APPLICATIONS OF ANTISCALANTS IN CIRCULATING WATER SUPPLY SYSTEMS

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Received 08 June 2022
Accepted 17 October 2022

ABSTRACT

The development and implementation of circulating water supply systems at industrial companies makes it possible to create the maximum closed cycle with a minimum amount of waste, which is appropriate from an economic and environmental point of view. Corrosion and scale inhibitors must be used to comprehensively address the problem of biofouling, deposits of insoluble compounds and corrosion products. The possibility of using gipan for water stabilization with different levels of mineralization at increased temperatures has been evaluated. Gipan provides effective stabilization water treatment.

Keywords: mineralized waters, tap waters, artesian waters, antiscalant, stabilizing effect, anti-scale effect.

INTRODUCTION

The problems of drinking water safety are important for Ukraine for many years. Their acuity not only does not decrease but even increases in recent years, especially in industrial regions [1 - 4]. Today, one of the largest consumers of water in industry are circulating cooling water supply systems [5 - 7]. When operating thermal networks, it is necessary to ensure their functioning without damage and efficiency reduction due to biofouling, corrosion of network equipment, as well as the formation of deposits and sludge in the equipment and pipelines of thermal networks [8 - 10]. Reuse of different categories of treated industrial wastewater can reduce the intake of natural water to feed circulating systems. However, in order to avoid such negative processes as scaling ($CaCO_3$, $CaSO_4$, $Ca_3(PO_4)_2$, CaF_2, etc.), corrosion products (Fe_2O_3, Fe_3O_4, CuO, etc.) and biological formations, it is necessary to make a detailed assessment and forecast of the operation modes of circulating water supply systems at companies and to apply appropriate water treatment [11 - 13]. Otherwise, a deterioration not only of the circulating water supply systems, but also of the entire production cycle may take place, for example, extended downtime for cleaning, more often replacement of equipment, deterioration of heat transfer parameters between a cooling agent and the product, etc. [14]. Currently, the most of industrial companies in Ukraine, due to the inefficient quality of water treatment, discharge large volumes of wastewater into water bodies when purging systems to maintain the salt composition of circulating water at a proper level. This leads to environmental degradation and causes additional damage to businesses [15, 16]. Therefore, solving the problem of stabilization water treatment will allow to move to closed cooling systems, which in turn allows to ensure the rational use of water and protection of natural water bodies from excessive anthropogenic load [17, 18].

The chemical, membrane and ion exchange methods of water treatment are used to prevent the formation of scale on the heating surfaces of heat exchange equipment. The chemical method of water purification can be used only for the preparation of industrial water at large stations (high residual hardness prevails in the water, the equipment has low productivity) [19

- 21]. The disadvantage of using membrane method pretreatment of water is the pre-treatment of water, creation of overpressure and the inability to regenerate the membrane [22 - 24]. The ion-exchange method requires the development of methods for processing concentrates [25 - 27].

The introduction of stabilization water treatment will increase the efficiency of water use. Inhibitory protection of heat exchange equipment, in particular corrosion and scale inhibitors, is used for effective stabilization treatment of water in circulation systems [28 - 30]. Methods of stabilization water treatment that increase the reliability of circulating cooling systems need to be improved.

The quality of water resources depends on many factors, one of which is corrosion monitoring of main pipes and water supply systems [31 - 33]. To increase the chemical resistance of metals, various methods are used, in particular corrosion inhibitors, which in turn can affect the quality of water in general [34, 35]. Using of antiscalants to inhibit the formation of scales appears to be the most recommended approach because of its advantages - environmental and safety compared to other alternative technologies, operational and capital cost reduction and it will eliminate the use of expensive and cumbersome water softening and deaeration systems [36, 37].

The use of ultrasonic technology to combat scaling is widely known both in the publications and in industrial practice. It is defined that the complex action of ultrasound and antiscalants allows to optimize the formation and retaining of the phase microlayer of scale with anticorrosive properties, which does not worsen the heat transfer conditions in the heat exchange equipment [38 - 40].

The aim of the study was to investigate the efficiency of the stabilization water treatment reagent and increase its efficiency in ultrasonic treatment for resource-saving circulation water supply systems for heating and cooling in industry. To achieve this goal, the following tasks were set:

- to study the processes of scaling, to determine the effectiveness of gipan for water stabilization depending on the conditions of its application and the dose of the reagent;
- to determine the possibility of using this inhibitor to stabilize aqueous solutions at increased temperatures.

