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QUALITY OF SURFACE WATER SOURCES FROM A CENTRAL TRANSYLVANIAN AREA AS A POSSIBLE PROBLEM FOR HUMAN SECURITY AND PUBLIC HEALTH

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Abstract: As a fundamental human right "sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses" is vital for all. Drinking water must have a quality that promotes and protects public health, the safe water expressing the accordance to the maximum admissible limits of the relevant water parameters for human health. Industry and agriculture are considered as having the greatest impact on the quality and quantity of water and an overwhelming majority of Europeans think that climate change will have an impact on the water resources. In Romania, most of the water sources are surface waters (lakes and rivers). The process of providing safe drinking water has relied on the protection of water sources, the application of the specific treatment technologies and the protection and maintaining quality in the distribution system. The health risk factors which can be associated with a drinking water treatment plant are related to: water contamination during treatment steps, final disinfection efficiency, distributed water quantity and distribution continuity, all these factors contributing to the presence or absence of the waterborne diseases, influencing human security and public health.

Keywords: human security, water sources, water quality, public health.

1. INTRODUCTION

Ecological security is closely connected to human security and public health because it represents the degree of guarantee that mankind is not affected by ecological destruction and environmental pollution concerning productivity, lifestyle and health, including basic elements like water and food security, air quality and green environment.

From the public health perspective water is a determining environmental factor for promoting health.

The relationship between water and health arouses three essential problems: a) Quantitative restrictions related to water and their consequences upon human activities; b) Maintaining the quality of water in terms of a growing demand for water; c) Existence of direct link between water and health. Drinking water must have a quality that promotes and protects the public health, the safe water expressing the accordance to the maximum admissible limits of the relevant water parameters for human health.

Over 2100 contaminants have been detected in drinking water since 1974 with 190 known or suspected to cause adverse health effects (Bahnareanu, 2008).

For centuries, the process of providing safe drinking water has relied on the application of the "multiple barrier concept". Traditionally, the barriers have included: protection of the water source (water used for drinking water should originate from the highest quality source possible); water treatment (basically consisting in coagulation, decantation, filtration and disinfection); protection of the distribution system. (LeChevallier & Kwok-Keung, 2004).

Water quality criteria for raw water used for drinking water production and supply usually depend on the potential of different treatment technologies to reduce the concentration of water contaminants to the level set by the drinking water criteria. The European regulations on drinking water quality are set by the Drinking Water Directive 98/83/EC which is in accordance with the World Health Organization guidelines. The Romanian legislation in force in this field (Law 458/2002 with subsequent amendments Law 311/2004) is harmonized with European Drinking Water Directive.

Drinking water treatment can range from simple physical treatment and disinfection (A1 category), to chemical treatment and disinfection (A2 category), to intensive physical and chemical treatment (A3 category). Many countries strive to ensure that the quality of raw water is such that it would only be necessary to use near-natural conditioning processes (such as bank filtration or low-speed sand filtration) and disinfection in order to meet drinking water standards. (LeChevallier & Kwok-Keung, 2004). The treatment process efficiency resulting in the significant reduction of organic load before chlorination is essential in controlling the formation of disinfection by-products which are significant toxics to humans.

Ensuring the population a safe drinking water in sufficient quantity is the most relevant indicator for the state of health of the population. Safe drinking water expresses the degree of compliance with the maximum admissible values for the parameters that are relevant to the human health. In accordance with the Bonn Objective for obtaining "sanogenetic drinking water, in which consumers trust" the water safety plans (PSA) have the following objectives: a) setting targets according to the state of health, b) risk assessment from the source to consumer, c) management of risk mitigation processes, d) operational monitoring in order to ensure optimization systems at any time, and e) recording and auditing.

From the public health point of view, water is a decisive environmental factor promoting health (Summerill et al., 2010).

2.THE AREA OF STUDY

The area of study is represented by the central Transylvanian area: Cluj, Salaj and Mures counties (Fig.1).

We proposed a synthetic data analysis concerning the quality of two artificial water accumulations that represent the water sources that are processed for drinking water purposes - Gilau and Varsolt reservoirs, and a source of running water - Mures River, followed by the functionality analysis of the three different treatment plants that use these sources.

