

PILOT-SCALE TESTS OF THE EFFECT OF WATER QUALITY ON SELECTED MATERIALS IN CONTACT WITH DRINKING WATER

Jozef Kriš¹, Karol Munka², Monika Karácsonyová², Margita Slovinská²,
Stanislav Varga², Dušan Rusnák¹

¹ Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering,
Slovak University of Technology Bratislava, Radlinského 11, 813 68 Bratislava, Slovak Republic

² Water Research Institute, Nábr. arm. gen. L. Svobodu 5, 812 49 Bratislava, Slovak Republic

Abstract

Drinking water in the distribution system is subject to a number of physical-chemical changes that may have significant adverse effects on its quality. The extent and intensity of the changes depends on the operation of distribution system and the interaction between water and pipe material.

The pilot-scale tests of the effect of water quality on materials in contact with drinking water were performed at two group water supply systems Nova Bystrica - Čadca - Žilina and Hriňová - Lučenec – Fiľakovo which differ in quality and disinfection methods (chlorine, chlorine dioxide) of water supplied. The following materials were used to assess the effect of water quality: steel, cast iron, polyethylene and polypropylene. The exposure time ranged from 210 to 363 days. The evaluation of the interaction between water and materials was based on determining the mass loss in relation to the mass of test standards before the exposure, expressed in percentage.

Key words: *interaction between water and materials, pilot-scale tests, mass loss*

1. INTRODUCTION

Drinking water in the distribution system is subject to a number of physical-chemical changes that may have significant adverse effects on its quality. The extent and intensity of the changes depends on the operation of distribution system, but especially on the properties of water distributed through the system. These changes are influenced considerably by the interaction between water and pipe material.

Each material used in manufacturing, packaging and distribution of drinking water is subject to government regulations. The aim of regulations is to limit the risk of adverse effects on human health arising from the consumption of drinking water. The basic requirement of these regulations is that the material, products and technologies used for the treatment, accumulation and distribution of drinking water do not reduce the quality properties specified under the relevant drinking water standards and decrees. Material intended for the contact with drinking water shall not contain pathogenic or selected conditionally pathogenic microorganisms and shall not be a source of microbial or other contamination of drinking water. In addition, materials shall not affect the quality, sensory properties and biological value of drinking water (Council Directive 1998), (Government Regulation 2010), (STN 757 151).

2. ASSESSMENT OF MATERIALS IN CONTACT WITH DRINKING WATER

The assessment of materials in contact with drinking water is based on a model migration test, where the material is in contact with water (meeting the criteria defined) at a certain temperature and a constant ratio of water volume to the surface of tested material. The duration of a migration test is specified based on the expected contact of material with drinking water under the real conditions; in case of short contact no longer than 24 hours (Government Regulation 2004). The migration tests are usually performed three times in succession using the same sample in order to monitor the migration of contaminants in relationship with time. In addition to deionized or demineralized water (required

water quality), the filter systems are also tested using drinking water. In such cases, the test system is connected to a source of drinking water. Sample of water (aqueous extract) that flowed through the system like under the real conditions is taken for an analysis. The effect of materials on drinking water quality indicators is monitored, and aqueous extracts taken from the model tests are processed analytically.



Fig 1. Pilot scale test model for evaluation of the interaction between water and materials (Photo - Gálik)

3. PILOT-SCALE ASSESSMENT OF THE EFFECT OF WATER QUALITY ON SELECTED MATERIALS

The service life of materials plays an important role in distribution of drinking water. The only method that is used to define the service life of steel and cast iron pipes is based on the determination of corrosion rate between 30 and 365 days of exposure (corrosion rate – pipe service life estimate). Precise determination of a service life of pipe along with the assessment of interaction between water on the pipe material requires longer exposure times. A migration test cannot be used to evaluate the service life of materials. Based on this fact, the pilot test of the impact of water quality on selected types of materials was carried out. The exposure times ranged from 210 to 426 days. The following materials were tested: steel, cast iron, polyethylene and polypropylene. Pilot tests were conducted using the same equipment as for the corrosion tests (Munka 2002), (Munka 2005).

