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The Use of Phosphate-Silicate Inhibitor, in Corrosion Control of Drinking Water Distribution System

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Abstract: The chemical content of water - pH, mineralization, alkalinity, hardness, calcium and magnesium compounds, carbon dioxide free provide guidance about buffering capacity of water. Therefore, if the mineralization and pH is low, the water is aggressive towards the materials used in manufacturing pipes - concrete, steel, HDPE, PVC, PAX. If the mineralization is high, the pH is high, too and the water forms crust and hardness deposits on the pipe. To control corrosion in water distribution networks, the methods most commonly applied are: adjusting pH, increasing the alkalinity or hardness, adding corrosion inhibitors. The phosphate-silicate inhibitor (the Folmar technology) is a complex solution, completely soluble in water and very harmless to the human body and is used to control the chemical corrosion of pipes in water distribution system, the biological corrosion (due to iron bacteria, sulphate reducing bacteria, Pseudomonas), to control the bio-film and secondary pathogen growth in drinking water distribution system. This study presents the results for their evaluation performance in different pipes and different water chemistry content. The evaluation of Folmar technology lasted for at least minim 1 month to 1 year for each water source. The results obtained have revealed the ability of this bycomponent inhibitor type to reduce corrosive water and pipe trends.

Keywords: Corrosion Inhibitor, Folmar Technology, Pipe Protection

1. Introduction

Corrosion degrades the useful properties of materials and structures, including resistance, appearance and their permeability [1]. It affects metal components but also the cement, concrete, ceramics and polymers (PVC, HDPE, PEX). Corrosion is an economic burden for many industries [2]. According to the World Corrosion Organization [3], the annual cost of corrosion is more than 3% of global GDP. The corrosion influenced by microorganisms is called bio-corrosion [4, 5]. Bio-film formation and corrosion in the distribution system are dependent on: pH, the content of bicarbonate and calcium carbonate ions, all salts dissolved, water temperature, and on the bacterial content [6, 7, 8]. Each of the listed factors may influence independently the corrosive tendencies of the water.

Thus, in the case of water with low alkalinity, the low concentration of calcium carbonate cannot form a protective film, and in this case the water is aggressive and dissolves the components of the pipe material: iron, lead, copper, cement. Waters with high pH and alkalinity can also be corrosive. In this case, calcium and magnesium compounds form crusts, in which iron deposits can multiply, and the iron bacteria are proliferated – "Fig. 1".

Figure 1. Biochemical corrosion, due to the deposits type crust combined with iron bacteria action on metal pipes.

Neither material such as HDPE, PVC, PEX does provide complete protection from corrosion.

Figure 2. Biochemical corrosion due to the deposits crust type, combined with iron bacteria action in PVC pipes [9].

The aggressive waters which are low mineralized, attack the organic material, weakening its elasticity, ensuring favorable conditions for the formation and maturation of bio-film, and those with high mineralization level deposited crusts are favorable habitats for multiplying iron bacteria, bio-film and biological pathogenic bacteria which promote corrosion.

Bacteria are simple prokaryotic organisms from structurally, but complex metabolic point of view, this enabling them the adaptation to the most varied types of habitats [4]. These microorganisms can reproduce at a pH between 0.5 and 13, temperatures between -2 and 110 °C and pressures up to 1400 bar [15]. Approximately 98% of the microorganisms which form bio-film are bacteria [4].

In a water pipe in which water flows, some planktonic bacteria approach pipes walls and they will enter the organic layer. Some of these cells will strike and will be adsorbed to the surface for some time and then will be desorbed, this phenomenon is called reversible adsorption. This initial adheres are based on electrostatic attraction and physical forces without any chemical reaction. When they begin to accumulate nutrients, "the pioneer cells" start to reproduce. The bio-film surface is covered with gelatinous and it is slippery. When bacteria reach the critical density, they begin producing a gelatinous substance that gives the bio-film its sticky nature. This sticky layer is responsible in a large part for the weight and volume of the bio-film. After the layer formation, they can develop a micro-ecological community that can attract other types of microbial cells. These secondary colonizers metabolize "the wastes" of the first layer, while in turn they produce "wastes" that other cells can use. A bio-film can reach to maturity in few hours or several weeks, depending on the local conditions [10]. Pseudomonas aeruginosa is a "pioneer bacteria" commonly found and used in the research about bio-film. [1]. Depending on the chemical, physical and hydraulic, bio-film formed may suffer erosion passing directly into the water stream. These phenomena are shown in “Fig. 3” [11].