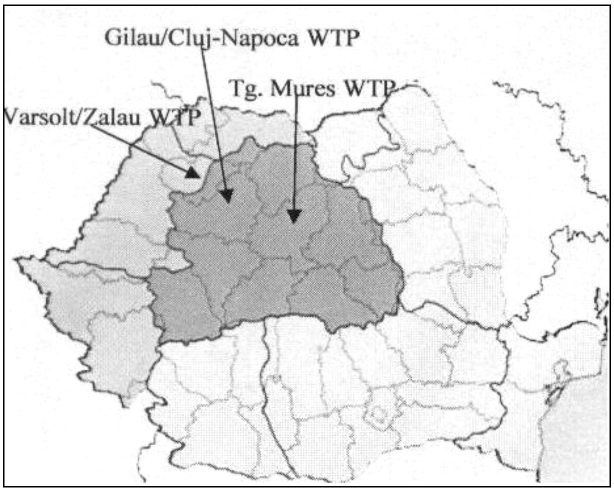

Figure 1. Area of study

Gilau reservoir formed on the Somesul Mic River follows a system of reservoirs on the Somesul Cald River, receiving water from the Somesul Rece River and Agarbiciu Creek. It is the water source for the Gilau water treatment plant that provides the water for human consumption (drinking water) for Cluj-Napoca, Gherla, Baciu, Gilau, Floresti, Aghires and other localities (approximately 500,000 inhabitants).

Varsolt reservoir (accumulation on Crasna River) is the raw water source for the Varsolt water treatment plant that provides drinking water for Zalau and Simleul Silvaniei localities (approximately 79,000 inhabitants).

Mures River is the drinking water source for Targu Mures water treatment plant which supplies with drinking water the inhabitants of Targu Mures (approximately 150,000 people).

3. MATERIALS AND METHODS

In this paper we analyzed both the data collected in 2005 and 2009 relative to the supervision of the three surface water sources: Gilau and Varsolt reservoirs and Mures River and the treatment water plants that process these water sources. For the reservoir water quality assessment, we used the usual monitoring data for the 2005 year (January, April, July and October months) collected by the laboratories owned by the drinking water suppliers and for Mures River we used data from specialty published studies. In order to characterize the raw water quality due to the oxidizable organic matter load, the analysis results were processed for oxidability and content of ammonium and, nitrates in these waters. During 2009, a total of 40 water samples were collected in three steps from the water source and during the technological treatment process at Gilau, Varsolt and Targu Mures water treatment plants. The water samples were analyzed in the laboratories of the Environmental Health Center Cluj-Napoca for a series of quality indicators using accredited analysis methods like: chemical oxygen demand – $KMnO_4$ (CCOMn) – titrimetric method (SR EN ISO 8467); nitrates (SR ISO 7890-3) and ammonium (SR ISO 7150-1/2001) - spectrometric method.

Databases were obtained by introducing water quality data in the Microsoft Excel version 5.0 program and processed statistically. The "**t**" test was performed to verify if there was a statistical difference between the averages of two samples. Also, the "p" value was calculated in order to verify that the difference is not aleatory. The graphs were performed by the Microsoft Excel version 5.0 program.

4. RESULTS AND DISCUSSIONS

4.1 Description of surface waters– sources for drinking water treatment-2005

The chemical characteristics of the Gilau and Varsolt water reservoirs using the monthly average values for the chemical oxygen demand - CCO-Mn, ammonium and nitrates from analyzed samples in 2005 during January, April, July and October are shown in the figure 2 and table 1.

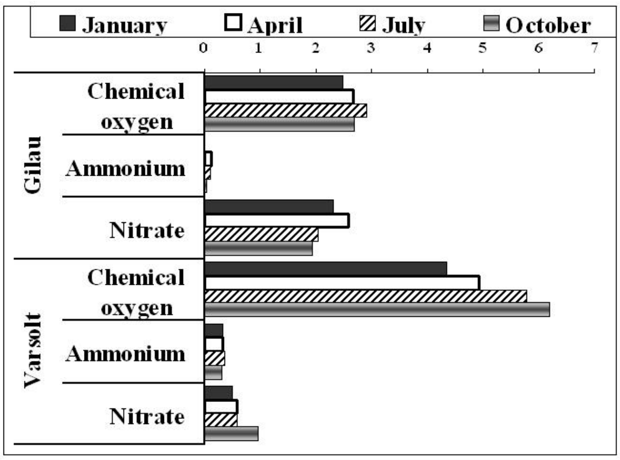

Figure 2. Chemical characteristics of water in Gilau and Varsolt reservoirs – 2005.