Group water supply systems Nová Bystrica-Čadca-Žilina and Hriňová-Lučenec-Fil'akovo including a branch to Detva were selected for the pilot assessment of the impact of water quality on the above-mentioned pipe materials. The group water supply lines selected for the tests are different in quality of drinking water transported as well as in disinfection methods applied. Testing devices were installed in the group water supply system Nová Bystrica-Čadca-Žilina at the outlet of the water reservoir in Nová

Bystrica water treatment plant (WTP) and in the Považský Chlmec Water Reservoir. For the group water supply system Hriňová -Lučenec-Fil'akovo with a branch to Detva, water reservoirs in Hriňová water treatment plant and Ľuboreč were selected for the tests. Pilot tests of each material were carried out at two different exposure times ranged from 210 to 426 days.

Tests of material in the water supply system Nová Bystrica-Čadca-Žilina:

steel:	exposure time 216 and 426 days
cast iron:	exposure time 210 and 328 days
polyethylene:	exposure time 210 and 328 days
polypropylene:	exposure time 210 and 328 days

Tests of material in the water supply system Hriňová-Lučenec-Fil'akovo with a branch to Detva:

steel:	exposure time 238 and 363 days
cast iron:	exposure time 238 and 363 days
polyethylene:	exposure time 238 and 363 days
polypropylene:	exposure time 238 and 363 days

The assessment of interaction between water and material was done based on determining exposure loss according to the following procedure (Equation (1)):

$$mK = m_0 - mBU \quad (1)$$

m_0 – mass of a test standard before exposure

mBU – mass of a test standard after exposure (without sediments)

mK – exposure mass loss

The test standards were processed after exposure as described in the Annex A, STN 75 7151 Water Quality - Requirements for water quality in piping systems. Exposure loss shows the resistance of material to water (Munka 2002), (Munka 2005). The article presents the assessment based on the exposure losses in relation to the mass of a test standards before exposure, expressed as a percentage (percentage exposure losses) using the following relation (Equation (2)):

$$mK(\%) = [(m_0 - mBU)/m_0] \cdot 100 \% \quad (2)$$

4. WATER QUALITY IN MONITORED SAMPLING SITES OF THE GROUP WATER SUPPLY SYSTEMS

Group water supply system Nová Bystrica-Čadca-Žilina

During the pilot assessment of the impact of water quality on selected materials, the pH value ranged from 7.40 to 8.00 at the monitored sampling sites of this water supply system; ANC 4,5 (acid neutralizing capacity) = 1.45-2.00 mmol/l and calcium concentration = 30-40 mg/l. The water temperature reached 3.7 to 9.2 °C depending on the season. Water distributed from the water treatment plant in Nová Bystrica was characterized by a low content of organic substances (CODMn = 1.1-1.7 mg/l), nitrates (2.1 to 3.6 mg/l), chlorides (1.0 to 6.4 mg / l) and sulfates (18-25 mg/l). During that period, the iron concentrations were measured below 0.1 mg/l, manganese < 0.06 mg /l, ammonium ions <0.07 mg /l, turbidity <1.0 FTU and nitrites <0.01 mg /l. The concentrations of chlorine dioxide

were in the range between 0.20 and 0.50 mg/l at the inlet of the group water supply system. Chlorine dioxide concentrations in Považský Chlmec Water Reservoir were measured below 0.02 mg/l, and only one sampling showed the concentration of 0.05 mg/l.