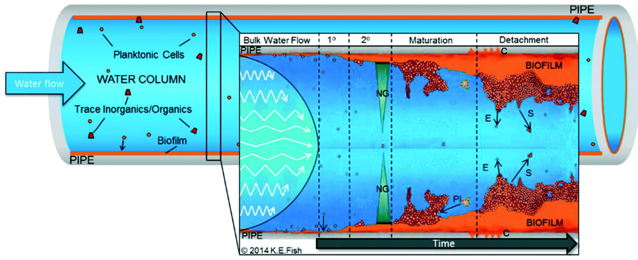

Figure 3. Biofilm development within DWDS incorporating water flow within the pipe [11].

1° – primary adhesion, 2° – secondary adhesion, NG – nutrient gradient, concentrates within the bio-film, PI – protozoan interactions, C – corrosion of the pipe surface, E – erosion, S – sloughing[11]

Undesirable growth of bio-film has a negative impact on the various activities and represents significant losses for industries [12]. An estimated 20% of all damage caused by corrosion is influenced by microorganisms [4].

The EPS-producing bacteria, acid-producing bacteria, sulfur oxidizing bacteria, iron precipitating bacteria and sulfatereducing bacteria (SRB) are involved in the process of bio-corrosion exopolysaccharid[4]. The major responsibility for bio-corrosion is attributed to SRB, because their release of H_2S during its metabolism, a poisonous and corrosive reagent [13, 14].

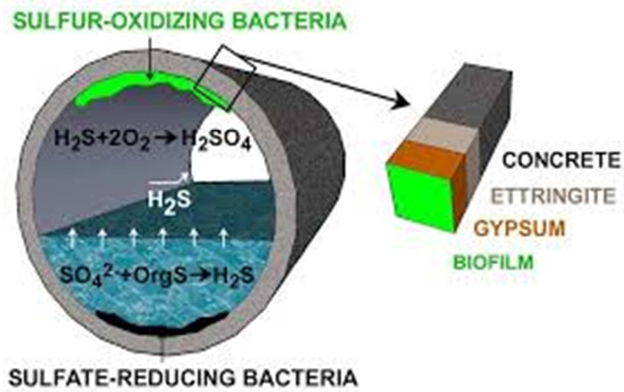

Figure 4. The biofilm formation due to sulfate reductive bacteria [13].

The polymeric materials used to waterproof storage tanks, fittings containing rubber, epoxy materials, increase heterotrophic bacteria content. Pilot scale tests conducted for 2 years [15] revealed that the bio-film formation potential of plastic pipes differs depending on the material which is used. The susceptibility of the tested materials to colonization and bio-film formation was: HDPE > PEX > PVC [15]. For polymeric materials, the terms usually used are “degradation” to illustrate corrosion process. So all pipe materials may be subject to corrosion, the water contents, temperature, pH are important factor.

Silicates and polyphosphates are often described as “corrosion inhibitors”, they can complex dissolve iron (in the iron(II) state) and prevent its precipitation visibly obvious red “rust”. These compounds may act by masking the effects of corrosion rather than by preventing it. Orthophosphate is a possible corrosion inhibitor and, like polyphosphates, is used to prevent "red water". [16]

Changes in the bio-film structure and microbial community have been reported following phosphate (or phosphoric acid) addition [17, 18]. The disinfection efficiencies of chlorine and monochloramine treatments were found to increase with phosphate addition [19, 20].

The sodium silicate is used as a corrosion inhibitor for more than 60 years, it acting so as ionic and colloidal forms. Folmar technology use both silicates and polyphosphates in a stable compound that can be easily dosed and manipulated, completely soluble in water and totally harmless to the human body. The solution is absorbed in the anodic area of the pipe and forms a thin film that is a molecular film. This is in fact an insulator layer which stops the electro-bio-chemical reactions leading to the corrosion. At the same time, the solution contains polyphosphates which protects the cathode area of the pipe [21] –"Fig. 5".

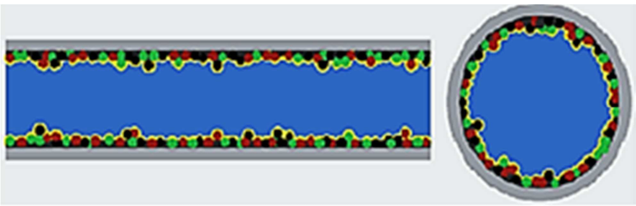

Figure 5. Formation of protection corrosion film by applying Folmar technology.

