- ORAL PRESENTATIONS -

QUALITY CONTROL OF DRINKING WATER IN BRASOV MUNICIPALITY USING FIRST DRAW AND FULL FLUSH SAMPLING PROCEDURES

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Abstract

The present study investigates the influence of in-house installation systems to the tap water quality in Brasov Municipality in order to get an overview of the current contamination levels of drinking water at the consumer's tap. In a sampling campaign organized in March 2013, the samples were collected from customer's cold line pipe with first draw (1st liter taken in the morning from kitchen without previous flush of the tap) and fully flushed sampling (after flushing five minutes same tap) procedures. In the monitoring program were included samples from Tarlung Water Plant, drinking water samples from storage tanks situated in different Brasov areas, 34 samples from customer's tap and 12 samples from branch pipes. The investigated parameters (metals, organic compounds and microbiological parameters) were those included in Romania Legislation in accordance with European Drinking Water Directive 98/83/EC.

The metallic element Al, As, Cd, Cu, Cr, Fe, Mn, Ni, Pb, Se, Sb and Zn were analyzed in tap water samples using inductively coupled plasma atomic emission spectroscopy technique. The monitoring data show an influence of the material used in the internal distribution system within the customer buildings to the tap waters quality. Around 18% of first draw samples indicated a pollution of drinking water with Ni (two samples) and Pb (two samples). The metal concentrations recorded in tap waters collected with tap flushing procedure and also the samples collected from branch pipe were situated in the limit values in all studied cases.

It was notice a decrease of free chlorine concentration in stagnated water (in most samples, below the limit of detection for the test method) compared with branch pipe and fully flushed samples. This permits the development of microorganisms, the stagnated water being unprotected from the bacteriological point of view.
The present study demonstrate that materials used in water supply domestic installations have a major contribution in deterioration of water quality provided by the local distribution network, due to the processes of water stagnation and lack of maintenance of the internal distribution materials.

Keywords: tap water, stagnation, metals, microbiological parameters

INTRODUCTION

A drinking water system is commonly described as a supply chain composed of three main sub-systems: raw water, treatment and distribution. Together, these sub-systems cover the entire supply chain, from the water source to the consumers' taps. Regular monitoring of raw water quality, treatment processes and water quality in the distribution systems are integral parts of total drinking water quality management for the implementation of a multi-barrier approach for maintaining high-quality tap water for consumers.
Along the supply chain there are hazards that may harm the system in different ways. The hazardous events may be different but their consequences are usually categorized as quantity- or quality-related. This means that either the ability to deliver water to the consumers or the water quality itself is affected. According to some authors [1] the objective of water treatment is to produce an adequate and continuous supply of water that is chemically, bacteriological and aesthetically acceptable. In addition to be bacteriological safe, the water should also be microbiologically safe. It is not only pathogenic bacteria that may cause harm to public health; there are also viruses, protozoa and other biological contaminants.
Water distribution systems are subjected to adverse reactions and events that could change the high-quality water ton a non-potable and unsafe for human consumption in the time it arrives at the tap of the consumer [2-4]. As water quality change significantly in the distribution system, regular monitoring is essential to ensure that high-quality drinking water reaches the consumer.
Pipelines corrosion can affect water quality, public acceptance of a water supply and the cost of providing safe drinking water. The release of corrosion by-products of household plumbing systems can be a significant source of trace metals found in tap waters [5]. Pollution with metals may originate mainly from old and poor quality distribution networks and piping systems.
When drinking water is distributed through pipelines, bio-films will grow on the inner surface of the pipes and soft deposits (organic and inorganic matter) and several metals will accumulate to the pipelines [6]. Coloration of drinking water is one of the main reasons customers complain to their water company. An elevated concentration of iron or increased turbidity affects taste, odor and color in drinking water. Unlined iron pipes in drinking water distribution networks develop extensive internal corrosion scales as the time of use increases. These

corrosion scale deposits reduce the hydraulic capacity of the pipes and more energy is required to deliver water at a desire flow rate [7].
The main sources of drinking water in Romania include rivers (about 60%), drillings, and much less lakes. Drinking water quality is routinely monitored in the distribution network but not inside households at the point of consumption. According to Romanian legislation, the last segments checked by the Water Companies are branch pipe and water meter. Less than 0.1% of domestic network of customer is included in monitoring plan of drinking water; usually, the tap water is controlled only at customer request or complaint.
The aim of the study was to identify issues that may affect public health and the risk prevalence of relevant metals in in-building installation systems, in Brasov municipality, city situated in central part of Romania. Thus, it is possible to take measures to increase security of water systems, replacement of the pipelines at risk of metal corrosion, improve drinking water quality and protect human health against adverse effects caused by contamination of drinking water [8].