Group water supply system Hriňová-Lučenec-Fil'akovo with a branch to Detva

Water from the Hriňová Water Reservoir was different mainly in low mineralization, low alkalinity (0.35-0.60 mmol / L) and low calcium concentration (13 -23 mg / L) as compared to water from the Nová Bystrica Water Reservoir in terms of quality requirements for water transported through the supply systems. The pH values reached the level of 6.50 to 8.80 at the monitored sampling sites; water temperature ranged from 3.3 to 16.4 ° C; CODMn = 1.1 – 2.2 mg / l; iron from 0.05 to 0.50 mg/l; manganese from 0.03 to 0.09 mg/l; ammonium ions from 0.05 to 0.28 mg/l; nitrites from 0.01 to 0.16 mg/l; nitrates from 4.4 to 7.9 mg/l; chlorides from 1.0 to 4.3 mg/l and sulphates from 31 to 38 mg/l. Chlorine concentration at the outlet of the WTP Hriňová during the monitoring period ranged from 0.11 to 0.21 mg/l and from 0.02 to 0.05 mg/l in Ľuboreč Water Reservoir.

5. ASSESSMENT OF THE IMPACT OF WATER QUALITY ON THE MATERIALS EXPOSED IN THE GROUP WATER SUPPLY SYSTEM HRIŇOVÁ-LUČENEC-FIL'AKOVO INCLUDING A SUPPLY BRANCH TO DETVA

The results of the pilot assessment of the impact of water quality on selected materials clearly showed that this water had most aggressive effects on a steel material. After the 238-day exposure at the WTP Hriňová the exposure loss for steel was 16.5%, and after the 1-year exposure it reached 24.5%. Significantly lower values of exposure loss were measured for cast iron, i.e. 3.2% and 4.4% (Figure 2). The lowest impact was observed on the plastic material - polyethylene and polypropylene, where the exposure loss ranged from 0.04 to 0.05%, almost without change in exposure loss in relation to the exposure time (Figure 3).

The exposure loss for steel and cast iron was lower at the Ľuboreč Water Reservoir as compared to those exposed at the WTP Hriňová. For an exposure time of 238 and 363 days, the exposure loss for steel reached 14.2% and 17.6%, and for cast iron 2.7% and 2.8% (Figure 4). The exposure loss of polyethylene was the same as for the WTP Hriňová, i.e. 0.05%. On the other hand, the polypropylene exposure loss ranged from only 0.002 to 0.003% (Figure 5). No changes in the exposure loss of plastic material in relation to the exposure time were observed at the WTP Hriňová and Ľuboreč Water Reservoir.

The differences in exposure losses of steel between the WTP Hriňová and Ľuboreč Water Reservoir at the same exposure time were mainly due to different concentrations of chlorine, as no significant changes in water quality occurred. Differences in the exposure losses due to the effect of different chlorine concentrations on steel reached 3-5% for an exposure time of 238 days and about 5-7% for the 1-year exposure. The corrosive effect of water on cast iron was lower as compared to steel (Munka 2002).

Group Water Supply System Hriňová-Lučenec-Fil'akovo including a branch to Detva

Relationship between the mass exposure loss and the exposure time of 238 and 363 days
for selected types of material

