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Tap water quality regarding metal concentrations in Timisoara city, Romania

Gabriela Vasile[1], Liliana Cruceru[1], Jana Petre[1], Adriana Anghelus[2], Daniela Gheorghe[2], Diana Landi[2], Adriana Stefanescu[2]

[1]National Research and Development Institute for Industrial Ecology, Road Panduri no. 90-92, district 5, code 050663, Bucharest, Romania

[2]AQUATIM Company, Street Gheorghe Lazar no 11A, code 300081, Timisoara, Timis County, Romania

Corresponding author e-mail: ecoind@incdecoind.ro

Abstract

The aim of the study was to identify the risk prevalence of relevant metals in in-building installation systems in Timisoara City. In the study were collected more than 250 tap water samples in order to get an overview of the overall current contamination level of drinking water at the point of consumption. In the monitoring program were included three water plants, fifteen points from the control program of the company, thirty-three tap waters (first draw and fully flushed sampling procedure) and thirty-two tap water samples (random daytime sampling). The quality of drinking water produced by AQUATIM Company was in accordance with the European Directive 98/83/EC requirements. In samples collected from customer's tap the percent of non-compliance samples was around 50% in first draw, 10% in fully flushed and 25% in random daytime samples. The domestic distribution systems have an important influence to the quality of drinking water delivered by the AQUATIM Company.

1. Introduction

Access to safe drinking water is a basic concern for human health and health protection. According to the World Health Organization (WHO) and European Council Directives, a concentration of microorganisms, parasites or substances posing a possible risk to human health has to be prevented (WHO, 2008). The provision of safe drinking water is one of the main requirements of drinking water supply infrastructure. Therefore, the monitoring of the drinking water from source to tap is an essential step towards hygiene safety.

At the European Community level, Directive 98/83/EC (Council Directive, 1998) regulates water quality at the tap. The objective of this directive is to protect human health from adverse effects resulting from contamination of water intended for human consumption for drinking, cooking, food preparation or other domestic purposes (Roccaro et al, 2005).

As a result of the Council Directive 98/83/EC, water authorities around Europe are obliged to monitor water for public use, so that the consumer is provided with safe and substance – free water.

In some European countries such as Romania or Germany, the water distributors have to ensure that microbial and chemically clean water reaches water meters. After that, the owner of the building is responsible for the water quality. Up to the water meter the drinking water quality is very good (Volker at al, 2010), but the water provided by the water distributors may have a higher microbial and chemical quality than that available from taps in the customers households.

Household pipe can have a considerable impact on the water quality, which was already shown in several large scale studies addressing metal concentrations in tap water after overnight stagnation (Haider et al, 2002; Vasile et al, 2009; Ziez et al 2003; 2007). All these studies reported an increased concentration of lead, cadmium, copper, iron and nickel after stagnation in household tap water in Austria, Germany and Romania.

Numerous studies have highlighted and reviewed the influence of water quality parameters (e.g. pH, dissolved oxygen, temperature, alkalinity, chloride, sulfate, phosphate and organic matter) and operating conditions (stagnation time and pipe age) on copper release into drinking water from copper pipes (Darren, 2010).

Lead in drinking water is a major public health concern. It can create irreversible intellectual impairment in infants and young children, even at blood lead levels below 10 µ/L. (Jusko et al, 2008). Generally, source waters are free of lead, but significant amounts of lead may be present in the tap water due to dissolution of lead corrosion products, which are formed in water distribution network and domestic plumbing systems.

In the absence of lead pipe, Pb-based solder and brass fittings (materials containing up to 8% lead) are know to be dominant lead sources in public water supply system (Kimbroungh, 2001).

In a domestic plumbing system several types of materials could release lead into water. First source could be Pb-pipes as a predominant source (Cheng et Foland, 2004). Second, before 1987, solders used in plumbing systems contained significant amounts of lead are even today solders containing lead (low quantity, around maxim. 0.2%). The Pb-bearing solders could be in direct contact, and, therefore, release lead into water. In addition, some faucet assemblies and fixtures are also problematic sources of lead, as shown by Gulson et al (1994). Other materials, even those with low Pb contents may contribute to water Pb as well.