EXPERIMENTAL

The tap water, artesian water and model solution similar in composition to mine water in Zhovti Vody were used in the research (Table 1). Gipan with concentrations of 0.5 - 20.0 mg dm^{-3} was used as a stabilizer of scale formation. Quality indicators of hydrolyzed polyacrylonitrile are:

➢ appearance - viscous liquid from yellow to dark brown color;

➢ mass fraction of dry residue - not less than 27.5 %;

➢ dynamic viscosity of 1 % aqueous solution - not less than 16.5 %.

Table 1. Characteristics of natural waters.

Indicator	Tap water of the city of Kiev	Artesian water of the city of Kiev	Model solution of mine water
Hardness, mg-eq/dm^3	4.1	4.7	17.3
Ion concentration calcium, mg-eq/dm^3	3.0	2.5	10.7
Ion concentration magnesium, mg-eq/dm^3	1.1	2.2	6.6
Alkalinity, mg-eq/dm^3	3.7	3.5	5.3
Nitrates, mg/dm^3	39.5	170.5	45.0
Chlorides, mg/dm^3	21.1	107.4	319.5
Sulfates, mg/dm^3	34.3	11.5	720.0
Mineralization, mg/dm^3	295.0	375.0	1070.0
pH	7.7	8.1	7.9

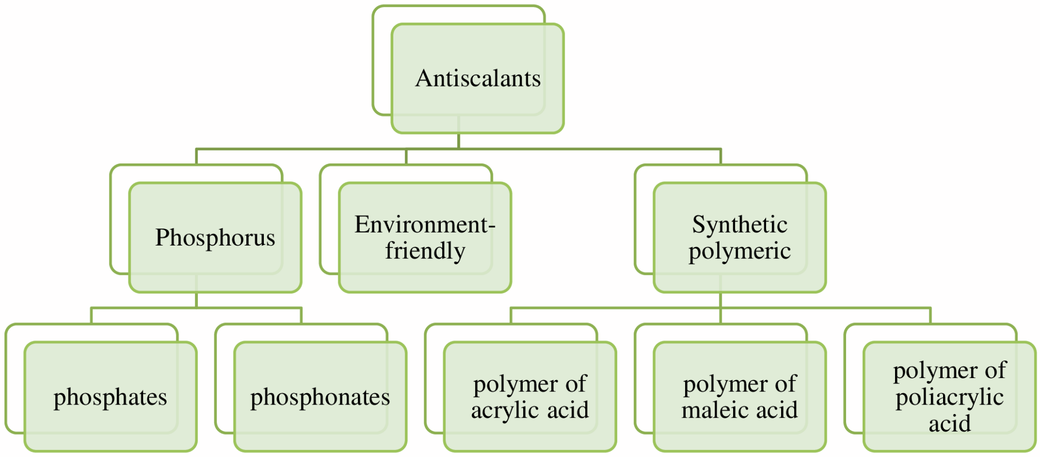

Fig. 1. Classification of antiscalants.

To increase the efficiency of the process, the gipan was treated with ultrasound (US) for 20 minutes.

$$(CH_2\text{-}CH\text{-}(CN)\text{-})_n + US \rightarrow (CH_2\text{-}CH\text{-}(CN)\text{-})_{(n-m)} + (CH_2\text{-}CH\text{-}(CN)\text{-})_m$$

The solutions were heated for 6 hours up to 95ºC. To determine the stabilizing effect (SE) and anti-scale effect (ASE), the samples were cooled and the residual water hardness was determined after filtration [41].

RESULTS AND DISCUSSION

It should be noted that the efficiency of stabilization water treatment depends on the quality of the intake water. The tap and artesian water of Kyiv and a model solution, which is close in composition to mine water, were used in the study. The model solution is quite unstable to the formation of sediments due to high mineralization and alkalinity. When heated, its hardness decreases from 17.3 to 11.3 mg-eq dm^{-3}. Water circulation systems operate at 40ºC - 60ºC, there was almost no reduction in water hardness in the control experiments at this temperature for 6 hours. However, when the temperature increased to above 95ºC, the water became quite unstable and precipitation occurred. In thermal power plants, the water temperature usually exceeds 90ºC - 95ºC that is the reason for the choice of temperature for experiments.