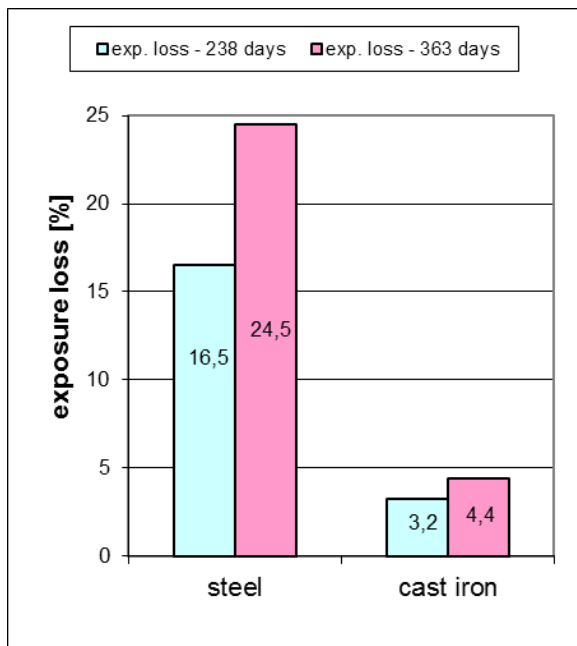


Fig. 2. WTP Hriňová - steel, cast iron

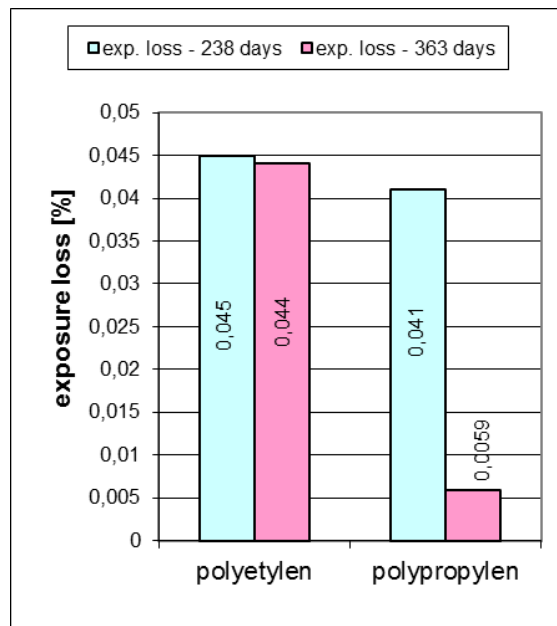


Fig.3. WTP Hriňová-polyethylene, polypropylene

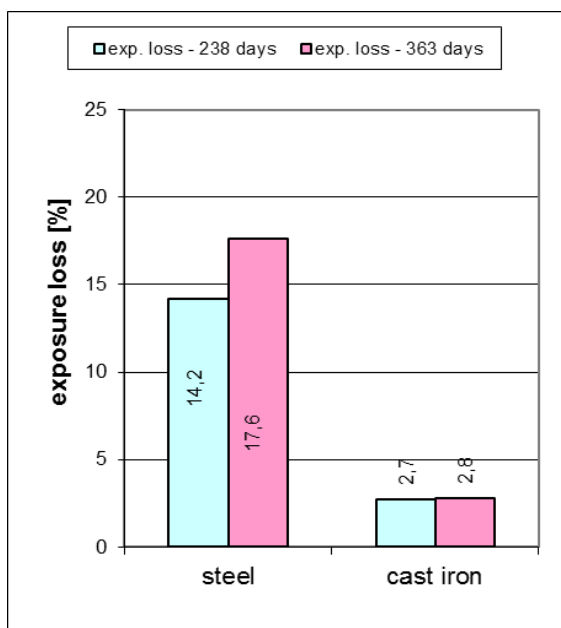


Fig.4. WR Ľuboreč - steel, cast iron

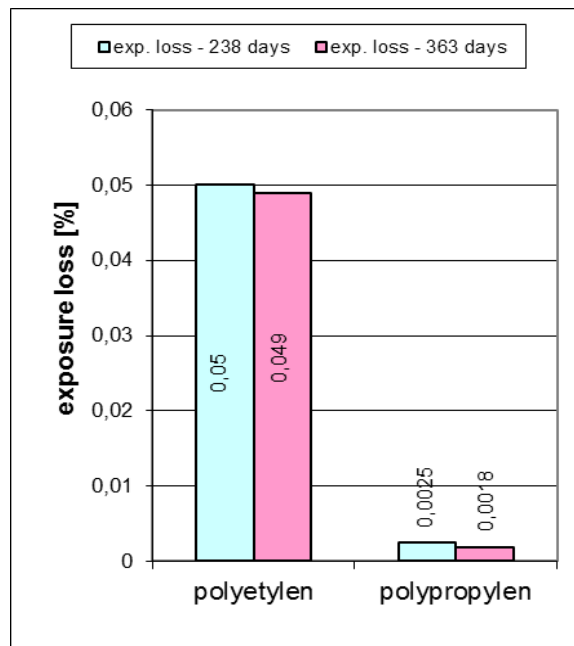


Fig.5. WR Ľuboreč-polyethylene, polypropylene

6. ASSESSMENT OF THE IMPACT OF WATER QUALITY ON MATERIALS EXPOSED IN THE GROUP WATER SUPPLY SYSTEM NOVÁ BYSTRICA-ČADCA-ŽILINA

