# Influence of Metallic Pipes from Domestic Distribution System on the Tap Water Quality

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*The present paper summarizes the procedure and the results of a study concerning the influence of domestic installation systems on tap water quality in Brasov, Romania. Random daytime sampling procedure (RDT) was applied and 44 tap water samples were collected at the consumption point in March 2013. The monitoring data shows that the material used in the internal distribution system of the consumers' buildings significantly impacted on the tap water quality in terms of metal pollution.*

*Keywords: tap water quality, metals, random daytime sampling procedure (RDT) Brasov*

It is generally accepted that drinking water quality is of relevant importance for human health, in terms of composition and safety risks [1]. Directive 98/83/EC sets quality standards for drinking water. The directive allows Member States to adapt the monitoring of drinking water to local conditions, in order to evaluate its safety to consumption, to detect any critical problems, to introduce the measures for obtaining good quality drinking water [2].

The main problems related to drinking water quality are associated with the conditions of the water supply networks, the pollution of raw water and in particular the contamination of groundwater with pollutants of both anthropogenic and natural origin [3,4].

As tap water from the municipal supply system is the main source of drinking water for most Romanian consumers, and since drinking water quality is usually monitored only within the distribution network but not inside households at the consumption point, observing tap water at the final stage appears as a necessary step towards ensuring its quality. Many studies around the world reported tap water contamination as a result of its contact with materials used both in the municipal distribution system and in consumers' buildings [5, 6].

Tap water quality monitoring is achieved applying various sampling techniques depending on the purpose of the study. The Random Daytime (RDT) Procedure (1$^{st}$ liter randomly collected during office hours, without fixed stagnation or prior flushing) has been developed in order to best reflect human exposure to drinking water consumption [7, 8].

Brasov Municipality is situated in the central eastern part of Romania, in the curvature of the Carpathian Mountains, having approximately 250,000 inhabitants. Around 80% of the drinking water produced by Brasov Water Company is supplied by Tarlung Water Plant, using the surface water from Tarlung Lake as the main source of raw water. Other raw water sources consist of Ciucas, Solomon, Racadau Springs and 30 deep drillings in Sinpetru area.

Within the study, a total of 90 tap water samples were collected in Brasov in order to get an assessment of the current metal contamination levels of drinking water at the consumer's tap. The sampling campaign carried out in March 2013 investigated metals as main parameters, as stipulated in the Romanian legislation [9], in accordance with European Drinking Water Directive 98/83/EC.

This paper focuses on the part of the monitoring program related to RDT procedure, which included 44 samples from different sampling points selected from private companies offering food services. The samples were collected within the working hours without prior tap flushing. Metallic elements such as Al, As, Cd, Cu, Cr, Fe, Mn, Ni, Pb, Se, Sb and Zn were analyzed using inductively coupled plasma optimal emission spectrometry technique (ICP-EOS), carried out at the National Research and Development Institute for Industrial Ecology (ECOIND), Control Pollution Department in accreditation system according to SR EN ISO 17025/2005 referential standard.

## Experimental part

During the current study, a tap water quality monitoring program was developed in Brasov through a sampling campaign in March 2013. In order to achieve a baseline for drinking water quality, multiple samples were collected as follows: raw water samples (surface water of the Tarlung accumulation lake, spring water from Racadau and Solomon sources, water from drilling points Sanpetru - Harman), drinking water produced by Tarlung Water Plant of Brasov Water Company, 11 samples of drinking water from storage tanks located in Dealul Melcilor (4), Darste (2), Iepure (1), Rulmentul (1), Solomon (1) and Lupan (1). The samples were collected owing to the qualified personnel of Brasov Water Company, who have kindly collaborated during the development of the monitoring program.

