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Evaluation of Physico-Chemical Quality of Drinking Water using Water Quality Index in Tetova City, North 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. The quality of drinking water is a crucial factor for human health. For this purpose, we assess the quality of drinking water in the city of Tetova with fifteen 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 EC, TRAE, TDS, COD, TOC, SUVA, nitrates, chlorides and THMs were found to be within the permissible limits, while WT, TU, RC, pH, DOC and UV254 in some cases were found to be below ore above the recommended limit. Finally, the Water Quality Index (WQI) for fifteen sample stations is calculated. It has been found that drinking water in the measurement period was of a Marginal category (average value of WQI = 59.47) and not very suitable for drinking because water quality is frequently impaired; conditions often depart from desirable levels. 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, WQI, physico-chemical parameters, drinking water quality.*

1. Introduction

Drinking water is one of the daily needs of mankind for drinking, preparation and production of food, hygiene, etc. It is supplied by surface and groundwater sources all over the world. Surface and groundwater always contain dissolved and suspended substances of organic and mineral origin [1]. Drinking water is not always safe, hygienic and of good quality. According to the WHO, over one billion people in the world do not have access to safe water and over three billion lack access to adequate hygiene [2], thus a very high level of care is needed for drinking water [3].

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, inadequate management of water systems can cause serious problems in the water availability and quality of water [4]. Hence it is necessary to evaluate the quality of the drinking water. 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) [5]. 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 [6].

The assessment of water quality is done in various ways. A very powerful tool for this purpose is the Water Quality Index (WQI). The objective of an index is to turn multifaceted water quality data into simple information that is comprehensible and useable by the public [7]. The WQI represents a simple number from 0 – 100 where a highest value indicates the best water quality and vice versa [8], [9], [10]. The aim of the article is to assess the physical-chemical quality of the drinking water in Tetova during the December 2019 – November 2020, 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 values of the measured parameters with drinking water guidelines of Macedonia, the WHO and the EU. Categorization of drinking water is done with WQI. The purpose of this paper was to assess the water quality of the city of Tetova by measuring the physico-chemical parameters and making the assessment with WQI.

2. MATERIALS AND METHODS

2.1. Study Area

The city of Tetova is situated in the north-west part of Macedonia and has about 70 000 inhabitants. The drinking water is supplied from surface sources of Sharr Mountain. Even though it has sufficient water resources and permanent water flows, the lack of water is being felt in this city. Statistics show that the average amount of water per inhabitant is about 350-400 litres per day. The drinking water in Tetova is disinfected with gaseous chlorine without any kind of special treatment, whereas the South East European University (SEEU) utilizes the underground drinking water that is extracted from three individual wells and is disinfected only by a UV radiation used as primary disinfectant (sample point T14 and T15).

The city of Tetova, although it has sufficient resources and permanent water supply, still lacks it. The lowest inflows are during the winter. The city of Tetova has enough water for supply, but the problem is the large water losses in the network, spills and low pressure in the pipes. The main criteria is the inflow, which in the flow pipes of the reservoir is 30800 m^3/day. Statistics show that June is the month with the highest water inflow. In this part of the year the inflow exceeds the demands of the residents and the excess water flows out of the network in the hydropower plant number 4.

2.2. Sampling Stations and Sampling

We have collected the drinking water samples in an appropriate way. We have assigned 15 sampling stations (T1 - T15) in the city of Tetova and from them every month we have taken samples of drinking water in a period of one year December 2019 - November 2020 to determine the quality of drinking water.

Sampling was done after a study of sampling stations and according to the recommendations of the State Regulation on Drinking Water of the Republic of Macedonia, which is harmonized with the recommendations of the WHO and the EU [11]. Serious account has been taken of the distance between the sampling sites in order to cover most of the city and enable logical conclusions to be drawn.

Drinking water samples were taken in 1.5 L polyethylene and glass bottles. Before sampling, 1.5 mL of sodium thiosulfate solution (10%) was added to the glass bottles to eliminate any amount of residual chlorine and to stop the additional formation of THMs. We filled the bottles up to the lid without leaving space and air bubbles through the sample.

2.3. Measured Parameters

In this paper we have performed the one-year monitoring of additional parameters as follows: water temperature (WT), turbidity (TU), residual chlorine (RC), pH, electrical conductivity (EC), total residue after evaporation (TRAE), total dissolved solids (TDS), chemical oxygen demand (COD), total organic carbon (TOC), dissolved organic carbon (DOC), ultraviolet absorption at 254 nm (UV254), specific ultraviolet absorption (SUVA), nitrates, chlorides and trihalomethanes (THMs).

2.4. Determination Methods and Chemicals

The experimental part of this research was conducted in the laboratories of the University of Tetova. For the realization of the research of this research we have planned standard methodologies and techniques in accordance with the Standard Methods for Examination of Drinking Water [12]. For quantitative determination of parameters we have used modern methods of determination: UV/Vis spectrophotometry, gas chromatography, electrochemical methods and classical standard methods of analysis.

During research and numerous analyzes we used various chemicals that were needed to determine the parameters. Some chemicals were of chemical purity "pro analysis", some of HPLC purity, while some suprapur. For rational spatial reasons we will not mention them.

2.5. Instruments

To determine the parameters of drinking water in the Tetova water supply network, we used the following apparatus and instruments: for measuring the electrical conductivity and total dissolved solids, the portable conductor Conductivity Meter, WTW LF 320 was used; pH measurement was done with 330i portable pH meter, WTW; turbidity measurement is done with turbidimeter; spectrophotometric measurements were made with the UV/Vis Ultrospec spectrophotometer equipped with appropriate software and the UV/Vis HACH spectrophotometer; Chromatographic measurements were made with the gas chromatograph: Hewlett-Packard HP 5890 Series II ECD/FID, while TOC and DOC measurements were made with the Shimadzu TOC-V CPH/CPN TOC analyzer.

2.6. Canadian Water Quality Index

In order to assess the drinking water quality, we have widely used the Water Quality Index (WQI) developed by the Canadian Council of Ministers of the Environment [13]. WQI consists of three measures of variance from selected drinking water quality objectives. Those are: scope (F1), frequency (F2), and amplitude (F3).