The formation of the protective film requires continuous dosing in the drinking water distribution pipes, of the solution based on silicates and orthophosphate alkaline, whose recipe for manufacturing is held by Mösslein GMBH, Germany. To form the protective film, the required dose of Folmar is 20 ml/mc for 1 month, with orthophosphate content monitoring, after which it can be reduced to a 5 ml/mc - maintenance dose of the protective film.

2. Obtained Results

In this section are presented the results obtained by introducing the Folmar tehnology in different water distribution systems of Romania. The water quality control was conducted in accordance with European Directive 98 CE requirements.

2.1. For Drinking Water with Moderate Alkalinity

The chemical content of this water type shows moderate salt content:

alkalinity =150-180 mg/l $CaCO_3$
total iron outlet treatment plant = 0.03-0.05 mg/l
total iron at consumers'= 0.27-0.32 mg/l
pH outlet treatment plant = 7.8-8.0 unit
pH at consumers'= 7.1-7.3 unit
conductivity - 500-600 microS/cm

This type of potable water comes from surface water sources, the distribution system is of steel pipes which have been used for over 30 years. The consumers' complaints were related to the "red water" colour and frequent interruptions of water supply due to pipeline repair. Different quality of water entering the distribution network and the water consumers' shows a corrosion process underway.

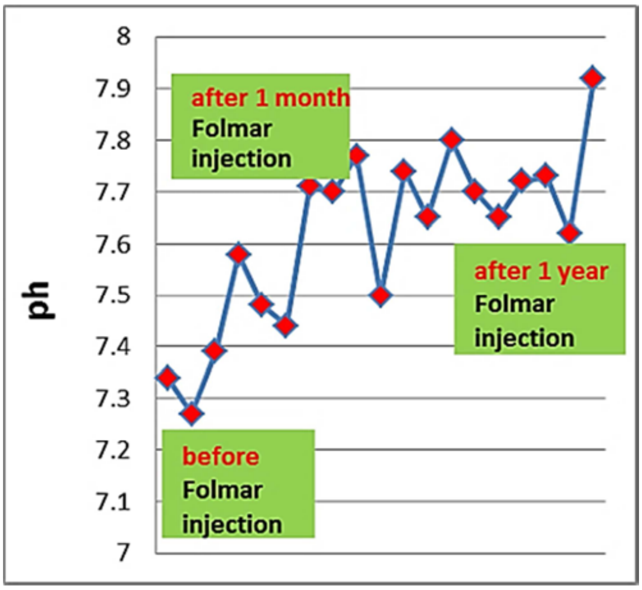

Figure 6. Stabilizing water pH by applying Folmar technology for waters with moderate alkalinity.

After entering Folmar technology, water quality monitoring results at 30 days (for a dosage 20ml/mc drinking water solution Folmar) show that the water pH increased from 7.3 pH units to 7.7 pH units.

After one year of using Folmar solution with maintenance dosage of the protective film of 5 ml/mc water, water's pH was stabilized at 7.8-7.9 pH units, considerably reducing water aggressiveness –"Fig. 6".

Because the biochemical corrosion had been stopped, the total iron content of the drinking water was reduced by 7-fold, after 2 months Folmar treatment – "Fig. 7",

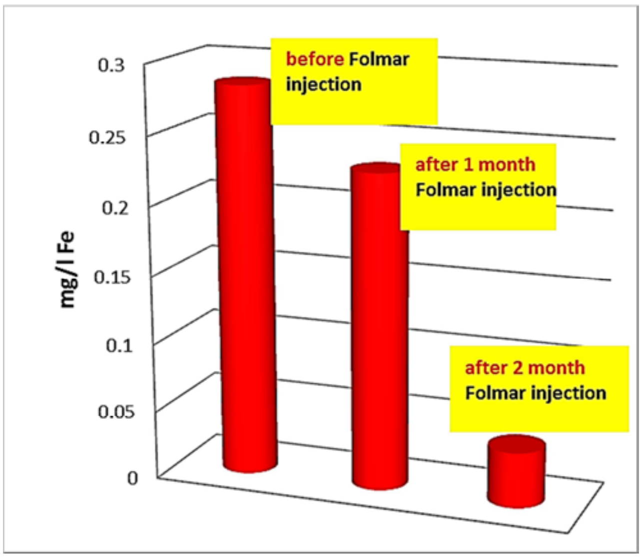

Figure 7. Reduction of total iron content, by Folmar technology implementation for moderate alkalinity water.

The ortophophates content in drinking water distribution system did not exceed 1.4 mg/l after 1 month entering the Folmar technology. After one year of using Folmar solution with maintenance dosage of the protective film of 5 ml/mc water, the ortphosphate content was stabilized to 0.8 mg/l – "Fig. 8".