In Europe, random daytime (RDT) sampling (1st liter taken during office hours, without fixed stagnation) and sampling after 30 minutes of stagnation (30 Ms) (1st and 2nd liter) were identified as the best approaches for estimating exposure and detecting homes with elevated lead concentration in tap water (Deshommes, 2010; Hayes, 2009; Hayes et al, 2010).

Iron release from corroded iron pipes is the principal cause of “colored water” problems in drinking water distribution systems. These corrosion scale deposits reduce the hydraulic capacity of the pipes and can adversely affect water quality during distribution. Some consequences are colored water when iron is released from corrosion scales, high demand for chloride and dissolved oxygen, biofilm growth, adsorption, and accumulation of substances such as arsenic, which can be released on modification of water quality (Sarin et al., 2004).

Tap water from the municipal supply systems is the source of drinking water for a majority of homes in Romania. The aim of the study was to identify the risk prevalence of relevant metals in in-building installation systems in Timisoara City from Romania with the population more than 400,000 inhabitants. In the study were collected more than 250 tap water samples in order to get an overview of the overall current contamination levels of drinking water at the point of consumption.

2. Experimental Data

In February and June 2010 were collected more than 250 tap water samples delivered by AQUATIM COMPANY, an important Romanian Drinking Water Producer. In addition, were collected samples from Drinking Water Plants and 15 control points of the Company in order to establish a baseline for comparison of the data obtained in the customers monitoring plan.

AQUATIM Company delivers the drinking water in Timisoara town and in the surrounding area. Two sources of raw water are used: surface water and groundwater.

- Bega Water Plant - about 67% of the total quantity of water is produced using surface water from Bega River.
- Urseni Water Plant - approximately 30% of the total quantity of water is produced using groundwater from 18 drilling points at a depth of 60 to 80 m, and 40 drilling points at a depth of 110 to 160 m.
- Ronat Water Plant is used only in certain cases, only to ensure the high water consumption (especially in the evening), using groundwater from five drilling points.

AQUATIM Company checks daily the quality of drinking water in 30 monitoring points, situated in different locations in the aria, such as elementary schools, kindergartens, markets, fountains, public institutions

The samples were collected in accordance with the monitoring plan established between INCD-ECOIND and the specialists from AQUATIM Company. In figure 1 is presented the map of public network system in Timisoara City. The locations of control points are marked with green, the Water Plants with blue and customer’s tap with red.

Figure 1. Timisoara tap water customer's monitoring plan

In order to obtain a large database, the samples were collected from customer's cold line-pipe with three different sampling techniques:

- first draw sampling (from kitchen, first in the morning, before using the tap) – 33 monitoring points from the customers with residence in different parts of the city (C1-C33);
- fully flushed sampling procedure after flushing five minutes the tap – same 33 points and other 15 points from the Drinking Water Producer, points situated in markets, schools, street fountains (P1–P15);
- random daytime procedure (within office hour, without previous flushing of the tap) – 32 sampling points situated in old buildings from the center of the city – medical centers, pharmacies, schools, private companies, public institutions (1P-32P).

The parameters Al, As, Cd, Cu, Cr, Fe, Mn, Ni, Pb, Se, Sb and Zn were analysed using inductively coupled plasma atomic emission spectroscopy ICP-EOS technique (OPTIMA 5300 DV Perkin Elmer with Flow Injection Hydride Generation System FIAS 400) after digestion of drinking water samples with nitric acid and concentration of the acid solutions from 150 mL to 25 mL.

For each set of samples was prepared a blank sample using the same procedure, blank obtained with ultra pure water and 5 mL of nitric acid suprapur. The WinLab 32 soft of OPTIMA 5300 DV equipment extract the blank value of the metal from the unknown concentration. Therefore, the obtained values of the parameters represent only the concentrations from the analyzed samples.