3. Results And Discussion

Water temperature (WT). Temperature plays a crucial role in the physico-chemical and biological behavior of the water system [14]. WT is a critical parameter for aquatic life and has an impact on other water quality parameters such as dissolved oxygen concentration and bacterial activity in water. Chemical reactions depend on the temperature of the water and it controls metabolic processes.

The recommended value according to the Macedonian State Regulation for WT is 10 - 12 ºC. WT has changed in sampling sites during the year, but this change is not so pronounced (Fig. 1). Slightly lower values than the state regulation were recorded in January, March and November as a result of the climatic conditions that have prevailed in these months. However, the deviations have been small and this does not pose any impact on the quality of drinking water. Slightly higher values in the samples farthest from the chlorination reservoir are due to the absorption of heat from the urban environment. The annual average with standard deviation was 10.48 ± 0.134 ºC which meets the drinking water criteria.

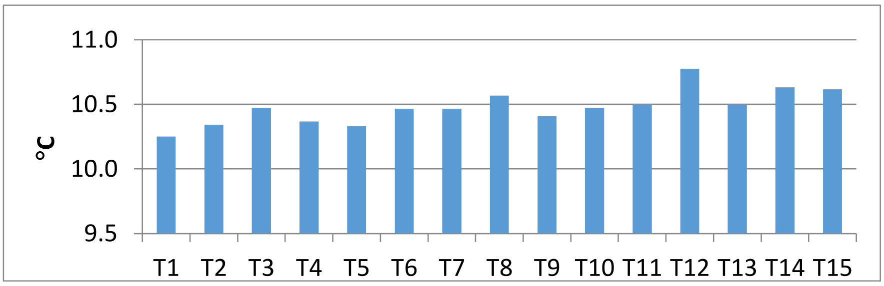

Fig1. *Spatial variation of average WT values.*

Turbidity (TU). TU is a measurement of the amount of material suspended in water. This material, which consists of particles such as clay, sludge, algae, suspended sediments and rotting plant materials, causes light to be scattered and absorbed, rather than being transmitted directly through water. High TU raises the water temperature because the suspended particles absorb more heat. This, in turn, lowers the concentration of dissolved oxygen (DO), because warm water contains less DO than cold water. High TU also reduces the amount of light that can penetrate water, which reduces photosynthesis and DO production. Pure water generally has low turbidity. Precipitation increases turbidity in surface waters by leaching sediments, organic matter and other materials into the water. Human activities such as vegetation and soil removal can lead to dramatic increases in turbidity levels. Consumption of highly turbid water can pose a health risk as excessive turbidity can protect pathogenic microorganisms from the effects of disinfectants, and stimulate the growth of bacteria during storage [15]. Measured TU in all samples was less than 1.5 nephelometric units of turbidity (NTU). According to the Macedonian Drinking Water Regulation, the maximum permissible level for turbidity in drinking water is 1.5 NTU units, while according to the WHO [16] the best drinking water for consumption and health purposes is the one with less turbidity than 1 NTU unit.

Most of the samples examined showed few changes in TU (Fig. 2), except for 7 cases: two with 1.6 NTU in T1 (December and May), three with 1.6 NTU in T11 (April, July and August), one with 1.8 NTU in T12 (April) and one with 1.9 NTU in T13 (April), when state regulation was exceeded. The range of turbidity was 0.20 - 1.90 NTU units. The lowest value was 0.20 NTU in more sampling sites and in more months, while the highest was 1.90 NTU in the T13 in April. The annual average with standard deviation was 0.82 ± 0.36 NTU units. One year results have shown that drinking water according to TU is suitable for drinking. The highest values of TU in T9 - T15 are a consequence of the outdated network and the possibility of turbulent water after rainfall, while that in T1 is a consequence of the mixture of city water and the settlement Reçicë e Vogël, which is not treated and is often disturbed by solid particles. Samples at T14 and T15 (groundwater) are presented with an average turbidity of 0.98 NTU units, which are slightly higher values for groundwater. We think this refers to the infiltration of turbulent surface waters after precipitation into groundwater. The months with the lowest turbidity were January and February when there was no rain, while April was the month with the highest turbidity.

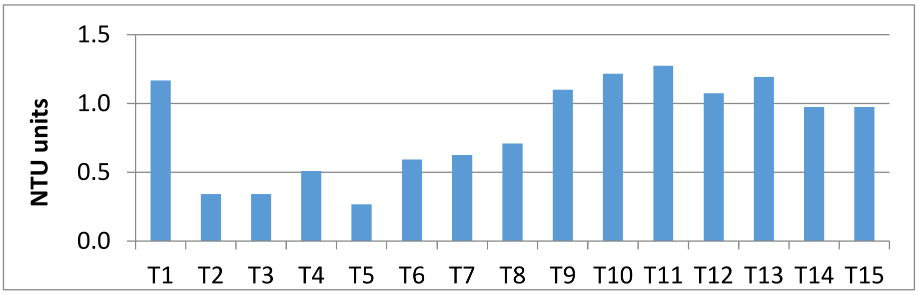

Fig2. *Spatial variation of average TU values.*

Residual chlorine (RC). RC is of great importance to ascertain the presence or absence of microorganisms in drinking water. The presence of RC in drinking water indicates that a sufficient amount of chlorine was initially added to the water to inactivate bacteria and some viruses that cause diseases such as diarrhea and also 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 water drinkability.

The annual results for RC are presented in Figure 3. The recommended value for this parameter is 0.2 - 0.3 mg/L. RC during the year was measured with a range of 0.00 - 0.36 mg/L. The maximum value was observed in T9 (April). The annual average with the standard deviation was 0.196 ± 0.09 mg/L. RC was not detected in T14 and T15 because SEEU uses groundwater that is extracted from three own wells and disinfected only with UV radiation used as the primary disinfectant. Out of a total of 180 RC tests below the recommended value, 87 tests resulted (48.33%), while 13 tests (7.22%) were above the recommended value. So 100 tests or 55.56% of them have failed and this is a concern that reduces the physico-chemical quality of drinking water for the monitored period. This shortcoming must be urgently eliminated by the competent authorities because no compromise can be made with disinfection and consumer health. Samples with annual average below the recommended value were T1, T14 and T15, while other samples had average values according to state regulation (Fig. 3). T1 uses mixed water from the town and settlement of Reçicë e Vogël and during the year most of it is unchlorinated water.