The indicator parameters allow the classification of the water from Gilau reservoir, according to the national legislation in force (HG 100/2002), mainly in the A1 potabilization category, excepting ammonium in April and July. The positive correlation is also observed between the seasonal evolution of ammonium and nitrates in 2005. Indicators levels increased in the warm months (April, July), reaching the maximum value in July. Lower values were recorded in the cold months (January, October). The positive correlation is also observed between the evolution of CCO-Mn, ammonium and nitrates in January and April. Analysis results show a clear and direct influence of external factors (rainfall and temperature) upon the water quality variations in Gilau reservoir. The situation is superposable with the snow-melting season (March-April) and heavy rainfalls recorded in July 2005 but also with the summer tourism in the area. During the heavy rainfalls in 2005, the phenomenon of soil wash on large areas and mobilization of organic sediments resulted in slightly increased values of CCO-Mn.

The comparative evolution analysis in 2005 of the indicator parameters investigated in the water of the two reservoirs noted the following aspects: water in Varsolt reservoir (Fig. 2) has double oxidability levels against the Gilau water source, ammonium concentration in water is almost identical to that in Gilau water source and nitrates content is much lower. Raw water intakes of both water plants frame in A1 and A2 quality categories, framing in A2 quality category being mainly due to the contamination of organic nature.

Table 1. Chemical characteristics of water in Mures River

Parameter	Mures River		
	Upstream pollution source	At the pollution source	Upstream water treatment plant
CCO-Mn mg O_2/l	7,06	58,8	2.88
NH_4 mg/l	0,37	49,3	1.73
NO_3 mg/l	4,77	3.89	3.96

The chemical characteristics of water in Mures River as the result of the analyzed parameters values (Table 1) allow the classification of the water inlet source in the A2 potabilization category. At that time, by comparing the parameters determined from the water samples collected from Mures River, downstream and upstream the localities situated on the river banks, it was observed that these localities do not represent a source of pollution, except for industrial units, and livestock farms which discharge wastewaters directly into the river. The water intake of Tg. Mures WTP is located in the area between Reghin and Targu Mures, an area that is subject to organized and non-organized pollution like sanitary sewer of Reghin city, floodable rural villages, etc. (Domahidi, 1996).

Romania is among the countries with poor water sources; 86% of the water sources are surface waters (lakes and rivers), which are preferably treated for drinking purposes because of the advantage of quantity, despite their poor quality compared to the groundwater. Continued deterioration of water sources accentuates the problem of maintaining the water quality, especially in urban areas and in places where multiple pollution sources exist. In broad terms there are two categories of pollution sources: organized sources, represented by units that discharge their wastewater in the receiving stream through a sewage system built for this purpose, and non-organized sources. The latter have the great disadvantage that it cannot be quantified nor monitored. (Ritter et al., 2002; Carrière et al., 2010)

In most countries there are three major water pollution sources: faecal pollution of wastewaters, industrial effluents and agriculture, thus residual waters being one of the most important pollution sources for the surface waters. (Ritter et al., 2002)

The possible risk assessment of changes in the water source quality showed the following issues: the water quality characteristics of the two reservoirs (Gilau and Varsolt) are influenced by their location downstream of populated areas with numerous utilities: permanent residential and tourist (Gilau) or agricultural areas even if the past big livestock farms no longer function (Varsolt), the main pollution sources are non-controlled sources: faecal pollution of wastewaters resulted from the human agglomerations upstream the reservoir, uncontrolled storage of household wastes upstream and wastewaters discharge (either directly or insufficiently treated).

Both reservoirs are characterized by a rather unstable climatic equilibrium; changes of the environmental factors influence them directly. Periods of prolonged drought alter the physico-chemical (pH, colour) and biological water quality through microorganisms' multiplication and increase of organic matter content resulted from plant or animal decay besides great development of the planktonic biomass. During heavy rainfall when floods and soil washing carry away a large amount of insoluble substances (suspensions) water turbidity increases. The water source quality is severely affected in case of extreme weather phenomena and risks upon the consumers' health have been demonstrated in several studies worldwide (Dura et al., 2010).

Gilau water treatment plant has a surface water source of neat superior chemical quality compared to other treatment plants in Transylvania, even if in time its overall quality has depreciated. On the whole, water contamination in the reservoir was lower than that in the river due to the more active self-purification processes, including a natural settling.