Drinking water samples were collected from consumers using random sampling procedure RDT applied in 44 locations, situated mostly within Tarlung distribution zone. The points have been selected mainly from units using drinking water for food manufacturing / processing, such as: fast-foods, bakery/pastry units, bars/pubs, pharmacies, public markets (trading vegetables, fruit). The selection of sampling points (depending on the distribution zone and

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| Parameter | Al | As | Cd | Cu | Cr | Fe |
|---|---|---|---|---|---|---|
| Max. Admissible Value (μg/L) | 200 | 10 | 5 | 100 | 50 | 200 |
| LOD (μg/L) | 1 | 0.2 | 0.1 | 0.3 | 0.4 | 0.6 |
| 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 | 0.1 | 0.3 | 6 |
| Analytical technique | ICP-EOS | ICP-EOS | ICP-EOS | ICP-EOS-FIAS | ICP-EOS-FIAS | ICP-EOS |

**Table 1**
DETECTION LIMITS, MAXIMUM ADMISSIBLE VALUE ACCORDING TO ROMANIAN LEGISLATION AND ANALYTICAL TECHNIQUES APPLIED IN THE STUDY

| Sample No. | Lining Material | Main material within municipal network | Sample No. | Lining Material | Main material within municipal network |
|---|---|---|---|---|---|
| 1RDT | Galvanized pipe+plastic | Steel | 23RDT | Copper | Steel; HDPE |
| 2RDT | No data | Steel; HDPE | 24RDT | No data | Steel |
| 3RDT | PPR + galvanized pipe | Steel; HDPE | 25RDT | Metal pipes | Steel |
| 4RDT | Copper + Galvanized pipe | Steel | 26RDT | PExAL | Steel; HDPE |
| 5RDT | Copper | Steel | 27RDT | Metal pipes | Steel |
| 6RDT | Zinc coated pipe | Steel | 28RDT | Zinc coated pipe | Steel; Cast iron |
| 7RDT | Copper | Steel | 29RDT | Metal pipes | Steel; Cast iron |
| 8RDT | Metal pipe | Steel | 30RDT | Copper | Steel; Cast iron |
| 9RDT | PExAL | Steel +HDPE | 31RDT | Zinc coated metal pipe | Steel; Cast iron |
| 10RDT | Metal pipe | Steel | 32RDT | Metal pipe | Steel; HDPE |
| 11RDT | PExAL | Steel | 33RDT | PExAL | Steel; HDPE |
| 12RDT | PExAL | Steel | 34RDT | Copper | Steel |
| 13RDT | Copper | Steel; Cast iron | 35RDT | Pexal + Steel | Steel |
| 14RDT | Galvanized pipe | Steel; HDPE | 36RDT | Pexal | Steel; Cast iron |
| 15RDT | PVC | Steel; HDPE | 37RDT | PPR | Steel; Cast iron |
| 16RDT | Plastic, possible Copper | Steel; HDPE | 38RDT | PP | Steel; HDPE |
| 17RDT | PExAL | Steel; HDPE | 39RDT | No data | Steel; HDPE |
| 18RDT | PExAL | Steel; HDPE | 40RDT | PP | Steel; HDPE |
| 19RDT | Copper | Steel; HDPE | 41RDT | Pexal | Steel; HDPE |
| 20RDT | PExAL | Steel; HDPE | 42RDT | No data | Steel; HDPE |
| 21RDT | Metal pipes | Steel | 43RDT | No data | Steel |
| 22RDT | Zinc coated metal pipe | Steel; HDPE | 44RDT | No data | Steel; HDPE |

**Table 2**
MATERIALS USED IN TAP WATER SUPPLY NETWORK FOR SAMPLES COLLECTED BY RANDOM DAYTIME TECHNIQUE

the type of materials from municipal supply system) and the sampling procedure (1RDT - 44RDT) were conducted by specialists of Water, Soil and Wastes Pollution Control Laboratory from the National Research and Development Institute for Industrial Ecology, Bucharest.

The samples were mineralized using Suprapure Nitric Acid (3 mL Nitric Acid were added to a 150 mL subsample). The solutions thus prepared were analyzed for the simultaneous determination of Al, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn contents ICP-EOS technique on an Optima 5300 DV Perkin Elmer Spectrometer. The method applied is rapid, precise and reproducible. Unlike other methods used for quality control of drinking water [10, 11], the method allows the simultaneous determination of several metals at trace level. As, Se and Sb were analyzed using Flow Injection Hydride Generation System (FIAS 400 Perkin Elmer) coupled to ICP-EOS [12].