Antiscalants can be classified into phosphorus and phosphorus-free antiscalants (Fig. 1). Phosphorus inhibitors have good cost-effective performance, but phosphorus emissions will lead to heavy eutrophication. The molecular structure of polymeric antiscalants should be considered a key factor for improving the design of novel effective antiscalants [28].

An inhibitor with carboxyl functional groups - gipan, was used to stabilize water. This reagent is a fairly stable substance and does not decompose in water in the temperature range of 0 - 100ºC [42]. As a stabilizer, gipan is ineffective at low concentrations (0.5 - 5.0 mg dm^{-3}). As the inhibitor concentration increases, the residual hardness of the solution also increases. The maximum value of residual hardness was observed at the concentration of gipan 20 mg dm^{-3} (Fig. 2). Gipan provided high stability of artesian water in terms of sediment formation at a concentration above 10 mg dm^{-3}. The effectiveness of water stabilization depends on the inhibitor consumption. At inhibitor doses of 1 - 20 mg dm^{-3}, SE varied from 58.8 % to 88.2 %. After ultrasonic treatment at the same doses, the SE varied from 61.8 % to 95.9 %. Gipan provided SE at the level of 47.0 % at a dose of 0.5 mg dm^{-3}. When the dose was increased to 20 mg dm^{-3} SE increased to 88.2 %. At the maximum dose of inhibitor and heating for 6 hours to 95°C, the hardness decreased by only 0.2 mg-eq/dm^3, after sonication of the reagent this value decreased to 0.07 mg-eq dm^{-3} (Fig. 3).

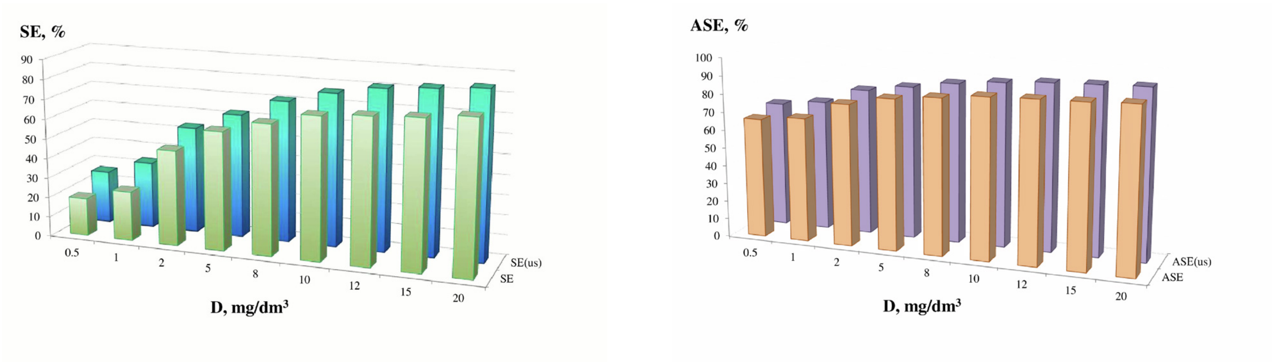

Fig. 2. The effect of the dose of gipan at 95°C on tap water stability: a) - SE; b) - ASE.