Water quality of rivers and reservoirs in the central counties of Transylvania outlined the water sources quality degradation for a time due to the anthropic impact. Previous studies have found different degrees of organic water contamination in reservoirs and rivers with repercussions for the drinking water quality as a result of poor treatment. During 1981-1995 in Transylvania the river waters were often inappropriate for drinking water treatment purpose; also, in 1996, the quality of 26% of the surface water sources did not comply for this purpose. The study showed a bacterial contamination of surface waters (that represented the water source for seven water treatment plants in Transylvania) with a 12% prevalence of the samples that did not frame for treatment on potabilization purpose, (Gurzau, 1996). A study conducted in the Mures County area (Hajdu et al., 2007) showed that the pollution sources (diffuse and punctual) from the localities effects the pollution of surface waters with nitrates, in each case a significant increase of nitrate concentration in the creek after running through the village being observed. Ferencz et al., (2010) detected pesticides in 16 water samples in Mures, Niraj, Lechinta, Tarnava Mare and Tarnava Mica rivers, and also in drinking water samples from fountains and tap-water. High heavy metals pollution levels were recorded in stream-courses that flow across areas where mining activities, like Aries River (tributary of Mures River). Various sources of contaminants occurring along its stream-course make it one of the most polluted rivers in Romania. Besides metals, the stream-water of Aries also contains organic pollutants, such as flocculants, surfactants, frothers and others, which all originate in ore dressing plants (Marin et al., 2010).

It is accepted worldwide that proper water sources identification, their severe protection and a complete and correct treatment can provide a water quality that does not represent a health risk. A correct choice and protection of water sources are essentially important in ensuring safe drinking water supplies. It is always preferable protecting the water sources than treating after contamination. A reservoir can be protected from the major human activities, but rivers protection may be performed in just a limited area. It is often necessary to accept the present and historic pollution of the water source and to consider a water treatment according to these circumstances (Jardine et al., 2003). The organic matter load and the dynamic of its degradation are very good indicators of the anthropogenic impact on the waters.

4.2. Quality of treated waters in Gilau, Varsolt and Targu Mures water treatment plants - 2009

According to the legislation in force (HG 100/2002) raw waters treatment is performed in accordance with the quality of water regarding the following treatment standard technologies: A1 - simple physical treatment and disinfection, A2 - normal physical and chemical treatment and disinfection (pre-chlorination, coagulation, fluoridation, decantation, filtration and disinfection).

Gilau water treatment plant applies the standard procedure for processing water for drinking purposes: decantation, coagulation, filtration and disinfection producing quality water whose values for the analyzed chemical parameters correspond to human consumption (Fig. 3).

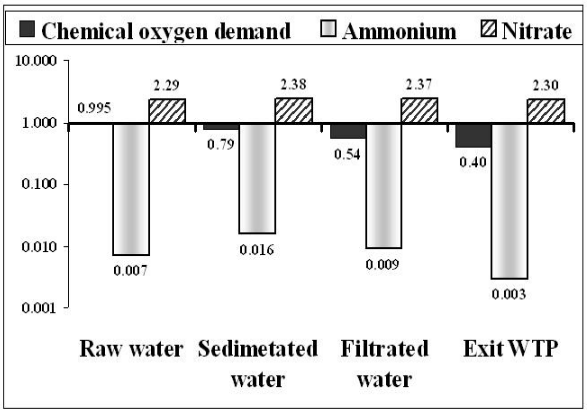

Figure 3. Comparative values for oxidability, ammonium, and nitrates in water Gilau water treatment plant 2009.

We estimated the efficiency of water decantation, filtration and disinfection in relation to the raw water by reducing the values of indicators as oxidability and nitrates. The importances of significant differences of the chemical indicators in treated waters from Gilau (2009) are presented in the table 2. According to the 't' and $p<0,05$ values, the differences between the values of the chemical oxygen demand (CCO-Mn) in the raw water and filtered water, the water exiting the water treatment plant respectively, show a statistical significant decrease. There are no statistically significant differences between the decantated water and the filtered or the chlorinated one. Starting from the water source quality and in full agreement with the historical pollution data, Varsolt water treatment plant applies in relation to Gilau water treatment plant an additional pre-chlorination process prior to coagulation and decantation obtaining finally water that meets the quality criteria for consumers' safety (oxidability 5 mg O_2\l, ammonium 0.5 mg/l, nitrates 50 mg/l). The comparative values for oxidability, ammonium and nitrates in water from Varsolt water treatment plant in 2009 are presented in the figure 4.

