct an electrical current. It is highly dependent on the amount of dissolved solids in the water. EC is an important water-quality measurement because it gives a good idea of the amount of dissolved material in the water. EC readings can help locate potential pollution sources because polluted water usually has higher values than unpolluted waters. The EC in spring season showed very narrow changes in sample points K1 – K5, but higher values in May (Fig. 4). The EC values varied between 281.00 and 325.00 μS/cm. The maximum value was recorded in K3 (May) and the minimum in K4 (March), while average values for three months were 285.00, 294.60 and 321.60 μS/cm respectively. The seasonal average with standard deviation was 300.40 ± 16.53 μS/cm and was under state recommended value.

3.6. Total Residue After Evaporation

Total residue after evaporation (TRAE) represents the sum of both dissolved and suspended material in water. The determination is not exact, because of the compromise that must be made in selecting the temperature at which the evaporated residue is to be dried. At temperatures sufficient to release water of hydration of the hydrated salts that form on evaporation, there is risk of volatilization of the more volatile dissolved or suspended materials in the sample. Because of these factors, the determination must be considered as providing only an approximation of the sum of dissolved and suspended matter. The TRAE values were found to be in range 165.00 – 202.00 mg/L within the permissible limits (Fig. 4). The lower value was measured in K4 (March) and highest in K3 (May), while average values in months were 170.40, 185.00 and 194.20 mg/L respectively. The seasonal average with standard deviation was 183.20 ± 11.40 mg/L.

3.7. Total Dissolved Solids

Total dissolved solids (TDS) is the term applied to the residue remaining in a weighed dish after the sample has been passed through a standard fiber glass filter and dried to constant mass at 103-105 °C or 179-181 °C. Dissolved minerals, gases and organic constituents may produce aesthetically displeasing color, taste and odor. Water with higher solids content often has a laxative and sometimes the reverse effect upon people whose bodies are not adjusted to them. TDS consists mainly of bicarbonate, carbonate, sulphate, chloride, nitrates and other substances. The values of TDS were in range 184.00 – 246 mg/L (Fig. 4). The lower value was measured in K1 (March) and highest in K3 (May), while average values in months were 188.80, 196.20 and 233.00 mg/L respectively. The seasonal average with standard deviation was 206.00 ± 20.74 mg/L and was under state recommended value.

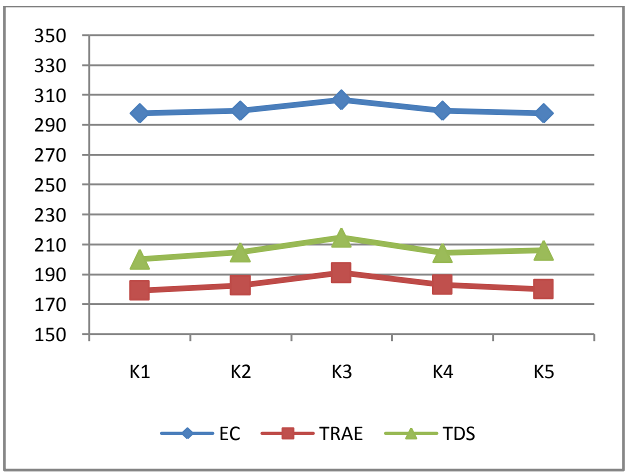

Fig 4: *Seasonal variation of average values of EC, TRAE and TDS*

3.8. The Chemical Oxygen Demand

The chemical oxygen demand (COD) is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water or wastewater, making COD a useful measure of water quality. COD is the amount of oxygen required to carry out oxidation of organic waste by using strong oxidizing agent. All water samples found to have COD values ranging from 4.20 – 5.80 mg/L (Fig. 5). The lower value was measured in K2 (March) and highest in K5 (May), while average values in months were 4.48, 4.70 and 5.52 mg/L respectively. The seasonal average with standarddeviationwas4.93 ±0.50 mg/L and was under state recommended value.

3.9. Nitrites

The content of nitrites as nitrogen in sampling points and different months was in a range of 0017 – 0031 mg/L (Fig. 6). So the lowest value was measured in March in K2, while the highest value was found at K3 in May. Average values during the months of March, April and May were 0.0192, 0.0232 and 0.0274 mg/L respectively. Sample site with the lowest average 0.0213 mg/L was K1, while with the highest average 0.0263 mg/L was K3. Seasonal average value with the standard deviation was 0.023 ± 0.004 mg/L, which was within the allowed values of state regulation.

3.10. Nitrates

Nitrates generally occur in trace quantities in surface waters but may attain high levels in some ground waters. The main sources of nitrate in water are human and animal waste, industrial effluent, use of fertilizers and chemicals, silage through drainage system [16]. In excessive limits of nitrates (above 40 mg/L), it contributes to the illness known as methenoglobinemiaor "blue baby" in infants. The nitrate values of the samples were found to be in range 17.30 – 27.80 mg/L within the permissible limits (Fig. 5). The lower value was measured in K4 (March) and highest in K3 (May), while average values in months were 17.64, 18.60 and 25.58 mg/L respectively. The seasonal average with standard deviation was 20.61 ± 3.80 mg/L and was under state recommended value.

