Drinking water disinfection strategies for health risk minimization in case of cement-mortar lined pipes

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KEY WORDS
Disinfection; Drinking water; Pipelines material; Migration

INTRODUCTION

In recent years, increasing attention has been posed to assure stable and safe quality of drinking water (DW) from source to tap, according to a holistic risk approach proposed by World Health Organization by means of Water Safety Plans (WSPs). Biological stability can be guaranteed through DW disinfection. However, the disinfectant decays along the DW distribution networks (DWDNs), due to both water characteristics (bulk decay) and interactions with pipe material (wall decay). These interactions can enhance pipe ageing and deterioration, causing leaching of material constituents, to be minimized as also stated by the recent EU DW Directive 2020/2184. As a consequence, an alteration of DW chemical quality could be observed, as well as of DW microbiological quality. Cement-mortar lined cast iron pipelines are widespread in DWDNs, but so far, no literature studies provided a comprehensive investigation of the effects of the interaction among disinfectant, water quality and pipeline material.
In the present work, the effect of two chemical disinfectants (sodium hypochlorite and chlorine dioxide) on DW quality in contact with cement-mortar lined cast iron pipes was studied. Lab tests were performed to investigate jointly leaching and disinfectant decay, depending on the DW quality, to estimate potential health risks and to propose best practices for disinfection management along DWDNs.

METHODOLOGY

EN 14944-3:2007 standard method was adopted as a reference for the experimental plan. Ten new cement-mortar lined cast iron pipes were supplied by a water utility in northern Italy. Pipes properly sealed at the bottom were filled with the test water and covered with a coated mobile watch glass to avoid headspace formation and light intrusion. Experiment was structured in two consecutive stages, conditioning and migration test, mimicking the conventional practice of putting into operation new pipes (preliminary sanitization, followed by normal operation). Details are reported in table 1.

Table 1. Main operating parameters of the experiments (AI: Aggressive Index)

Stage	Step number	Duration [h]	Test water quality
Pre-conditioning (static washing and sanitizing)	1	24	AI = 12; Hardness = 20 °F; Alk = 244 mg/L HCO_3^-; pH = 7.4; no disinfectant
	2	24	
	3	24	
	4	72	
	5	24	as in steps 1 to 4; 50 mg/L active chlorine (sodium hypochlorite)
Migration Test	6	72	AI = 11-13; Hardness = 10-20 °F; Alk = 100-240 mg/L HCO_3^-; pH = 7-8.3; 1 mg/L active chlorine (sodium hypochlorite or chlorine dioxide) + re-disinfection or no disinfection
	7	72	
	8	72	

The pipe samples were emptied and refilled with new test water at the end of each step. The surface-volume ratio was set at 5 dm^{-1}. In steps 6 to 8, three conditions were tested: (i) dosage of sodium hypochlorite at 1 $mgCl_2/L$ + re-disinfection, (ii) dosage of chlorine dioxide at 1 $mgCl_2/L$ + re-disinfection (iii), no disinfectant dosage. Blank tests (i.e. tests in glass beakers) were also performed with the same test waters.
Total organic carbon (TOC), aluminium, iron, manganese, chromium, lead, zinc, silicon, calcium, magnesium was measured at the end of each step. The complete water ionic composition (alkalinity,

calcium, magnesium, chloride, sulphate, nitrate, fluoride, sodium, potassium, bromide, phosphate) was measured at step 8 and compared with starting water characteristics. Disinfectant concentration was measured periodically during steps from 6 to 8, to properly tune the re-disinfection.

RESULTS

No significant heavy metal release was observed in both stages. Conversely, water hardness varied relevantly as shown in figure 1: magnesium was quickly released in water and was not detected anymore after step 2, while an increase of calcium was observed in water samples in each step. As for step 5, the high concentration of disinfectant triggered a pH increase (up to 9.6) that caused an oversaturation and precipitation of calcium salts, resulting in an apparent decrease in water hardness.

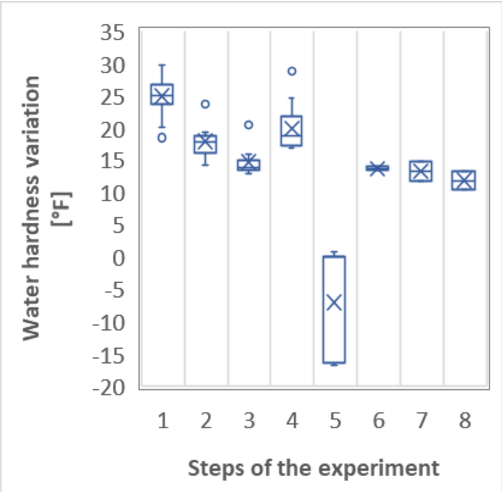

Figure 1. Hardness variation in water samples

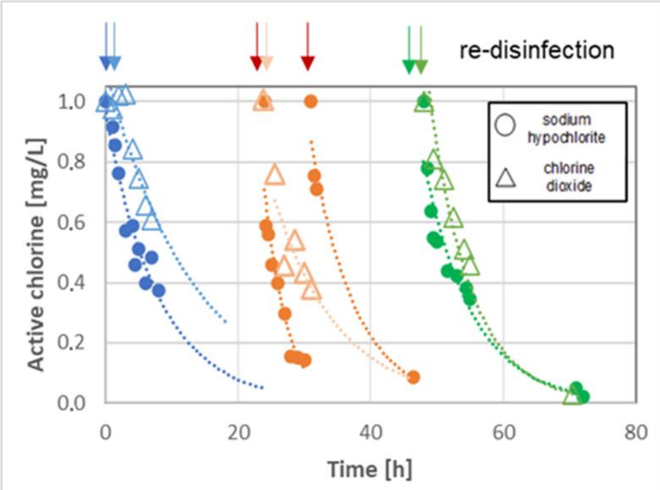

Figure 2. Example of disinfectant decay during step 7

A gradual release of TOC was also observed, up to 6 mg/L in steps 1 and 2 and up to 1.5 mg/L at the end of step 8, likely due to additives contained in cement-mortar (up to 0.2% of clinker mass, according to standard normative BS EN 197-1:2011). At the end of step 8, a significant increase in the concentrations of sulfate (up to 160 mg/L) and bromide (up to 900 μg/L) was measured. No difference was observed in release with respect to the presence or absence of disinfectant, and the type of disinfectant. Disinfectant decay followed a first-order kinetic in case of sodium hypochlorite and of chlorine dioxide (figure 2). The TOC increase in DW affected strongly sodium hypochlorite decay during step 6 to 8 and a higher number of re-chlorinations were necessary between 24 and 48 hours to maintain a residual disinfectant.

DISCUSSION AND CONCLUSION

Despite water pre-conditioning, DW quality is severely influenced by the contact with cement-mortar lined cast iron pipes during the migration tests. First, the water hardness increase can impact on the acceleration of pipe ageing because of scaling formation. Secondly, the release of sulfate could lead not only to a limit non-compliance but also to trigger heavy metals release along DWDNs (Sun et al., 2017). Lastly, TOC release could impact on biological stability and disinfection by-products formation in case of sodium hypochlorite disinfection, as well as bromide release which can enhance the formation of brominated trihalomethanes, displaying a higher toxicity. Because of the observed releases and their potential impacts, chlorine dioxide results to be more suitable for disinfection in case of recently installed cement-mortar lined cast iron pipes. This is proved by the health risk evaluated in terms of benchmark quotient which should be included in the WSPs framework for a comprehensive assessment.

REFERENCES

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