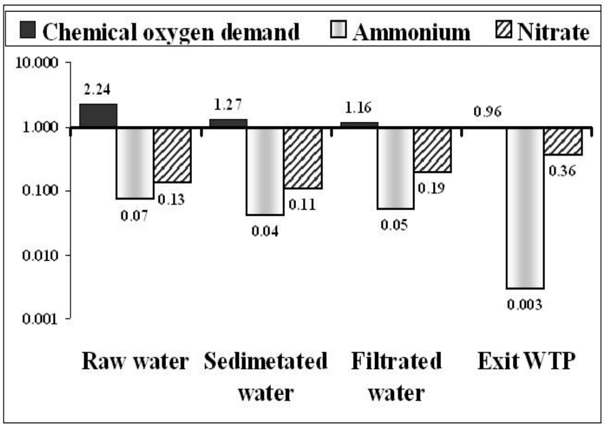

Figure 4. Comparative values for oxidability, ammonium and nitrates in water Varsolt water treatment plant 2009

Table 2 - Importance of significant differences of the chemical indicators in treated waters - Gilau 2009

IMPORTANCE OF DIFFERENCES - GILAU				
Compared waters		Oxidability	Ammonium	Nitrates
Raw - Decantated	t	0,84	-1,06	-1,12
	p	0,22	0,18	0,16
Raw - Filtered	t	**2,09**	-0,36	-1,07
	p	**0,04**	0,37	0,17
Raw - Exit	t	**2,92**	2,20	-0,06
	p	**0,02**	0,06	0,48
Decantated - Filtered	t	1,10	0,69	0,27
	p	0,16	0,26	0,40
Decantated - Exit	t	1,82	1,65	0,58
	p	0,06	0,10	0,30
Filtered - Exit	t	0,76	1,19	0,50
	p	0,24	0,16	0,33

Generally the treatment determines a concentration decrease of the values of analyzed chemical water indicators: oxidability and ammonium. However, nitrates have a particular evolution, their level increases in water during potabilization operations.

The pre-chlorination effect is relieved by the appearance of statistically significant differences importance of the indicators in treated waters: chemical oxygen demand values between the raw water and the decantated water, filtered water and water exiting the water treatment plant (Table 3). The comparative values for oxidability, ammonium and nitrates in water Targu Mures water treatment plant in 2009 are presented in the figure 5.

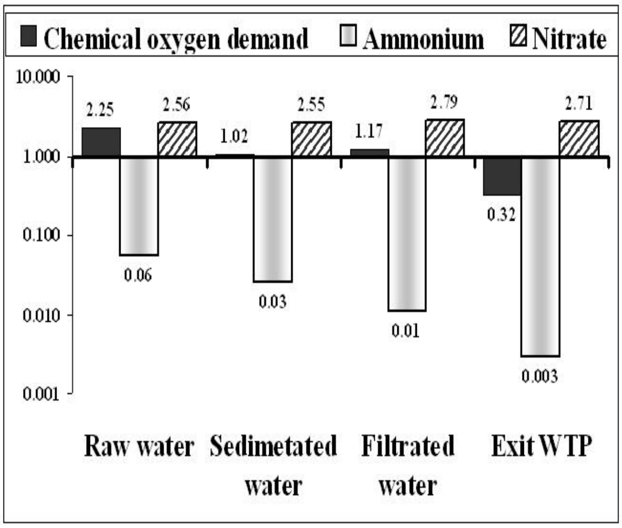

Figure 5. Comparative values for oxidability, ammonium and nitrates in water Targu Mures water treatment plant 2009

According to the results obtained by analyzing the indicators parameters in 2009, water treatment at Targu Mures water treatment plant distinguishes by the nitrates levels that are not reduced during treatment, moreover their value in the water exiting the water treatment plant is slightly higher than in the source. Inadequate filter exploitation may lead to increased values of indicators such as nitrates, by mobilizing them as a result of organic matter decay in the filter layer. Instead, decrease of the ammonium level and the chemical oxygen demand are statistically significant due to the treatment situation observed also in Varsolt water treatment plant. The importances of these significant differences of the chemical indicators in treated waters are shown in the table 4.

It must be mentioned that also in the in Gilau and Tragu Mures WTPs the values of analyzed indicators (chemical oxygen demand, ammonium and nitrates in the complete treated water has richen entirely the maximum admitted concentration by regulations in force.

The demand for water is growing rapidly due to the rapid population growth, urbanization and socio-economic development. The fundamental scope of water treatment is to protect consumers from pathogens and chemical impurities in water that can affect human health. The best results in obtaining an adequate microbiological and chemical quality of the drinking water are provided by combining the treatment processes. In order to comply with the drinking water criteria the surface water is subject to treatment processes that typically include: coagulation/decantation, filtration and disinfection.