Similarly to the impact assessment of water quality on materials performed at the group water supply system Hriňová-Lučenec-Fil'akovo with a branch to Detva, the most adverse effect of water was observed on steel material. The exposure loss for steel reached 6.7% after the 210-day exposure and 11.8% after the 328-day exposure at the WTP Nová Bystrica. Significantly lower exposure losses were observed for cast iron, i.e. 1.5% and 2.4% (Figure 6). Clearly the lowest impact was observed on plastics. The exposure losses for polyethylene ranged from 0.01 to 0.02%, and for polypropylene it was only 0.001% (Figure 7).

The exposure losses for steel material were lower by 1 % in the Považský Chlmec Water Reservoir as compared to the WTP Nová Bystrica (5.7% and 10.5%). On the other hand, the exposure losses for cast iron were higher (1.8% and 3.7%; Figure 8) as compared to the WTP Nová Bystrica (1.5% and 2.4%), despite the fact that significantly lower concentrations of chlorine dioxide were recorded in the Považský Chlmec Water Reservoir in comparison with the WTP Nová Bystrica. The exposure loss for polyethylene and polypropylene were 0.05%, and 0.02% respectively (Figure 9). The exposure losses observed for plastic material were higher at the Považský Chlmec Water Reservoir as compared to the WTP Nová Bystrica (Munka 2002).

Group Water Supply System Nová Bystrica-Čadca-Žilina

Relationship between the mass exposure loss and the exposure time of 210 and 328 days
for selected types of material