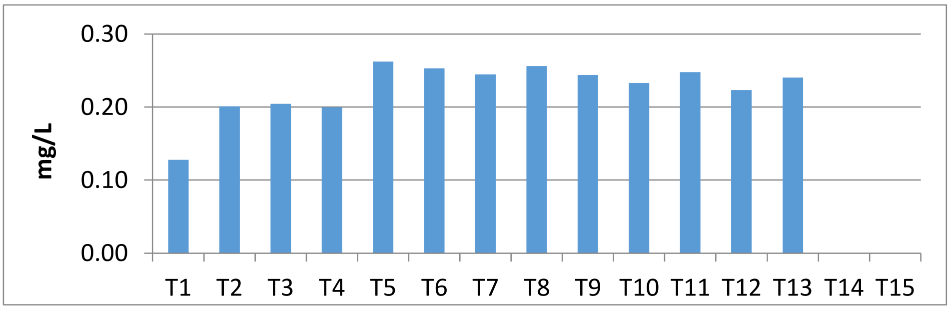

Fig3. *Spatial variation of average RC values.*

pH. The pH value is a measure of the activity of a hydrogen ion in water, or in other words, the acidity of water. The pH value is measured on a logarithmic scale from 0 - 14 and the value 7 indicates the neutral environment. A high pH indicates alkaline (or basic) conditions and a low pH indicates acidic conditions. The pH value is influenced by the geology and type of soil, organic acids (decay of leaves and other substances) as well as acid rain (which usually has a pH of 3.5 –5.5).

The pH value is classified as a secondary contaminant of drinking water, the impact of which is considered aesthetic. However, stricter regulations recommend that public water systems should maintain pH levels between 6.5 and 8.5. Low pH water can be acidic, naturally soft and corrosive. Acid water can dissolve metals (Cu, Pb and Zn) from pipes and joints. It can also damage metal pipes and cause aesthetic problems, such as metallic taste or dry taste, corresponding staining or dark blue-green stains on sanitary joints and sewers. Drinking water with a pH level above 8.5 indicates that high levels of alkaline minerals are present in it.

The state recommended pH value is 6.5 - 9.5. The pH values of drinking water were variable in the sampling sites and in the season (Fig. 4) and they varied between 6.08 in T8 (December and May) and 8.82 in T11 (July), while the annual average with standard deviation was 7.53 ± 0.28. The results of pH measurements show that no disturbing values were recorded, except for 4 cases: two in T8 (December and May) and two cases in T9 (December and May) where pH values below 6.5 were measured. We think that this deviation of the pH in these two sampling sites is a consequence of the damages in their vicinity, in which case substances with acidic properties have entered the water supply network. Slightly lower values in T14 and T15 may be due to groundwater quality. The highest pH values of 7.80 - 8.05 were measured in the T10 - T13 sampling sites.

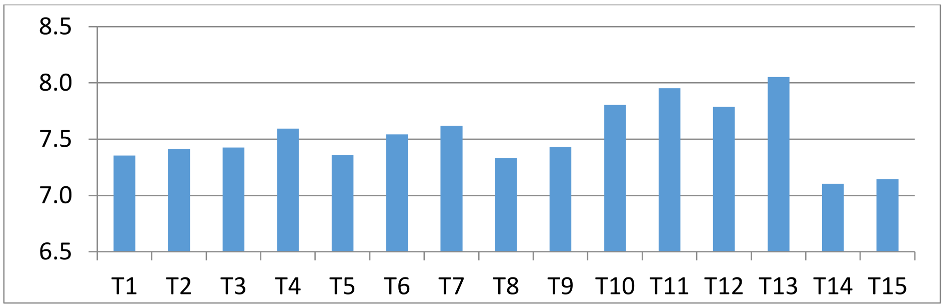

Fig4. *Spatial variation of average pH values.*

Electrical conductivity (EC). EC is a measure of the ability of water to conduct electricity. It depends a lot on the amount of salts dissolved in the water. EC is an important measurement of water quality because it gives a good idea of the amount of material dissolved in water. EC values can help to find potential sources of pollution because polluted water usually has a higher value than untreated water. EC values often indicate pollution from road salt, septic systems, sewage treatment plants, or urban/agricultural drainage.

The recommended value of PE is 1000 μS/cm. EC values in the samples surveyed during the year showed very narrow changes in the T1 - T13 sampling sites, but higher values in T14 and T15 (Fig. 5). EC values had a range of 175.00 - 693.00 μS/cm. The maximum value was measured at T15 (August) and the minimum at T7 (January), while the annual average with standard deviation was 291.55 ± 155.00 μS/cm.

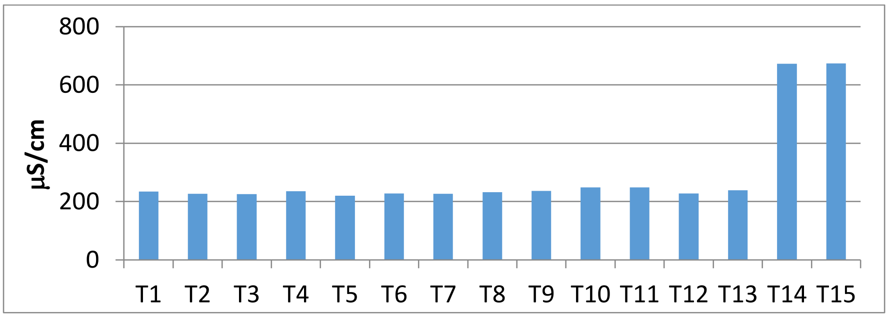

Fig5. *Spatial variation of average EC values.*

Total residue after evaporation (TRAE). TRAE represents the amount of dissolved and suspended material (including colloidal solutions) in a sample. The determination is not very accurate, due to the compromise to be made in selecting the temperature at which the evaporated residue should dry. At sufficient temperatures to release the hydration water of evaporating hydrated salts, there is a risk of evaporation of the most volatile soluble or suspended soluble materials in the sample. On the other hand, drying at a temperature low enough to preserve volatile compounds manages to remove the amount of bound water and ordinary hydration water. Due to these factors, the determination should only be considered as an approximation of the sum of dissolved and suspended matter.