EXPERIMENTAL PART

In the study the influence of in-house installation systems to the tap water quality in Brasov municipality, one important city situated in Central Part of Romania with approximately 300,000 inhabitants was investigated. In order to get an overview of the current contamination levels of drinking water (chemical and microbiological) at the consumer's tap, around 60 tap water samples (including water collected from branch pipes) were collected.
In a sampling campaign organized in March 2013, the samples were collected from customer's cold line pipe with two different sampling techniques: first draw sampling (from kitchen, before using the tap); fully flushed sampling procedure after flushing five minutes same tap. Each type of sampling technique provides different information's about influence of materials used in both distribution systems (municipal and domestic) to the tap water quality. Thus, the results obtained with fully flushed procedure indicated the influence of municipal distribution system to the tap water supplied by the Operator (Water Company). The first draw results show in principal the influence of materials used in domestic distribution system. A monitoring plan was developed and the concentration of metals was analyzed in drinking water samples collected directly from consumers.
In the monitoring program were included samples from Water Plant and storage tanks situated in Brasov – 12 samples, samples from customer's tap (first draw and fully flushed samples) – 34 samples and branch pipe (last segment checked by the Water and Sewerage Operator) - 12 points.
Raw water sources used by the Brasov Water Company for drinking water production are the following:

- surface water from Tarlung Lake (around 80% from the water supplied by the Brasov Water Company);
- springs water: Ciucas, Racadau, Solomon Caption (Solomon Rocks spring, Putreda spring, Water Valley spring);
- Sanpetru drillings – 30 boreholes with 180-200 m depth.

The investigated parameters (metals and organic compounds) were those included in Romania Legislation in accordance with European Drinking Water Directive 98/83/EC. For microbiological analysis, targeted indicators such as: Mesophilic bacteria, total coliforms and *Escherichia coli*, *Enterococcus* and *Pseudomonas aeruginosa* were analyzed in the first draw and fully flushed water samples.

RESULTS AND DISCUSION

The metallic elements Al, As, Cd, Cu, Cr, Fe, Mn, Ni, Pb, Se, Sb and Zn were analyzed in tap water samples using inductively coupled plasma atomic emission spectroscopy technique (ICP-EOS). The quality of drinking water provided by the Brasov Water Plant was situated in the limits imposed by the national regulation.
In the Table 1 are presented the statistical date for the results of the samples collected from consumer's tap with first draw technique. A low percentage of non-compliance samples were recorded (around 18%), the limit values were exceeded for Ni and Pb in three tap water samples. After washed the tap for 5 minutes and then collected and analyzed the samples (fully flush procedure), the analytical results indicated that all the tap water samples were in compliance, the values of the metals were situated below the limits.
It is important to mention that quality of drinking water samples collected from branch pipes (12 samples) was situated in the limits impose by the legislation.
Also, it was observed a decrease of free chlorine in stagnated water (almost in all samples the concentration was below the detection limit of the analytical method) in comparison with the one obtained in washed water and water collected from branch pipe. This fact increases the development of microorganisms, the tap water being unprotected from bacteriological point of view. The sampling campaign was performed in winter season, when the temperatures were situated around 10°C and this fact doesn't increase the development of bacteria.
In terms of microbiological parameters, a number of factors such as temperature fluctuations, times of stagnation, pipe materials and decreasing pipe diameters can promote bacterial growth in buildings.

Table 1. Tap water samples collected with first draw technique - 17 monitoring point - customer's from Brasov Municipality (µg/L)

Statistical parameter	**Element**						
	Al	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
0	***1***	***2***	***3***	***4***	***5***	***6***	***7***
Minimum value	**3.3**	**2.1**	**<0.3**	**< 0.1**	**< 1**	**< 1**	**15**
Maximum value	**85.7**	**92.2**	**153**	**24.7**	**185**	**33.1**	**1295**
Mean value for 25% of samples	**8.7**	**5.2**	**5.35**	**1.05**	**< 1**	**< 1**	**53.3**
Mean value for 75% of samples	**51.3**	**37.5**	**44.3**	**9.75**	**18.4**	**4.43**	**433**

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Median value	**44.4**	**14.3**	**25.5**	**5.95**	**< 1**	**< 1**	**224**
Mean value	**41.3**	**29.9**	**35.1**	**7.7**	**14.3**	**3.62**	**344**
Standard deviation	**24.5**	**28.4**	**36.2**	**6.28**	**44.7**	**7.22**	**319**
Maximum admissible value	**200**	**100**	**200**	**50**	**20**	**10**	**5000**
% non-compliance samples	**0**	**0**	**0**	**0**	**11.76**	**11.76**	**0**
No. non-compliance samples	**0**	**0**	**0**	**0**	**2**	**2**	**0**
Total non-compliance samples (%)	**17. 65**						
Total non-compliance samples	**3**						

In Table 2 are presented the results (metals and microbiological analysis) for three samples collected from Ciucas Distribution Zone (monitoring point 12), where the water delivered was un-chlorinated. The analytical results demonstrate that water from branch pipe contains bacteria that growth at 22˚C, bacteria founded both in stagnated water and in washed water, but the values are situated under the limit value. Also, the stagnated water contains bacteria that growth at 37˚C, with values over the maximum admissible limit.
The drinking water from Ciucas Source is a water of a very good quality (deposited in a natural reservoir in a mountain cave, water with excellent taste and odour). But, unfortunately, the water can't reach the customer's tap in that state, because bio-films grows on the inner surface of the pipes in the distribution systems and conducts to microbiological contamination of the water. Technical solutions for remediation are:

- Water Company will deliver the water after chlorination process or
- Each customer will install a filter for microbiological purification on cold water pipe.