In the study were prepared samples on three different level of concentration, using Standard Reference Materials (Quality Control Standard Perkin Elmer 21, 100 mg/L As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Sb, Se, Zn si Quality Control Standard Perkin Elmer 7A, 100 mg/L Al), nitric acid and ultra pure water. The recovery percents were situated in the range 94.5% ÷ 114.5% and were used for calculation of the results.

In table 1 are presented the detection limits obtained with the equipment and analytical methods used in the study and also the maxim admissible value for the metal concentration according to Romanian Legislation (Law 458, 2002).

Table 1. Detection limits, maxim admissible value according to Romanian Legislation and analytical techniques applied in the study

Parameter	**Al**	**As**	**Cd**	**Cu**	**Cr**	**Fe**
Max. Admissible Value (µg/L)	200	10	5	100	50	200
LOD (µg/L)	1	0.3	0.4	0.6	0.5	0.3
Analytical technique	ICP-EOS	ICP-EOS-FIAS	ICP-EOS	ICP-EOS	ICP-EOS	ICP-EOS
Parameter	**Mn**	**Ni**	**Pb**	**Se**	**Sb**	**Zn**
Max. Admissible Value (µg/L)	50	20	10	10	5	5 000
LOD (µg/L)	0.1	1	1	0.4	0.1	0.5
Analytical technique	ICP-EOS	ICP-EOS	ICP-EOS	ICP-EOS-FIAS	ICP-EOS-FIAS	ICP-EOS

3. Results and Discussions

The quality of drinking water provided by AQUATIM Company was situated in the limits imposed by the Romanian Legislation. The results obtained in the monitoring program of metallic parameters in drinking water samples collected from the customer taps are compare with maximum admissible values for metal concentrations according to Law 458/2002 (with subsequent modifications) on water quality for human consumption.

The monitoring data show important influences on the tap water quality of the material used in the internal distribution system within the customer buildings. The data indicates real problems for Cu, Fe and Pb.

The materials used in drinking water domestic installations in the selected points for tap water survey were galvanized steel, lead, copper, steel, cast iron, polyvinyl chloride (PVC). In the local public network, in same points, the majority pipes consist of galvanized steel, cast iron, high-density polyethylene (PEHD) and polyethylene (PE) (table 2). The materials responsible for metals leaching are cast iron (Fe. Mn), copper (Cu), lead (Pb), galvanized sheet (Fe, Mn, Ni, Zn).

Table 2. Materials used in domestic distribution and public network systems

Type of material	Cast iron	PEHD	Copper	Pb	PVC	Steel	PE
Primary material of domestic distribution system	**7.2%**	**-**	**32.1%**	-	13.3%	**21.4%** Galvanized sheet	25% pexal
Primary material of public network	**41.9%**	3.2%	-	-	9.7%	12.9%	32.3%
Branch pipe	**-**	3.5%	-	**17.9%**	-	28.6%	50%
Control points AQUATIM	**33.3%**	60%			1%		

In the tables 3 to 7 are presented statistical data (minim, maxim, mean, median values, porcent of non-compliance samples) for first draw, fully flushed and random daytime results.

In thirty-two samples collected with random daytime procedure from the histhorical center of Timisoara City, 28.13 % are non-compliance samples (highest concentrations than admissible values for Cu, Fe, Mn and Pb) (Table 3). These data show that internal distribution systems affect drinking water quality. In order to use a better drinking water, the tap must be washed before the water is collected.

Table 3. Random Daytime Data, June 2010 (µg/L)

Parameter / Element	Al	Cu	Fe	Mn	Pb	Zn
Minimum value	13.3	0.9	5.9	1.2	< 1	2.1
Maximum value	67.7	**1064**	**602**	**314**	**16.5**	2404
Median value	28	11.8	38.8	5	< 1	124
Mean value	31.5	57.4	90.3	20.5	2	335
Standard deviation	11.9	184	131	56.7	3.2	565
Maximum admisible value	200	100	200	50	10	5000
% of Non-compliance samples /element	0	**9.38%**	**12.5%**	**6.35%**	**2.13%**	0
No. of Non-compliance samples /element	0	**3**	**4**	**2**	**1**	0
Total % of Non-compliance samples	**28,13 %**					
Total of Non-compliance samples	**9**					

Problems occur in thirty-three tap water samples collected with first draw sampling procedure, for which some of the obtained values of Cu, Fe, Ni, Pb are higher than admissible values indicating an influence of the local equipments (pipe, tap, fitting) to the drinking water quality (Tables 4 and 6).