The recommended value for MPPA is 1000 mg/L. TRAE values of the samples were in the range 84.00 - 386.00 mg/L and within the allowed limits. The lowest value was measured in T5 (November) and the highest in T15 (August), while the annual average with standard deviation was 168.04 ± 83 mg/L. The values in T14 and T15 were higher than the larger amount of salts dissolved in groundwater with the same justifications as for EC. The spatial variation of TRAE values has had a tendency of slight increase in the T9 - T13 sampling sites (Fig. 6).

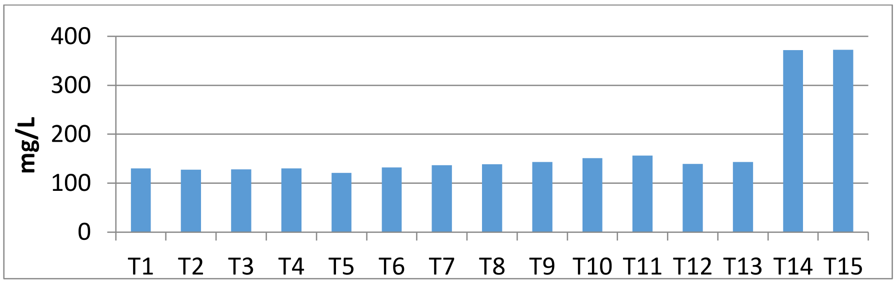

Fig6. *Spatial variation of average TRAE values.*

Total dissolved solids (TDS). TDS is the term applied to residual residue in a mass measuring container after the sample has passed through a standard fiberglass filter and dried at a constant mass at 103 - 105 °C ore 179 - 181 °C. Many substances dissolved in water are undesirable. Dissolved minerals, gases and organic compounds can produce aesthetically undesirable color, taste and smell. Water with high TDS content often has a laxative effect and sometimes the opposite effect on individuals whose bodies do not adapt to them. TDS consists mainly of Ca^{2+}, Mg^{2+} ions, bicarbonates, carbonates, sulfates, chlorides, nitrates and other substances. High concentrations of TDS around 3000 mg/L can also produce concern in animals.

The recommended value of this parameter is 1000 mg/L. TDS values had a range of 108.00 - 526.00 mg/L (Fig. 7). The lowest value was measured in T1 (March) and the highest in T15 (August), while the annual average with the standard deviation was 209.31 ± 99.82 mg / L. Values in T1 – T13 are common for drinking water. T14 and T15 had much higher values due to the higher amount of dissolved salts. The spatial variation of TDS during the year was almost uniform except for the values in T10 and T11 (slightly higher values), while T14 and T15 had significantly higher values than other but common groundwater sampling sites. All measured values of TDS have been below the recommended limits and it turns out that the water is suitable for drinking.

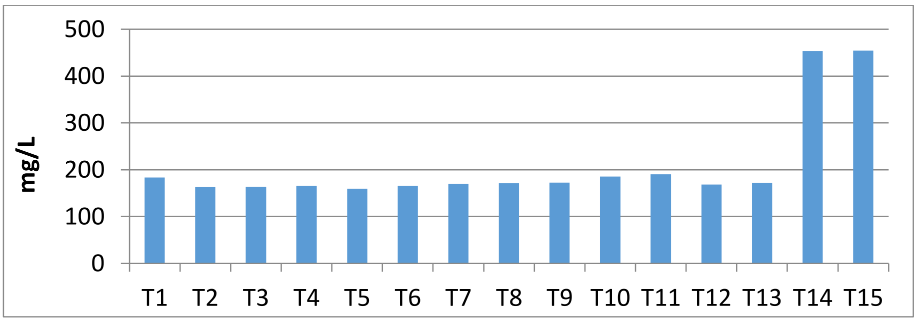

Fig7. *Spatial variation of average TDS values.*

Chemical oxygen demand (COD). COD is commonly used for indirect measurement of the amount of organic compounds in water. The main application of COD is to determine the amount of organic pollutants found in surface water or wastewater, making COD a useful measurement of water quality. COD is the amount of oxygen needed to carry out the oxidation of organic pollution using a strong oxidizing agent. Research conducted on organic pollution of drinking water and liver cancer shows that mortality due to liver cancer is in positive correlation with COD of drinking water.

The recommended value of COD is 8.00 mg/L. Drinking water samples had COD values ranging from 1.92 - 4.67 mg/L (Fig. 8). The lowest value was measured in T14 (October) and the highest in T11 (July), while the annual average with the standard deviation was 2.86 ± 0.31 mg/L. The relatively low values of COD are a consequence of the small amount of organic matter as the city's drinking water is provided by clean springs located in high mountainous areas. The lowest values were recorded in the winter and spring months, while in the summer and autumn they were slightly higher due to photosynthesis. Spatial variation has shown that the lowest values were in T2 - T7, while other sampling sites had approximate values. COD results show that the water is suitable for drinking.

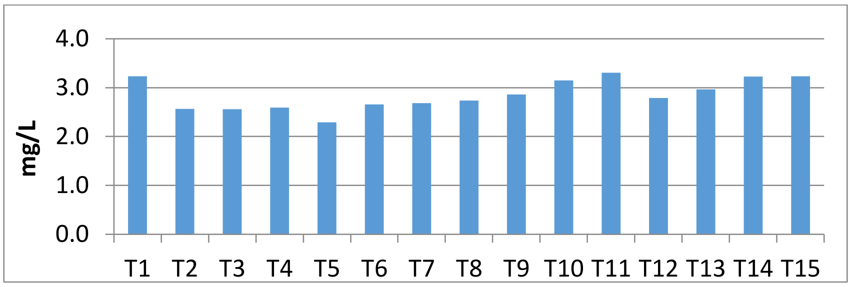

Fig8. *Spatial variation of average COD values.*

Total organic carbon (TOC). TOC is the measurement of the sum of the concentrations of all organic carbon atoms bound by covalent bonds to the organic molecules of a given water sample. As a summary measurement, TOC does not identify specific organic pollutants. It can, however, detect the presence of all carbon-containing molecules by identifying the presence of any organic contaminants, regardless of molecular masking.