Calibration curves were performed using Certified Reference Materials type Multi-element standard solution for ICP (CPAChem producer), 100 mg/L. The quality control of the data was carried out according to Quality Control Standards 21A and 7A, 100 mg/L, produced by Perkin Elmer. Table 1 presents the detection limits obtained with the equipment, the analytical methods used in the study and also the maximum admissible value for the metal concentration according to Romanian Legislation [9].

The information regarding the materials used in the municipal network was accurately provided by Brasov Water Company, the data being included in a program of surveillance in order to replace the damaged sections. The information about materials from domestic distribution systems reported by the consumers is, in some cases, approximate as owners do not always know the type of material used. In the municipal distribution system, most pipes consist of steel, cast iron and high-density polyethylene (HDPE), while the materials used in domestic installations were galvanized steel, copper, cast iron, polyvinyl chloride (PVC), PExAL (aluminum laminated polyethylene), reticular polypropylene (PPR) (table 2).

## Results and discussions

The quality of the drinking water provided by Brasov Water Company was situated for all parameters within the limits imposed by the national legislation.

In all samples under analysis, concentrations of As, Cd, Cr, Ni, Pb, Se and Sb in tap water ranged below the limit of detection of the analytical method (table 1).

Each set of results was statistically processed, aiming to obtain as much information as possible. The mean, the median and the standard deviation were calculated for each data set and were compared to the maximum value allowed by Romanian Drinking Water Law [9]. Afterwards, the number of non-compliant samples was expressed as a percentage of the total number of samples.

It is highlighted in table 3 that drinking water complies with the standards for tap water quality in a proportion of 75%, ranging below the limits imposed by Romanian Law [9]. The data obtained for 25% of the 44 random daytime samples indicated drinking water pollution with Cu (10 samples, 22.7%) and Fe (one sample), according to the data presented in table 3.

| Parameter | Al | Cu | Fe | Mn | Zn |
|---|---|---|---|---|---|
| Minimum value | < 1 | < 0.5 | <0.3 | < 0.1 | 4.3 |
| Maximum value | 112 | **280** | **1520** | 36.9 | 389 |
| Average value for 25% of samples | 20.3 | 1.33 | 5.98 | 1.35 | 10.6 |
| Average value for 75% of samples | 59.4 | 58.4 | 74.8 | 10.8 | 95.1 |
| Median value | 47.9 | 5.5 | 21.6 | 8.3 | 49.6 |
| Mean value | 49.6 | 44.2 | 57.6 | 8.4 | 74 |
| Standard deviation | 25 | 69.8 | 226 | 6.57 | 81.9 |
| Maximum admissible value | 200 | 100 | 200 | 50 | 500<br>0 |
| No. of non-compliance samples/element | 0 | **22.72** | **2.27** | 0 | 0 |
| % non-compliance samples / element | 0 | **10** | **1** | 0 | 0 |
| Total of non-compliance samples (%) | | | **25** | | |
| Total of non-compliance samples | | | **11** | | |