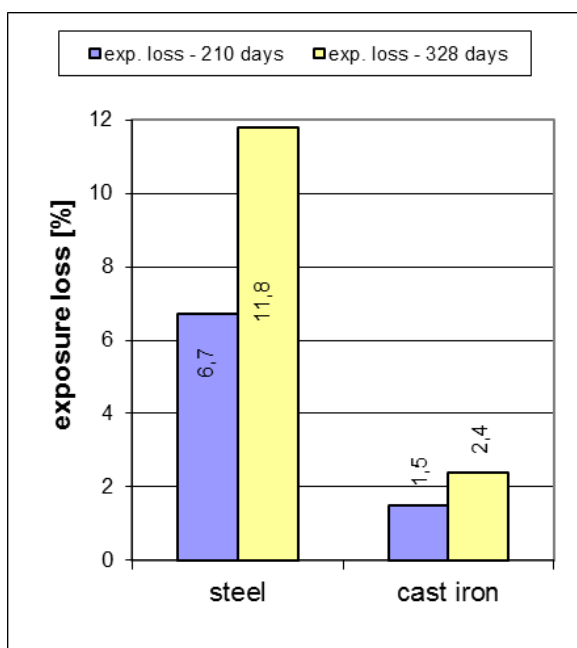


Fig.6. WTP N.Bystrica - steel *), cast iron

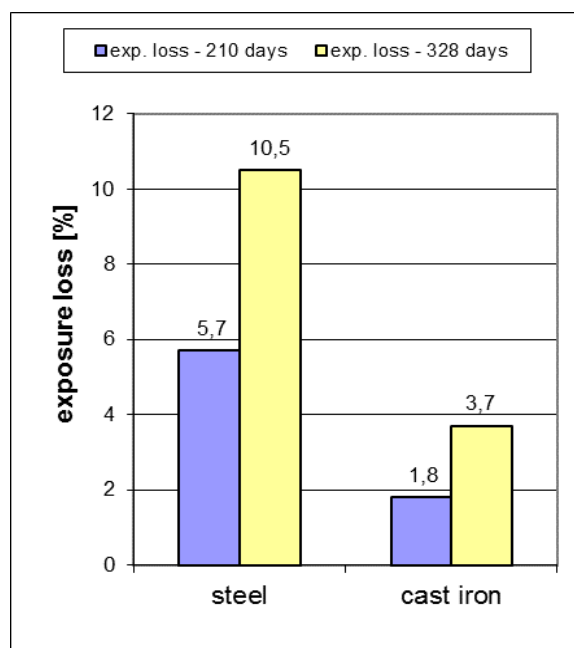


Fig.8. WR Považ.Chlmec - steel *), cast iron

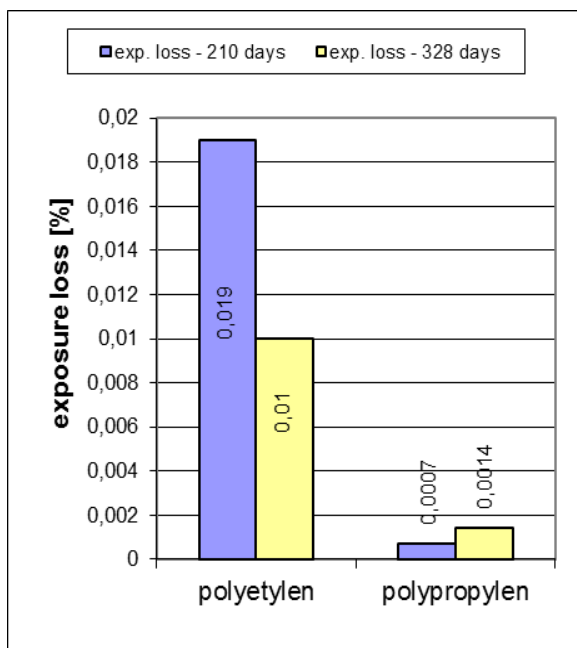


Fig.7. WTP N.Bystrica - PE, PP

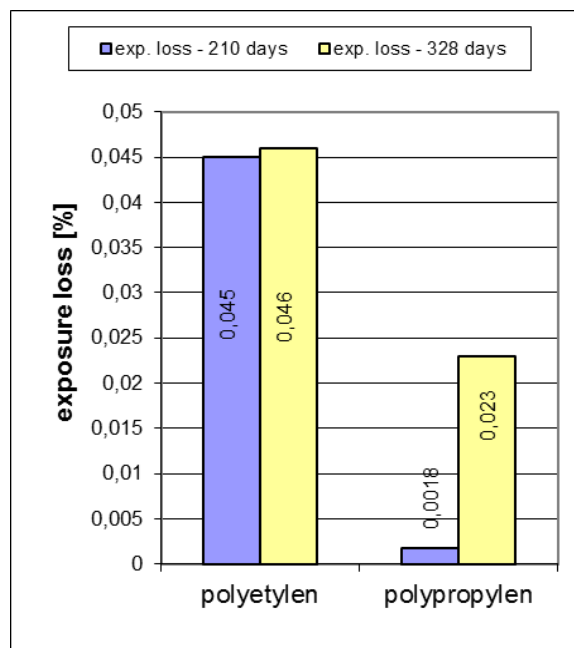


Fig.9. WR Považ.Chlmec - PE, PP

*) exposure times for steel are 216 and 426 days.