There is no recommended value for this parameter in the State Regulation of drinking water of Macedonia. TOC values were in the range of 1.76 - 4.54 mg/L (Fig. 9). The lowest value was measured at T15 (October) and the highest at T11 (July), while the annual average with the standard deviation was 2.74 ± 0.30 mg/L. Spatial variation has shown that the values in T2 - T7 have been lower, while in other samples that are farther from the chlorination tank have had slightly higher values. We think that this may be due to additional pollution from the outdated water supply network itself or the introduction of organic matter into the water network.

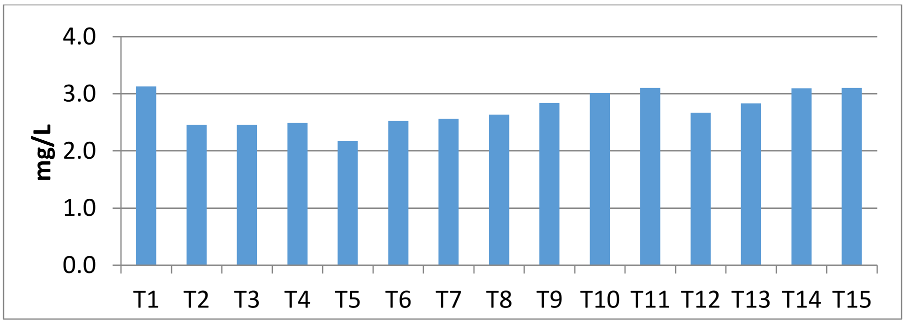

Fig9. *Spatial variation of average TOC values.*

Dissolved organic carbon (DOC). DOC can inhibit the effectiveness of disinfection processes such as, ultraviolet chlorination and ozone sterilization and it can promote the growth of microorganisms, providing for them a food source.

There is no recommended value for this parameter in the State Regulation of drinking water of Macedonia. DOC values were recorded in the range of 1.58 - 4.41 mg/L (Fig. 10). The lowest value was measured in T14 (October) and the highest in T11 (July), while the annual average with the standard deviation was 2.63 ± 0.30 mg/L. Spatial variation has shown that the values in T2 – T8 have been lower, while in other samples that are farther from the chlorination tank have had slightly higher values. We think this may be due to additional pollution from the outdated water supply network and organic pollution that may enter it.

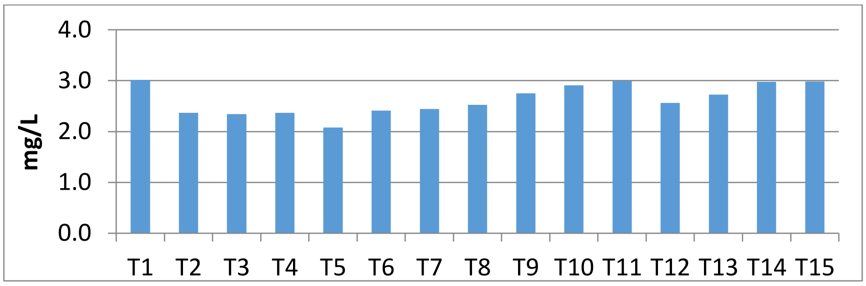

Fig10. *Spatial variation of average DOC values.*

Ultraviolet absorption (UV_{254}). UV_{254} at 254 nm is used as the surrogate parameter of chromophores in natural organic matter and indicates that many types of chromophores are precursors of THMs. Of the functional groups, aromatic carbon is considered one of the most important reactive molecular structures in relation to the formation of THMs during water chlorination. UV254 is proportional to the aromatic carbon content and has been used as a substitute for DOC concentrations in natural waters for over 35 years. UV254 is considered a good indicator of the value of THM precursors in water.

For this parameter there is no recommended value in the State Regulation of drinking water of Macedonia. UV_{254} values were recorded in the range of 0.0170 - 0.1490 cm^{-1} (Fig. 11). The lowest value was measured in T8 (January) and the highest in T11 (July), while the annual average with the standard deviation was 0.0791 ± 0.014 cm^{-1}. Higher values in the sampling sites indicate that the organic matter in the water contains more active and aromatic groups that absorb UV radiation. If we look at the spatial variation of the average values, it turns out that the lowest values of UV_{254} were in T2 – T7, while in T8 - T15 we have a slight increase.

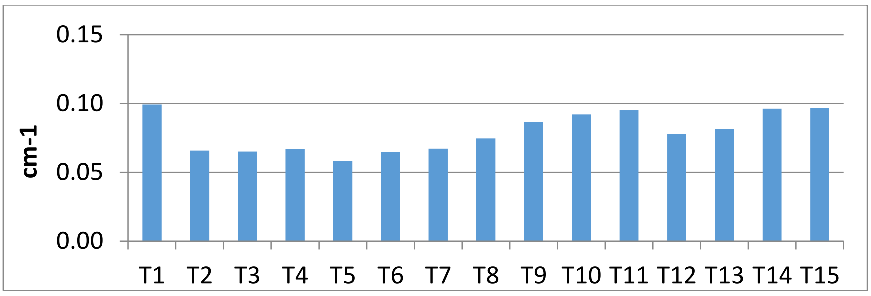

Fig11. *Spatial variation of average UV_{254} values.*

Specific ultraviolet absorption (SUVA). This parameter has not been measured experimentally but has been adequately calculated. The mean values of SUA are shown in fig. 12. Recommended value for SUVA does not exist. The SUVA values of the samples were in the range 0.00970 - 0.03844 $Lmg^{-1}cm^{-1}$. The lowest value was measured in T8 (January) and the highest in T15 (December), while the annual average with standard deviation was 0.0292 ± 0.002 $Lmg^{-1}cm^{-1}$. Low values indicate that low natural organic matter has low absorption reactivity.