Table 4. First Draw Data, February 2010(µg/L)

Parameter / Element	Al	Cu	Fe	Mn	Ni	Pb	Zn
Minim value	22.4	4.7	10.7	0.5	< 1	< 1	0.5
Maxim value	**735**	**397**	**1633**	49.7	**23.2**	**22.4**	1881
Median value	82	24.3	65.5	4.5	< 1	1.5	88.2
Mean value	101	80.7	186	7.2	5.2	4.2	321
Standard deviation	118	111	365	9.3	5	5.3	449
Maxim admisible value	200	100	200	50	20	10	5000
% of Non-compliance samples /element	**3.03%**	**27.27%**	**15.15%**	0	**3.03%**	**15.15%**	0
No. of Non-compliance samples /element	**1**	**9**	**5**	0	**1**	**5**	0
Total % of Non-compliance samples	**45,45 %**						
Total of Non-compliance samples	**15**						

It is not recommended to use first draw water for cooking or drinking purposes, because in this water can be leached high concentrations of metals depending on the retention time and material type. In the tap water collected from copper cold water pipes high concentrations of copper was recorded, much more than 100 µg/L, which is the maximum admissible value in Drinking Water Romanian Law. If the tap is washed more than 5 minutes, the copper content in tap water decreases, being situated under the limit.

Table 5. Fully Flushed Data, February 2010(µg/L)

Parameter / Element	Al	Cu	Fe	Mn	Ni	Pb	Zn
Minim value	22.7	2.5	15.2	3.9	< 1	< 1	0.5
Maxim value	**329**	52.8	**294**	12.5	3	**11.6**	873
Median value	82.9	6.3	36.1	4.3	< 1	< 1	3.6
Mean value	90.1	8.8	68.6	6.2	< 1	2.2	47.3
Standard deviation	53.7	9.2	68.2	4.6	0.6	3.0	152
Maxim admisible value	200	100	200	50	20	10	5000
% of Non-compliance samples /element	**3.03%**	0	**9.1%**	0	0	**6.06 %**	0
No. of Non-compliance samples /element	**1**	0	**3**	0	0	**2**	0
Total % of Non-compliance samples	**12,1%**						
Total of Non-compliance samples	**4**						

Table 6. First Draw Data, June 2010(µg/L)

Parameter / Element	Al	Cu	Fe	Mn	Ni	Pb	Zn
Minim value	17.8	5.4	7,5	1	< 1	< 1	0.5
Maxim value	199	**1029**	**589**	20.1	**32.7**	**36**	1570
Median value	28.4	35	60	3.9	< 1	< 1	340
Mean value	40.5	125	106	6.7	4.8	4.5	470
Standard deviation	37	210	130	5.3	8.6	9.5	398
Maxim admisible value	200	100	200	50	20	10	5000
% of Non-compliance samples /element	0	**39.1%**	**17.4%**	0	**8.7%**	**13%**	0
No. of Non-compliance samples /element	0	**9**	**4**	0	**2**	**3**	0
Total % of Non-compliance samples	**56,5%**						
Total of Non-compliance samples	**13**						

Another problem observed was related to iron content, possible leached by the cast iron or unprotected steel pipes. In addition, branch pipe and short piece of lead old pipe included in the internal distribution system has a negative influence on the tap water quality

Table 7. Fully Flushed Data, June 2010 (μg/L)