Table 2. Tap water quality from Ciucas Spring Source

No.	**Parameter**	**MU**	**12/1 stagnation**	**12/2 washed**	**12B Branch pipe**	**Maximum admissible value**
0	*1*	*2*	*3*	*4*	*5*	*6*
1	**Al**	**µg/L**	**14.2**	**24.9**	**6.0**	**200**
2	**As**	**µg/L**	**<0.2**	**<0.2**	**<0.2**	**10**
3	**Cd**	**µg/L**	**<0.4**	**<0.4**	**<0.4**	**5**
4	**Cr**	**µg/L**	**<0.5**	**<0.5**	**<0.5**	**50**
5	**Cu**	**µg/L**	**34**	**3.3**	**2.6**	**100**
6	**Fe**	**µg/L**	**4.1**	**17.7**	**1.9**	**200**

0	*1*	*2*	*3*	*4*	*5*	*6*
7	**Mn**	**µg/L**	**<0.1**	**<0.1**	**<0.1**	**50**
8	**Ni**	**µg/L**	**<1**	**<1**	**<1**	**20**
9	**Pb**	**µg/L**	**<1**	**<1**	**<1**	**10**
10	**Se**	**µg/L**	**<0.1**	**<0.1**	**<0.1**	**10**
11	**Sb**	**µg/L**	**<0.2**	**<0.2**	**<0.2**	**5**
12	**Zn**	**µg/L**	**199**	**12.9**	**7.4**	**5000**
13	**Free Chlorine**	**mg/L**	**< 0.035**	**< 0.035**	**< 0.035**	**-**
14	**Total coliforms bacteria**	**nr/100 cm^3**	**absent**	**absent**	**absent**	**0/100 ml**
15	***Escherichia Coli***	**nr/100 cm^3**	**absent**	**absent**	**absent**	**0/100 ml**
16	***Enterococcus***	**nr/100 cm^3**	**absent**	**absent**	**absent**	**0/250ml**
17	**Number of bacteria at 22˚C**	**UFC/cm^3**	**28**	**11**	**23**	**100/ml**
18	**Number of bacteria at 37˚C**	**UFC/cm^3**	**44**	**3**	**absent**	**20/ml**
19	***Pseudomonas aeruginosa***	**nr/100 cm^3**	**absent**	**absent**	**absent**	**0/250ml**

CONCLUSION

The influence of in house installation systems on the tap water quality in Brasov Municipality was investigated. This results showed that materials used in water distribution systems are part of the overall treatment process that affect the water quality which consumers drink at their tap. The interaction between water and the infrastructure used for its supply are fundamental in producing safety drinking water. Subtle reactions between water and different materials used for its transport could affect finally the quality of the water delivered to consumers.
It is also observed that materials used in drinking water domestic installations have a major contribution in the deterioration of water quality supplied by local distribution operators.

In some locations, in first draw samples collected in the morning from kitchen cold taps high quantity of Ni and Pb were detected in correlation with materials used in internal distribution system (Pb pipes, branch pipes, Ni-Cr plated taps).
The main causes are the process of water stagnation and the lack of maintenance of the internal distribution materials. The customers were advised to not use the first draw water for cooking and drinking purpose. Recommendations in case of exceeding the admissible values of metals in drinking water were either flushing water for more than five minutes or replacement of pipes and fittings in both, local or domestic distribution systems.

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REFERENCES

[1] Gray, N.F., Water Technology: an Introduction for Environmental Scientists and Engineers, 2 ed. Elsevier Butterworth-Heinemann, Oxford, 2005;

[2] LeChevallier, M.W., Welch, N.J., Smith, D.B., *Appl Environ Microbiol,* 62, 7, 1996, p. 2201;

[3] Vasile, G., Dinu, C., Cruceru, L., Petre, *Environ Eng Manag J*, 9, 11, 2010, p. 469;

[4] Vasile G., Dinu, C., Cruceru, L., Proceedings of International Symposium "The Environment and Industry", Bucharest, 16-18 October 2011, volume 2, p. 246;

[5] Agatenos, C., Okato, P.O., , *Environmentalist,* 28, 2008, p. 379;

[6] Lehtola, M.J., Juhna, T., Miettinen, I.T., Vartiainen, T., Martikainen, P.J., *J. Ind. Microbiol. Biotechnol.*, 31, 11, 2004, p. 489;

[7] Sarin, P., Snoeyink, U.L., Bebec, J., Jim, K. K., *Water Res*., 38, 2004, p. 1259;

[8] *Best Practice Guide on Sampling and Monitoring Metals in Drinking Water*, ed. Postawa A., IWA Publishing, London, 2012, p. 13;