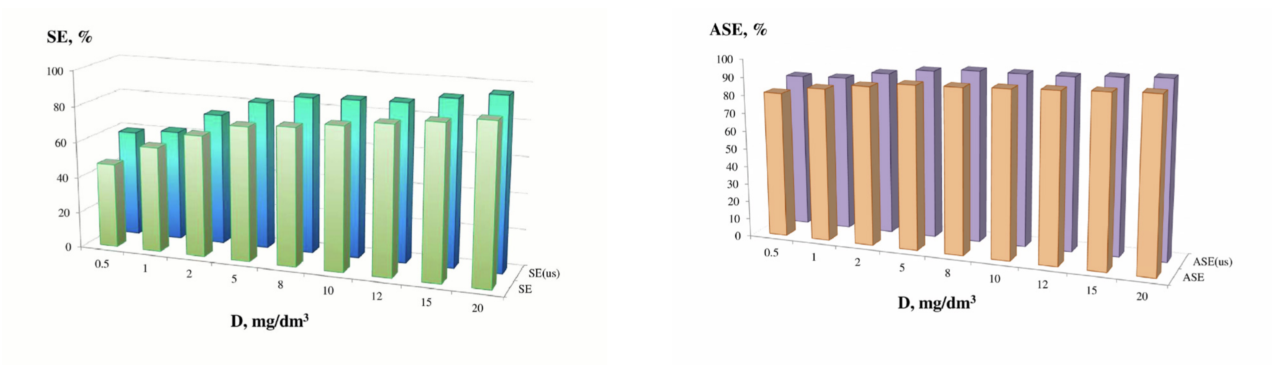

Fig. 3. The effect of the dose of gipan at 95°C on artesian water stability: a) - SE; b) - ASE.

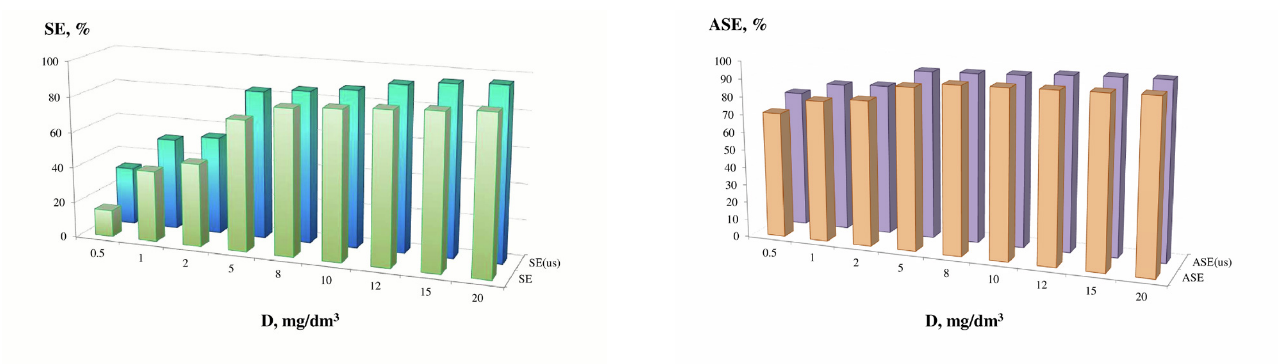

Fig. 4. The effect of the dose of gipan at 95°C on mine water stability: a) - SE; b) - ASE.

Quite many industrial regions have a shortage of water resources, so they are forced to use mineralized water in cooling systems. Stabilization of waters with high hardness to sediments formation is a rather challenging issue. Evaluation of the effectiveness of gipan was made by changing the hardness of mine water and when it was heated to 95ºC.

Scale inhibitor was quite effective. At the inhibitor dose of 0.5 mg dm^{-3}, SE and ASE reached 15.0 % and 70.5 %, respectively. At the inhibitor dose of 8.0 mg dm^{-3}, these values reached 81.7 % and 93.6 %, respectively. SE reached 81.7 % - 88.0 % at the inhibitor dose of 8 - 20 mg dm^{-3}.

After ultrasonic treatment of the inhibitor at its concentration of 1 mg dm^{-3} SE and ASE reached 51.7 % and 83.2 %, at the concentration of 5 mg/dm^{-3} 83.3 % and 94.2 %. With increasing inhibitor consumption rate to 15 - 20 mg dm^{-3} SE made up 95 % - 96 %. High values of ASE were also observed and, as a rule, they were larger than values of SE (Fig. 4).

Gipan is a very effective stabilizer of scale formation at a temperature of 95ºC for water with high carbonate hardness. This reagent will also be quite effective in cooling systems because the temperature in this case is much lower and does not exceed 60ºC. Therefore, the obtained results confirm the prospects of this reagent as a stabilizer of scale formation.

CONCLUSIONS

In the study is evaluated the effectiveness of gipan for tap water, artesian water and model solution stabilization. It was defined that gipan could be advised to use for stabilization water treatment in circulation systems to reduce the corrosion aggressiveness of water. It was shown that ultrasonic treatment of gipan increased the efficiency of stabilization water treatment. A directly-proportional dependence of the residual hardness on the reagent dose was found.

The application of antiscalant in water circulation cooling systems provides increased efficiency of heat exchange equipment, protection of metal elements against corrosion, reduction of the discharge of water for systems purging and, accordingly, the intake of natural water.

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