3.11. Ammonia

The content of ammonia as nitrogen was in a range of 0050-0180 mg/L (Fig. 6). The lowest value was measured in March at K5, while the highest value was measured in May at K3. Average values during the months of March, April and May were 0.064, 0.088 and 0.150 mg/L respectively. Sample site with the lowest average 0,087 mg/L was K1, while the highest average 0.123 mg/L was K3. Seasonal average values with the standard deviation was 0.101 ± 0.041 mg/L, which is within the allowed values of state regulation and was under state recommended values.

3.12. Chlorides

Chloride ions are found naturally in some surface waters and ground waters. Higher-than-normal chloride concentrations in freshwater is detrimental to water quality. Chloride ions are not degraded in the environment and tend to remain in solution, once dissolved. Chloride ions that enter ground water can ultimately be expected to reach surface water and, therefore, influence aquatic environments and humans. High chloride content in water sample may be due to the pollution from chloride rich effluent of sewage and municipal waste. The chloride content of the samples was well within the desirable limits and varying from 12.00 – 36.00 mg/L (Fig. 5). The lower value was measured in K1 (March) and highest at K3 (May), while average values in months were 15.00, 19.00 and 31.20 mg/L respectively. The seasonal average with standard deviation was21.73 ±7.68 mg/L.

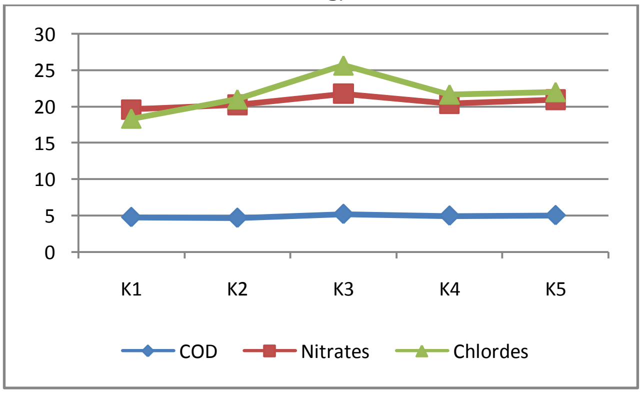

Fig 5: Seasonal variation of average values of COD, nitrates and chlorides

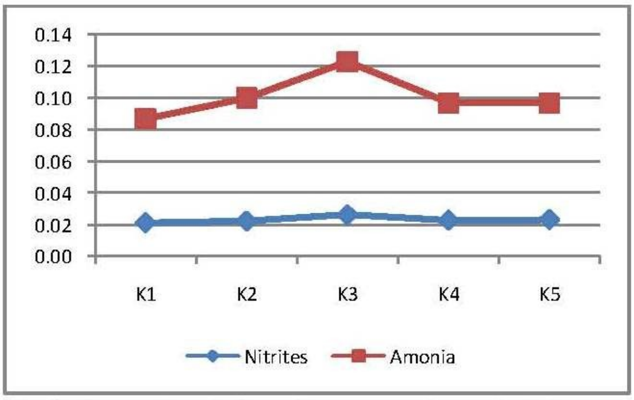

Fig 6: Seasonal variation of average values of nitrites and ammonia

3.13. Evaluation of Drinking Water with DWQI

The results of drinking water quality assessment of Kumanova by DWQI are shown in Fig. 7. It is found that drinking water in the spring season in all sample points has been of *Excellent* category with average value of DWQ I95.21. Lower index value was in K1 (DWQI = 94.93), while higher inK2, K3 and K4 (DWQI =95.29). In K1 from 12 parameters 1 have resulted failed, while from 36 tests 1 test failed. Compared with our previous results [17], [18], they shows that the DWQI values of Kumanova city have had a slight improvement in the quality of drinking water compared with drinking water of Tetova city for the same period.

4. CONCLUSIONS

From the results we can conclude that:

a) temperature, pH, turbidity, EC, TDS, TRAE, COD, TOC, DOC, nitrites, nitrates, ammonia and chlorides were found to be within Macedonian, WHO and EU permissible limits for drinking water;

b) RC (<0.2 mg/L) was in one case below the recommended values. Therefore we recommend the relevant municipal authorities to make regular and proper checks of the drinking water disinfection process as there are no compromise in regards to this issue;

c) a few failed parameter were RC, and its valuehave caused lower valuesof DWQI in sample points K1;

d) DWQIi savery powerful and adequate tool for assessing the quality of drinking water.

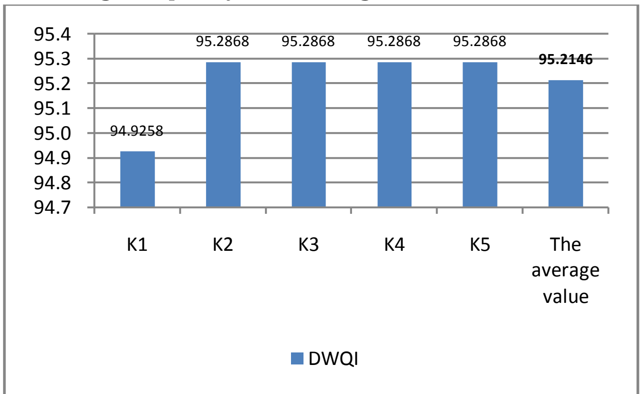

Fig 7: *DWQI values in the city of Kumanova*

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