**Table 3**
METAL CONCENTRATIONS IN RANDOM DAYTIME SAMPLES, (μg/L)

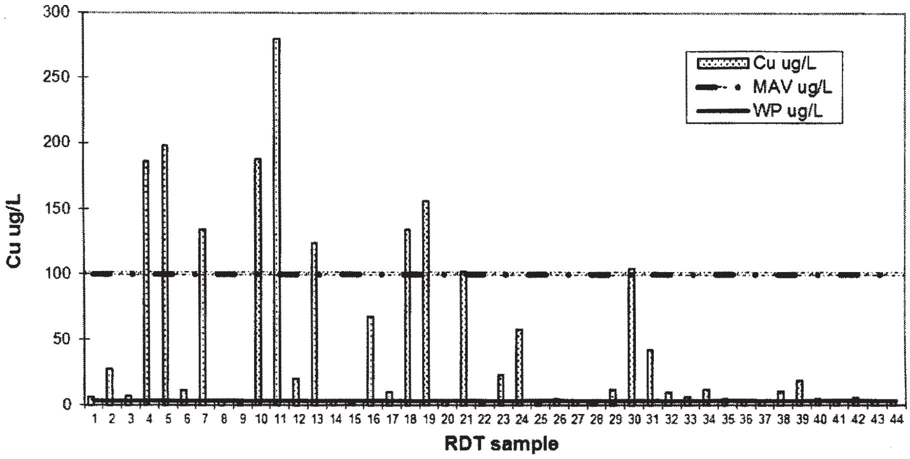


Fig. 1. Copper concentrations in tap water

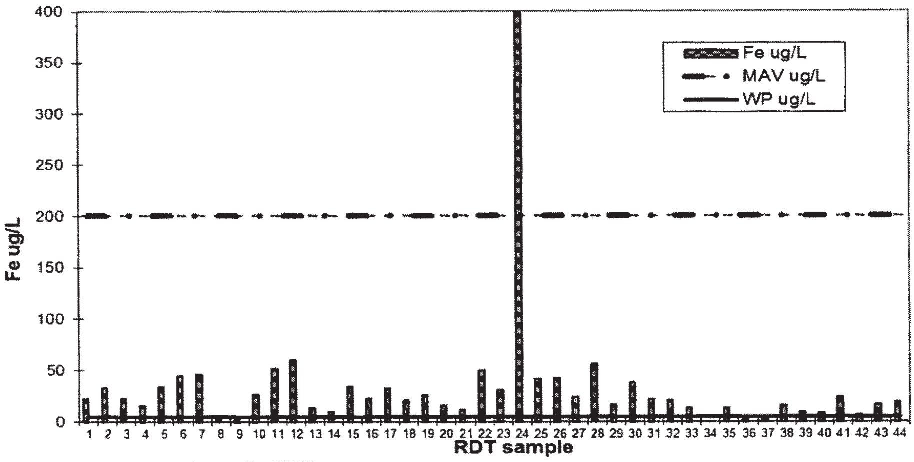


Fig. 2. Iron concentrations in tap water

High concentrations of Cu (more than 100 μg/L, which is the maximum admissible value stipulated by Romanian Drinking Water Law) and Fe were recorded in households where the main material used in the domestic distribution system consists in copper or cast iron (fig. 1 and fig. 2).

The results regarding Cu, Fe, Al and Mn were *graphically represented* comparing the values obtained for RDT samples with the maximum allowed value (MAV) in drinking water law, and also with the average concentration in drinking water stored before being delivered to the consumer (WP-Water Plant).

Data represented in figure 1 shows obvious high concentrations of copper in certain locations, which are exclusively caused by the corrosion of the materials used in consumers' domestic network since copper is not used in the composition of the municipal distribution system (neither for the main pipes nor for branch pipes) [13,14]. Copper pipes are used in residential homes for the central heating system, not just for the hot water circuit, but also for cold water transport pipes. As reported by previous studies conducted within other Romanian municipalities, the percentage of copper pipes in consumers' domestic installations is relatively high. Taking into account that the maximum admissible limit for Cu is lower than in the European legislation (2000 mg/L), frequent exceeding regarding copper indicator can be observed, both in samples collected via RDT and in samples collected after overnight stagnation [15-17].

As regards iron content, the highest value reported was 1520 μg/L (24RDT), 8 times higher than the maximum admissible value (fig. 2). The main material used in the municipal network is steel, but there is a lack of data regarding the materials in consumers buildings. In this particular case, the manufacturing space is rented by a pretzel producer and the tenant has no knowledge of the pipes' material inside the unit. The high concentration of iron obtained in tap water, which is used in the manufacturing process, indicates the need to replace the inner pipes with a material that does not allow metals levigation (e.g. PE - polyethylene, PPR).

Figure 2 shows iron enrichment in some sampling points compared to the average value for stored water before pumping into the network. Iron enrichment is due to corrosion of materials (unprotected steel, cast iron), which