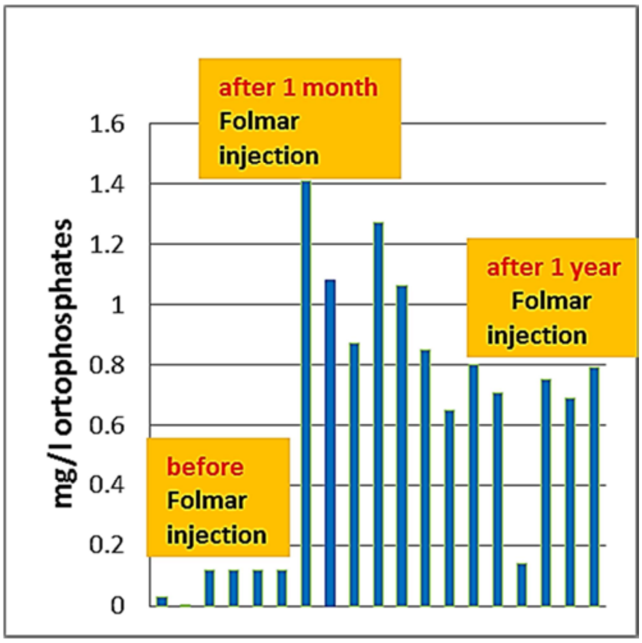

Figure 8. *The ortophosphates concentration during Folmar technology implementation.*

For this water type, the Folmar inhibitor reduces the water aggression and stops de pipe degradation process.

2.2. For High Alkalinity Drinking Water, Low pH and Iron Content Above the Permissible Limits

This water comes from an underground source, in which the content of iron and manganese is significantly, the steel pipes have been for over 10 years old. The chemical content of this water distribution system type is:

alkalinity = 300 mg/l $CaCO_3$
pH outlet treatment plant = 7.0- 7.1 unit
pH at consumers'= 6.7 units
total iron outlet treatment plant = 0.03-0.05 mg/l
total iron at consumers'= 4 mg/l Fe
turbidity outlet treatment plant= 2 NTU
turbidity at consumers'=34 NTU

The water from the distribution system shows turbidity and brown color due to the iron content of the corrosion process of pipeline distribution system. After Folmar technology implementation, the iron content was reduced by 6 times "Fig. 9".

Because of stopping the "rusting" process, the water coloration (default turbidity) was reduced 8 times -"Fig 10"

For this water type the Folmar action is significant because this inhibitor stops the corrosive pipe process and increases water quality within legal requirements.

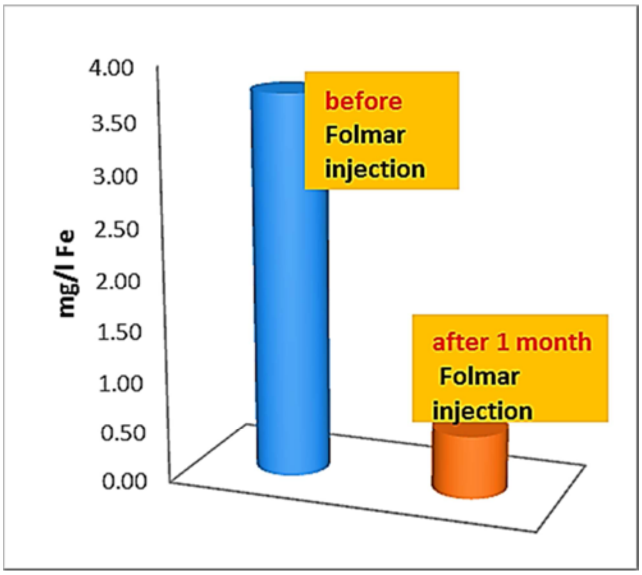

Figure 9. *Reducing of biochemical corrosion for hard waters by applying Folmar technology.*

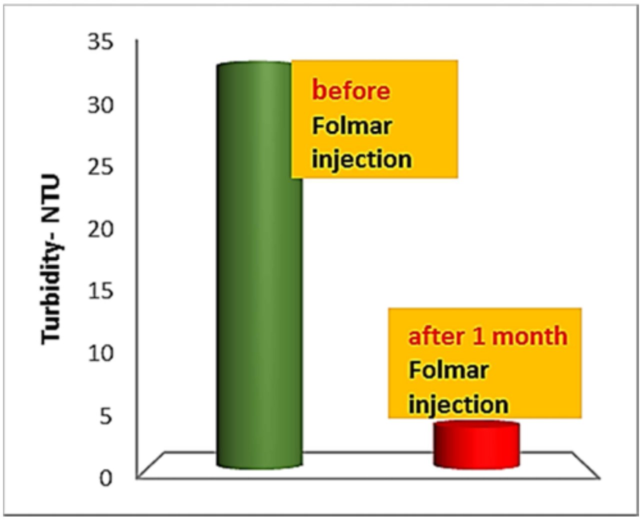

Figure 10. *Reducing the coloration and turbidity of the hard water by deployment Folmar technology.*