7. COMPARISON OF THE EFFECTS OF DIFFERENT WATER QUALITY ON SELECTED MATERIALS EXPOSED IN THE MONITORED GROUP WATER SUPPLY SYSTEMS

The comparison of the results obtained from the pilot impact assessment of water quality on selected materials showed the following:

7.1 Effect of water quality on steel material

The most significant exposure losses were recorded for steel material in both group water supply systems. The exposure loss was 6.7% at the WTP Nová Bystrica and 5.7% in the Považský Chlmec Water Reservoir after the exposure of 216 and 238 days respectively. Soft water transported from the WTP Hriňová had a more significant effect on exposure losses of steel at the same exposure time - 16.5% at the WTP Hriňová and 14.2% in the Ľuboreč Water Reservoir. The exposure loss for steel was 11.8% at the WTP Nová Bystrica and 10.5% in the Považský Chlmec Water Reservoir after an exposure time of 426 days. The exposure loss of steel at an exposure time of 363 days was 24.5% at the WTP Hriňová and 17.6% in the Ľuboreč Water Reservoir. As it can be seen, the exposure loss for steel in the WTP Nová Bystrica did not reach 50% of the exposure loss observed at the WTP Hriňová even after longer exposure time of two months.

7.2 Effect of water quality on cast iron material

The smaller differences in exposure losses were measured for cast iron materials in both monitored water supply systems as well as within each system separately. The exposure loss were 1.5% at the WTP Nová Bystrica after an exposure time of 210 days. The loss for cast iron slightly increased to 1.8% in the Považský Chlmec Water Reservoir. Similar trend was proved also for the tests at an exposure time of 328 days, where the exposure loss reached 2.4% and 3.7% respectively. After an exposure time of 210 days, the exposure loss for cast iron was 3.2% at the WTP Hriňová and 2.7% in Ľuboreč Water; after 363 days it was 4.4% and 2.8% respectively.

7.3 *Effect of water quality on polyethylene*

The exposure losses for polyethylene were nearly the same at about 0.05%, regardless of the water quality and the exposure time. A certain difference in exposure loss was recorded only at the WTP Nová Bystrica – exposure loss of 0.01-0.02%.

7.4 *Effect of water quality on polypropylene*

The similar results as for polyethylene were also obtained for polypropylene. The difference was only in lower exposure losses ranged from 0.001-0.006 %.

8. CONCLUSION

The pilot impact assessment of water quality on selected materials showed quite clearly that the least suitable material is steel due to the most significant corrosion effect observed on this type of material. Following the results, almost 25% of steel material corroded during the 1-year exposure to water at the WTP Hriňová. A significantly lower corrosive effect of water on steel was observed in the group water supply system Nová Bystrica-Čadca-Žilina, even if it was disinfected by chlorine dioxide.

Based on the results of the pilot impact assessment of water quality on selected materials along with the outcomes of corrosion tests, it can be concluded that the steel pipes are not suitable to be used for the distribution of water from the WTP Hriňová. Soft water has also adverse effect on the cement pipes (asbestos cement and sokoman). High corrosion of steel piping eliminates this type of pipes. Cast iron with inner plastic lining appears to be the most suitable material for this type of water.

When replacing or reconstructing the piping in this group water supply system, the use of the above mentioned pipes can be recommended as a passive protection. In case of failure or damage, the cast iron pipes have the longest life expectancy in such a type of water.

ACKNOWLEDGEMENT

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0372-12.

REFERENCES

- Council Directive 98/83/EC on the quality of water intended for human consumption, 1998
- Government Regulation No. 636/2004 Coll., determination of requirement to quality of raw water and monitoring quality of water in public water supply system.
- Government Regulation No. 496/2010 Coll., setting out the requirements for water quality intended for human consumption
- Munka K., Büchlerová E., Karácsonyová M. 2002 Stage 01.01. Research of physical-chemical changes in water quality during distribution. VTP 27-35 Drinking water quality assurance during distribution. Final Report, VÚVH, Bratislava (Slovak)
- Munka K., Karácsonyová M., Gajdoš Ľ. 2005 Pilot scale evaluation of impact to selected material in contact with drinking water. Proceeding from international Water Zlín 2005 (Slovak version)
- STN 757 151 Water quality requirement for water quality in piping systems