Table 3 - Importance of significant differences of the chemical indicators in treated waters - Varsolt 2009

IMPORTANCE OF DIFFERENCES - VARSOLT				
Compared waters		Oxidability	Ammonium	Nitrates
Raw - Decantated	t	2,04	0,51	0,39
	p	0,09	0,32	0,36
Raw - Filtered	t	1,85	0,34	-0,75
	p	0,07	0,38	0,25
Raw - Exit	t	**2,55**	1,26	-1,44
	p	**0,04**	0,17	0,14
Decantated - Filtered	t	0,30	-0,23	-1,02
	p	0,40	0,41	0,19
Decantated - Exit	t	1,65	1,27	-1,59
	p	0,10	0,17	0,13
Filtered - Exit	t	0,54	1,47	-0,98
	p	0,31	0,14	0,20

Table 4. Importance of significant differences of the chemical indicators in treated waters Targu Mures 2009

IMPORTANCE OF DIFFERENCES – TG. MURES				
Compared waters		Oxidability	Ammonium	Nitrates
Raw - Decantated	t	2,23	**-3,06**	0,05
	p	0,06	**0,05**	0,48
Raw - Filtered	t	**2,57**	1,30	-0,72
	p	**0,03**	0,14	0,26
Raw - Exit	t	**6,11**	2,05	-0,41
	p	**0,01**	0,07	0,35
Decantated - Filtered	t	-0,27	2,59	-0,94
	p	0,40	0,06	0,20
Decantated - Exit	t	1,49	1,05	-0,53
	p	0,14	0,18	0,31
Filtered - Exit	t	2,75	0,21	0,29
	p	0,06	2,92	0,40

To these technological steps that depend on the raw water quality a series of additional processes can be added such as pre-chlorination, process applied to the raw water containing a high load of pathogen germs and organic matter. Pre-chlorination consists in introducing a usually higher quantity of chlorine (1-5 mg/l and even more) than that used for the final chlorination, before coagulation, together with the coagulant or before filtration, thus filtration has a higher efficiency and through the final chlorination drinking water of proper quality is obtained (Ritter et al. 2002)

The Human Development Report describes the human security as being the state of safety from the constant threats of hunger, disease, crime and repression. It also means protection from sudden disruptions in the pattern of our daily lives.

At the same time four domains that may affect the human security were stated as follows:

- poor economic development,
- lack of food,
- poor health of population,
- degradation of environment and natural disasters.

The concept of Human Security unites the domains of security and development and consolidates the role of public health as part of the worldwide security.

In Europe about 120 million people do not have access to drinking water of adequate quality, safe, and even less access to sanitation facilities and this contributes to the occurrence of infectious waterborne diseases, microbiological contamination is known as a major problem regarding the water quality in Europe. Chemical pollution is limited but may also have a significant impact on the population's health.

Each nation's water resources must be protected, conserved, developed, managed, used, and controlled in ways that ensure efficient, sustainable and beneficial use of water in the public interest.

Environmental protection and pollution control may stop the consumption of freshwater by pollution and to return wastewater to the water cycle as a beneficial source of water. Protection of water resources is a major problem that has to be approached from the point of view of rational quantitative exploitation of sources and protection against human aggression in the worldwide circumstances of a growing demand for water. From the public health point of view, according to WHO, 2004, the poor water quality continues to pose a major threat to human health worldwide.

5. CONCLUSIONS

Overall, it can be stated that the three studied water sources in the central part of Transylvania frame in the A2 category for surface waters that can be processed for drinking water purposes. The investigated water sources present variable moderate characteristics regarding the chemical oxygen demand, ammonium and nitrates being influenced by the hydrological system and the upstream sources of pollution both in Gilau and Varsolt reservoirs and in Mures River. The water treatment plants in this study, through the performed technologies provide water exiting the water treatment plants that corresponds to the quality standards in terms of analyzed indicators that reflect the reduction or absence of microbiological pollution of the water. Using pre-chlorination dictated by the level of organic load in the water source created the prerequisites in obtaining drinking water with a statistically significant reduction of parameter indicators levels, but thus favouring the occurrence of disinfection by-products that can affect consumers' health. Corroborating the quality protection and conservation of the analyzed water sources with the application of treatment technologies appropriate to the water source quality enable us to state that the water sources for Gilau, Varsolt and Targu Mures water treatment plants do not generate any possible problems for the human security and public health.

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