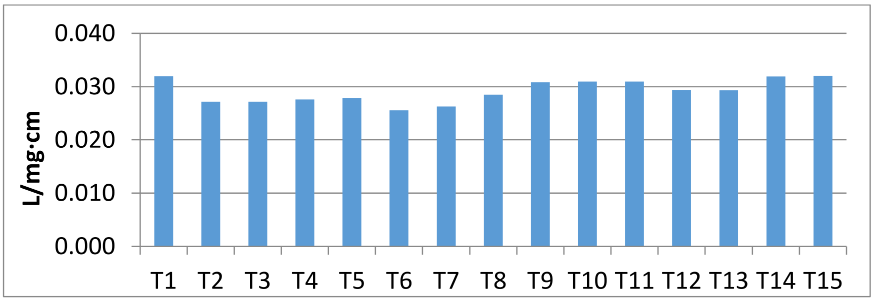

Fig12. *Spatial variation of average SUA values.*

Nitrates. Nitrates are generally found in trace amounts in surface waters, but can reach high levels in some groundwater. The main sources of nitrates in water are human and animal waste, industrial effluents, use of fertilizers and chemicals, silage through drainage system. Nitrites in water occur either due to oxidation of ammonium compounds or due to reduction of nitrates. In excessive amounts of nitrates (above 40 mg/L), they contribute to a condition known as methenoglo-binemia or "blue baby" in infants.

The recommended value of nitrates is 50.00 mg/L. Water samples had nitrate values ranging from 0.20 - 28.50 mg/L that are within the allowable limits (Fig. 13). The lowest value was measured in T5 (December and May) and the highest in T15 (August), while the annual average with the standard deviation was 3.29 ± 5.35 mg/L. The results show that Tetova drinking water has a low content of nitrates with the exception of samples T14 and T15 which had much higher values. The highest level of nitrates in groundwater of T14 and T15 is a consequence of leaching of agricultural land and their higher content in groundwater. Spatial variation has shown that samples T7 - T13 had slightly higher levels of nitrates as a result of possible pollution from the water supply network itself and to end up in samples T14 and T15 with much higher values.

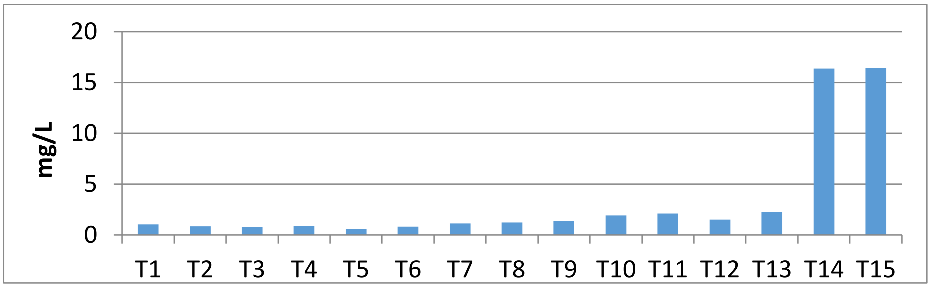

Fig13. *Spatial variation of average nitrate values.*

Chlorides. Chloride ions are found naturally in surface and groundwater. Concentrations of chlorides higher than normal in freshwater are detrimental to water quality. The use of road salt to prevent winter accidents is a major source of chlorides for the environment. Unfortunately, the chloride content has increased over time due to road widening and increased vehicle traffic. Road salt is easily digested and enters aqueous media in ionic form. The high content of chlorides in the water sample may be due to contamination by wastewater and municipal waste. However, excessive amounts of chlorides give the water a salty taste and cause a laxative effect in humans.

The recommended value of chlorides is 250 mg/L. The chloride content in the samples was in the recommended range and varied from 0.40 - 32.60 mg/L (Fig. 14). The lowest value was measured in T6 (December and May) and the highest in T15 (August), while the annual average with standard deviation was 5.77 ± 7.36 mg/L. The spatial variation of the mean values shows that the chloride content levels were higher in the T7 - T13 sampling sites as a result of the pollution of the water supply network and much higher in T14 and T15 as a result of the pollution from the road salt (Fig. 14). Low values in T1 - T6 indicate that chlorides do not come from household and urban waters but from natural salts.

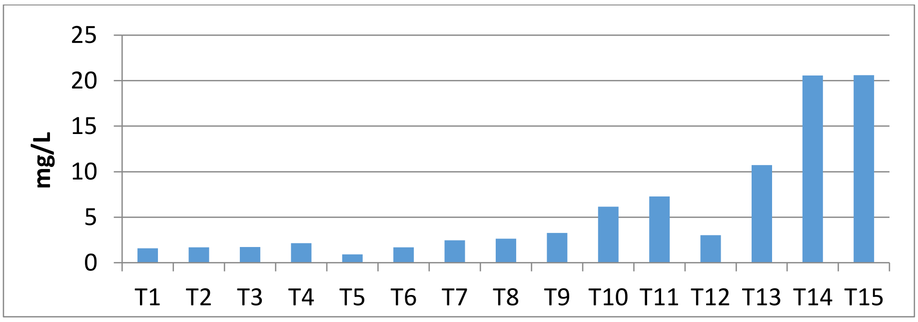

Fig14. *Spatial variation of average chloride values.*

Trihalomethanes (THMs). Cancerous Trihalomethanes (THMs) are created when the organic potable water matter reacts with chlorine during the process of disinfection. This has disturbed quite a lot the public and the scientific community [13].

The results of the experimental measurements of THM are presented in Fig. 15. The state recommended value for THMs is 100 μg/L. The variation of THM concentrations was in the range 0.00 - 45.50 μg/L.