Parameter / Element	Al	Cu	Fe	Mn	Ni	Pb	Zn
Minim value	15	1.8	7.1	1.3	< 1	< 1	0.5
Maxim value	63.5	69.5	159	20.8	< 1	**12.1**	151
Median value	31.7	5.6	26.1	3.1	< 1	< 1	15.2
Mean value	34.9	11.2	41.8	4.2	< 1	1.6	32.8
Standard deviation	13.5	15.1	45.2	4	0	3.2	38.1
Maxim admisible value	200	100	200	50	20	10	5000
% of Non-compliance samples /element	0	0	0	0	0	**8.7%**	0
No. of Non-compliance samples /element	0	0	0	0	0	**2**	0
Total % of Non-compliance samples	**8.7%**						
Total of Non-compliance samples	**2**						

The metal concentrations recorded in tap water collected with tap flushing procedure were situated, almost in all cases, in the limit values. The values of Pb in the flushed tap waters were situated in most cases below the detection limit of the method used (1 μg/L) or were recorded very low values, close to the limit of detection. Only 2 samples (same in both compagnes) had Pb concentrations higher than the admissible limit (tables 5 and 7).

Table 8. Fully Flushed Data – Control Points, February 2010 (μg/L)

Parameter / Element	Al	Cu	Fe	Mn	Ni	Pb	Zn
Minim value	22.7	2.5	15.2	3.9	< 1	< 1	0.5
Maxim value	**329**	52.8	**294**	12.5	3	**11,6**	873
Median value	82.9	6.3	36.1	4.3	< 1	< 1	3.6
Mean value	90.1	8.8	68.6	6.2	< 1	2.2	47.3
Standard deviation	53.7	9.2	68.2	4.6	0.6	3.0	152
Maxim admisible value	200	100	200	50	20	10	5000
% of Non-compliance samples /element	**6.66%**	0	**20%**	0	0	**13.33%**	0
No. of Non-compliance samples /element	**1**	0	**3**	0	0	**2**	0
Total % of Non-compliance samples	**26.66%**						
Total of Non-compliance samples	**4**						

In tables 8 and 9 are presented results from control points samples recorded in February and June 2010. Samples were collected with fully flushed procedure. The data shows high contents for Al, Fe and Pb in some points (27% - winter champagne; 14% - summer period; non-compliance samples).

Table 9. Fully Flushed Data – Control Points, June 2010 (μg/L)

Parameter / Element	Al	Cu	Fe	Mn	Ni	Pb	Zn
Minim value	17.8	1.8	19.5	2	< 1	< 1	5.8
Maxim value	65.5	80.4	**290**	22.8	2.2	**12.9**	2681
Median value	26	7.4	47.5	5.1	< 1	< 1	83
Mean value	29.3	15.5	81.4	7.3	< 1	2.5	338
Standard deviation	12.8	19.7	75.9	6.5	0.5	3.7	672
Maxim admisible value	200	100	200	50	20	10	5000
% of Non-compliance samples /element	0	0	**14.3%**	0	0	**7.1%**	0
No. of Non-compliance samples /element	0	0	**2**	0	0	**1**	0
Total % of Non-compliance samples	**14,3%**						
Total of Non-compliance samples	**2**						

4. Conclusions

The quality of drinking water provided by AQUATIM Company was situated in the limits imposed by the Romanian Legislation.

High concentrations of Cu, Fe, Ni and Pb in first draw samples were recorded in apartments where the majority of the material for installation was copper, cast iron, galvanized sheet and the branch pipe was made from Pb.

In samples collected from customer's tap the percent of non-compliance samples was around 50% in first draw, 10% in fully flushed and 25% in random daytime samples.

The customers were advised to don't use the first draw water for cooking and drinking purpose, because in this water can be leached high concentrations of metals depending on the retention time and material type. Water volume and time of stationary are the most important parameters that determine the concentration of metallic elements released from the materials of consumer distribution installations.

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.

If the limit values of metals in drinking water are exceeded the recommendations are either flushing the tap more than five minutes and then use water for household consumption or replacement of the pipes and fittings in both, local or domestic distribution systems.

This research demonstrates 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 safe drinking water. Subtle reactions between water and different materials used for its transport can result in alterations that affect the finale quality delivered to consumers.

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