2.3. For Drinking Water with Low pH and Low Mineralization Level

The chemical content for this water type is:
alkalinity = 20 mg/l $CaCO_3$
pH outlet treatment plant = 7.0 unit
pH at consumers'= 6.6 pH units
total iron oulet treatment plant=0.02-0.03 mg/l
total iron at consumers= 0.09 mg/l Fe

This water type is very aggressive for the distribution system due to reduced buffers capacity. The pipes are made of steel and concrete, their usage age being between 3 and 50 years.

After Folmar technology was implemented, the pH increased by 0.2 pH units, and the iron content was reduced by 30% - "Fig. 11".

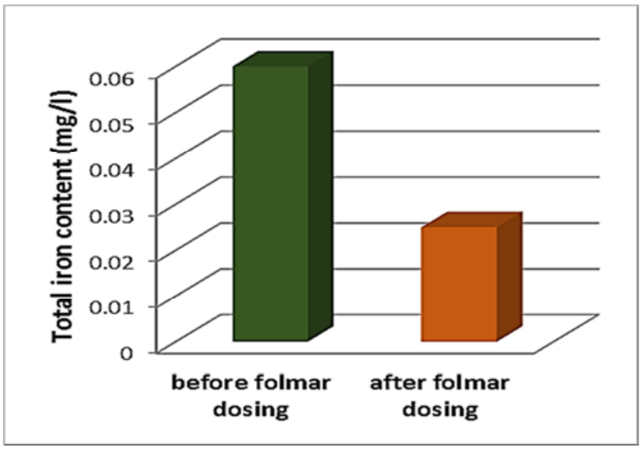

Figure 11. *The reduction of iron contents in low alkalinity waters, by applying Folmar technology.*

Residual disinfectant monitoring in the distribution network - free residual chlorine has stabilized also in the points situated at the end of network. "Fig. 12".

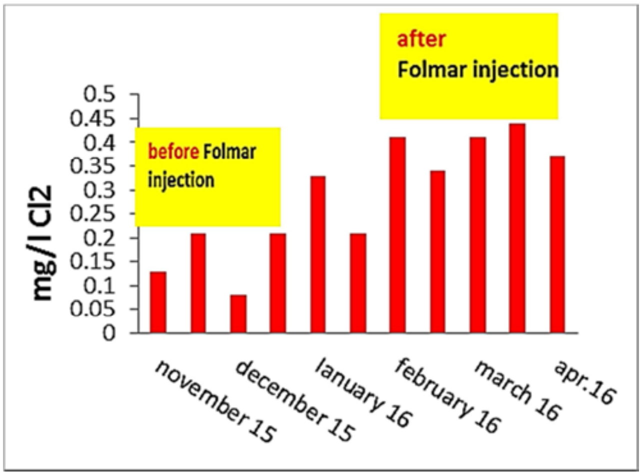

Figure 12. *Free residual chlorine in water network.*

The results obtained show the positive effect of this inhibitor type on the water quality stabilization in the distribution system. For this reasons the consumer complaints dropped and the interruption of water supply for replacing pipe damage was significantly reduced.

3. Conclusions

The dosing of Folmar inhibitor in different drinking water distribution system types with different chemical content shows the following:

reduces the iron content and thus reduces the of corrosion pipe body;

stop de crust deposit due to iron and hardness water content

stabilizes water pH reducing his aggressiveness;

stabilizes the concentration of disinfectant (free residual chlorine) in the water network;

stops the possibility of secondary pathogenic bacteria growth in the distribution system.

For this reasons this inhibitor type is a solution for drinking water distribution system for corrosion control, because it increases the pipe age, reduces the water operation costs and stabilizes water quality.

The corrosion control as an important part of water safety plan is key to limiting bio-film growth in distribution systems and quality water assurance. The internal corrosion of pipe sand fittings can have a direct impact on the concentration of water constituents, including lead and copper. Corrosion control is therefore an important aspect of the management of a drinking-water system for safety [16].

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