The lowest value was measured at sample T14 and T15 in all months, while the highest at sample T10 in September. The average annual value with standard deviation was 21.11 ± 10.30 μg/L. If we neglect the sampling sites T14 and T15 (with values 0.00 μg/L), then the annual average with standard deviation was 24.36 ± 7.80 μg/L, which is very little different from the previous average. The spatial variation for the one-year period has shown that THM concentrations across the sampling sites have changed (Fig. 15). Thus lower levels were measured at samples T5, T1 and T6 with an average of THMs lower than 20.00 μg/L. Average concentrations of THMs up to 30.00 μg/L were recorded in samples T2, T8, T3, T7 and T4, while samples T9 - T13 had higher average concentrations of THMs (30.00 - 34.18 μg L). The lower and higher results are influenced by the respective values of the parameters that directly affect the formation of THMs such as: COD, TOC, RC, contact time, pH, WT and chlorides.

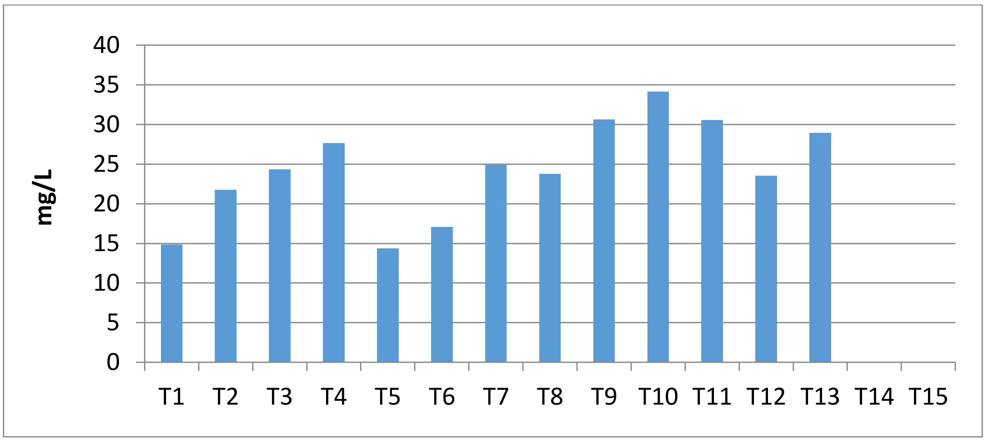

Fig15. *Spatial variation of average THM values.*

Water quality evaluation of Tetova using WQI

The calculation of Water Quality Index was done using the Water Quality Index Desktop software developed by [17].

In T1 failed were 5 parameters (WT, TU, RC, DOC and UV254) and 27 tests (3 test of WT, 1 test of TU, 12 test of RC, 5 test of DOC and 6 test of UV254). In T2 failed were 2 parameters (WT and RC) and 11 tests (3 test of WT and 8 test of RC). In T3 failed were 2 parameters (WT and RC) and 7 tests (3 test of WT and 4 test of RC). In T4 failed were 2 parameters (WT and RC) and 8 tests (3 test of WT and 5 test of RC). In T5 failed were 2 parameters (WT and RC) and 6 tests (3 test of WT and 6 test of RC). In T6 failed were 4 parameters (WT, RC, DOC and UV254) and 6 tests (3 test of WT, 1 test of RC, 1 test of DOC and 1 test of UV254). In T7 failed were 4 parameters (WT, RC, DOC and UV254) and 9 tests (3 test of WT, 2 test of RC, 2 test of DOC and 2 test of UV254). In T8 failed were 5 parameters (WT, RC, pH, DOC and UV254) and 13 tests (3 test of WT, 2 test of RC, 2 test of pH, 3 test of DOC and 3 test of UV254). In T9 failed were 5 parameters (WT, RC, pH, DOC and UV254) and 18 tests (3 test of WT, 6 test of RC, 2 test of pH, 3 test of DOC and 4 test of UV254). In T10 failed were 5 parameters (WT, TU, RC, DOC and UV254) and 21 tests (3 test of WT, 2 test of TU, 6 test of RC, 5 test of DOC and 5 test of UV254). In T11 failed were 5 parameters (WT, TU, RC, DOC and UV254) and 22 tests (4 test of WT, 4 test of TU, 2 test of RC, 6 test of DOC and 6 test of UV254). In T12 failed were 4 parameters (WT, RC, DOC and UV254) and 10 tests (3 test of WT, 4 test of RC, 1 test of DOC and 2 test of UV254). In T13 failed were 5 parameters (WT, TU, RC, DOC and UV254) and 15 tests (3 test of WT, 3 test of TU, 2 test of RC, 4 test of DOC and 3 test of UV254). In T14 failed were 4 parameters (WT, RC, DOC and UV254) and 30 tests (3 test of WT,12 test of RC, 8 test of DOC and 7 test of UV254). In T15 failed were 4 parameters (WT, RC, DOC and UV254) and 30 tests (3 test of WT,12 test of RC, 8 test of DOC and 7 test of UV254).

The WQI values results for the fifteen stations are graphically presented in Figure 16. Lower index value was in T1 (WQI = 55), while higher in T14 and T15 (WQI = 63). It is found that drinking water in this period in all sample points has been of ***Marginal*** category with average value of **WQI = 59.47**. According to this average value water quality is frequently impaired; conditions often depart from desirable levels. Compared with our previous results [8], [18], [19], [20] and [21], this results shows that the WQI values have had a worsening in the quality of drinking water in Tetova city.