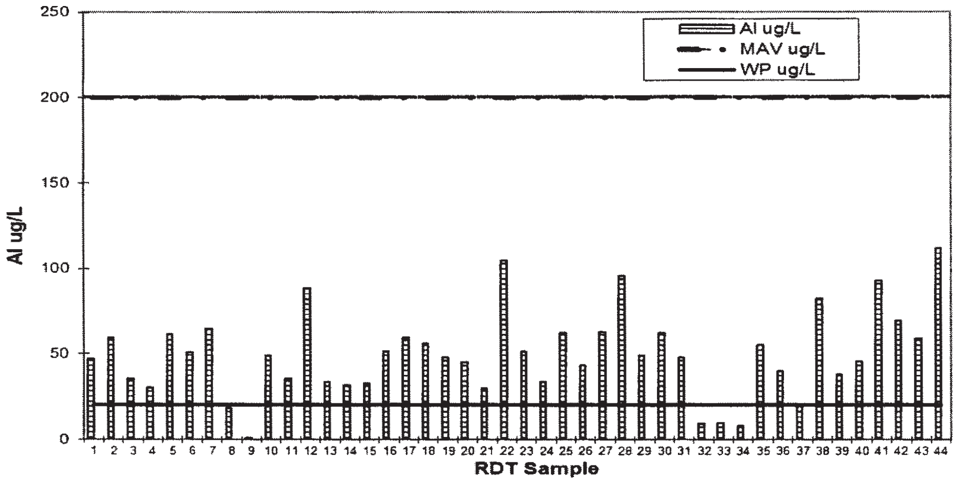


Fig. 3. Aluminium concentrations in tap water

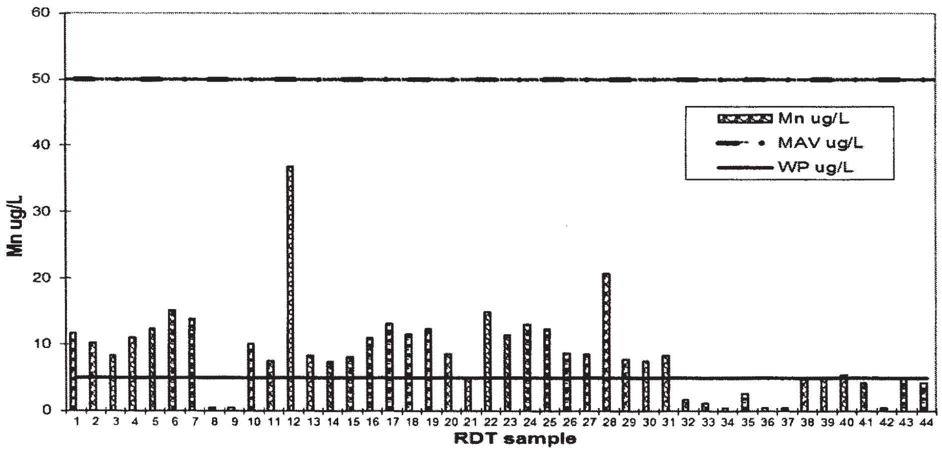


Fig. 4. Manganese concentrations in tap water

belong to either the municipal or domestic distribution system [18, 19]. There are sampling points in which the data provided by consumers indicates the presence of plastic pipes, but the concentration of several metals (Fe, Mn) (ex. 12RDT) significantly exceeds the average value for the stored water. Such cases require further evaluation in order to clearly identify the source of contamination by analyzing the water from branch pipes (contribution of the municipal distribution system) and consumer samples at the same time.

The aluminum concentration detected in tap water samples (fig. 3) originates from two sources:

- residual aluminum from the aluminum sulphate treatment of the supplied water;
- PExAL pipes connections whose internal and external layers are made of cross-linked polyethylene, while the middle layer material is aluminum.

About 23% of the materials used in domestic installations consist of PExAL. Particular attention should be paid to the joints between pipes, where the middle layer can come into direct contact with the drinking water.

The manganese concentration in drinking water samples ranges, in a proportion of 66%, above the average of the storage tanks, but totally below MAV in drinking water (fig. 4). The sources of manganese enrichment are cast iron pipes and galvanized steel.

## Conclusions

The project included in the CORE Program attempted to monitor the metal content (Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Se, Sb and Zn) of tap water collected both from consumers using random daytime sampling procedures and from the municipal distribution network in Brasov (produced and stored drinking water) for the purpose of identifying the issues that may affect public health.

The monitoring data shows important influences of the material used in the internal distribution system within the consumers buildings on the tap water quality as a result of stagnation processes and pipe corrosion due to lack of system maintenance.

Intermittent use and stagnation of drinking water in residential installations can produce the deterioration of the chemical quality resulting in increased metal concentrations.

The consumers were advised not to consume stagnated water for cooking and drinking purposes and to replace the pipes (made of copper, cast iron, or unprotected steel) from all domestic distribution systems.

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