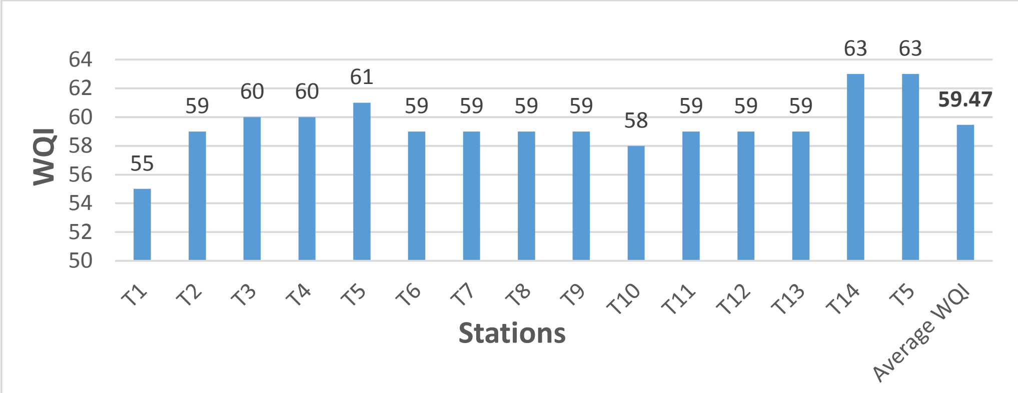

Fig16. *WQI values in the city of Tetova.*

4. CONCLUSIONS

From the results of this paper, we can conclude the following:

a) nine parameters of drinking water quality (EC, TRAE, TDS, COD, TOC, SUVA, nitrates, chlorides and THMs) were found to be within Macedonian, WHO and EU permissible limits for drinking water;

b) six drinking water quality parameters (WT, TU, RC, pH, DOC and UV254) were outside the permitted standards of North Macedonia, WHO and EU;

c) RC (<0.2 mg/L) was in some cases 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;

d) failed parameters and tests have caused lower WQI values at the respective stations;

e) Water Quality Index Desktop software was also used as a highly efficient tool for WQI calculation;

f) we propose that the state authorities and institutions should support drinking water monitoring as an effective measure for examining their ecological status and protection against various types of pollution.

REFERENCES

[1] Jain, P., Sharma, J.D., Sohu, D., Sharma, P. (2006). Chemical analysis of drinking water of village of Sanganer Tehsil, Jaipur District. *Int. J. Environ. Sci. Tech., 2 (4)*, 373-379.

[2] WHO. (2001). *Sustainability and optimization of water supply and sanitation services.* Geneva: WHO.

[3] Bujar H. Durmishi (2013). Study of the variation of the content of trihalomethanes (THM) in the drinking water of the water supply of the city of Tetova with advanced analytical methods. Dissertation, University of Tirana, 2013, 3-9.

[4] R.R. Krishnan, K. Dharmaraj and B.D.R. Kumari, 2007. A comparative study on the physicochemicaland bacterial analysis of drinking, borewell and sewage water in the three different places of Sivakasi, *J. En. Biol.* 28, 105-108.

[5] V. Magnuss, 2009. Chemical composition and assessment of drinking water quality: Latvia case study, *Proc. ECOpole* 3, 267-272.

[6] E. Chirila, T. Bari and L. Barbes, 2010. Drinking water quality assessment in constanta town, Ovidius Univ. *Ann. Chem.*, 21, 87-90.

[7] M. Alam and J.K. Pathak, 2010. Rapid assessment of water quality index of ramganga river, western Uttar Pradesh (India) using a computer programme, *Nature Sci.* 8, 1-8.

[8] B.H. Durmishi, M. Ismaili, A. Shabani, Sh. Abduli, 2012. Drinking Water Quality Assessment in Tetova Region, *American Journal of Environmental Sciences*, 8 (2), 162-169.

[9] L. Li, P. Byleveld, A. Leask and W. Smith, 2009. Assessment of chemical quality of drinking water in regional New South Wales, Australia, Proceedings of the 18th World IMACS/MODSIM Congress, Jul. 13-17, Cairns, Australia, 4326-4332.

[10] Z.A. Napacho and S.V. Manyele, 2010. Quality assessment of drinking water in temeke district (part II): Characterization of chemical parameters, *Afr. J. Environ. Sci. Technol.* 4, 775-789.

[11] Government of the Republic of Macedonia, 2004. State Drinking water regulation, Official gazette No. 57/2004, Skopje, Government of the Republic of Macedonia, 1-40.

[12] APHA, AWWA, Examination of water and waste water, 1998. 20th edition, American Public Health Association, Washington APHA, AWWA, WEF standard.

[13] CCME, 2001. Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index 1.0 User's Manual. Canadian Council of Ministers of the Environment.

[14] P. Dwivedi and S. Sonar, 2004. Evaluation of physical-chemical and biological parameters in water reservoir around hills, Doimukh (Dist. Papum Pare), *Arunanchal Pradesh, Poll. Res.* 23(1)**,** 101-104.

[15] H. Zvikomborero, 2005. An assessment of the water quality of drinking water in rural districts in Zimbabwe. The case of Gokwe South, Nkayi, Lupane, and Mwenezi districts, *Physics and Chemistry of the Earth.* 30, 859-866.

[16] WHO, 1998. Guidelines for drinking water quality. Health criteria and other supporting information, Geneva, World Health Organization Vol. 2.

[17] Ramadani E., Memeti A., Durmishi B.H. 2017. Water Quality Index: A New Automated Way of Measuring the Quality. International Journal on Information Technologies & Security, 3, 43–52.

[18] Durmishi H. Bujar, Arianit A. Reka, Murtezan Ismaili and Agim Shabani, 2013. Physico-Chemical Quality Assessment of the Drinking Water in the Summer Season in Tetova. Journal of Chemical, Biological and Physical Sciences. Vol. 3, No. 3; 2352-2360. Vol. 3, No. 3; 2352-2360.

[19] Bujar H. Durmishi, Daut Vezi, Murtezan Ismaili, Agim Shabani, Shemsedin Abduli, 2013. *Physical-Chemical Quality Assessment of the Drinking Water in the Spring Season in Tetova*. Journal of Selcuk University Natural and Applied Science, No. 9, 60 - 69.

[20] Bujar H. Durmishi, Daut Vezi, Murtezan Ismaili, Agim Shabani, Arianit A. Reka, 2013 *Variation of Trihalomethanes Concentration In Tetova's Drinking Water in the Autumn Season*. Middle-East Journal of Scientific Research, Vol. 16, No. 6, 814 - 821.

[21] Bujar H. Durmishi, Arianit A. Reka, Murtezan Ismaili, Agim Shabani, 2013. *Physico-Chemical Quality of Drinking Water in The Autumn Season of Tetova City, Macedonia*. Universal Journal of Environmental Research and Technology, Vol. 3., No. 3, 407- 414.

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