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MOBILE DEVICE FOR WATER PURIFICATION WITH BOILER

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Abstract: Water is the best-known universal solvent, which in nature is almost always loaded with minerals. Those minerals can be removed by purifying water, which involves physical and chemical processes that produce higher-quality water.
The goal of this work was the development of an economical mobile device for softening and heating water used in packaging washing processes in the food industry. The designed device was built and assembled, and then tested in operation at the PIK Oplenac winery in Topola. It was concluded that the device provides the desired quality of packaging washing and the required amount of softened and heated water.

Keywords: water quality, ion exchange, water softening, washing, boiler.

Introduction

Food industry plants often require a higher quality of water than prescribed by the Rulebook for drinking water. For many elements present in drinking water, there is a maximum allowed concentration - MAC, as well as a maximum allowed concentration in waste water defined as emission limit value - ELV. Water hardness as a parameter has no MAC, so the user is left to judge for himself whether that parameter should be corrected in drinking water. Our water most often belongs to the group of hard and very hard water, so scale is deposited on elements of sanitary equipment and household appliances, and stains often appear on linen and dishes.

Water hardness can be of carbonate or non-carbonate origin. Transient or carbonate hardness originates from carbonates and bicarbonates of calcium and magnesium, when water is heated to boiling it is lost because the carbonate precipitate is translated into a precipitated solid state. Non-carbonate hardness -

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permanent hardness of water comes from sulfates, phosphates, chlorides, nitrates of calcium and magnesium.

Total hardness (TH) is equal to the sum of carbonate and non-carbonate hardness: TH = CH + NH, i.e. the sum of transitory and permanent hardness: TH = TH + PH, the SI unit of measuring water hardness is: mg $CaCO^3$ / dm^3 of water. In our country, hardness is expressed in German degrees.

Hardness can be reduced in several ways: thermally, magnetically and electromagnetically, high-frequency currents and chemically. In this article, chemical softening is applied.

Chemical softening of water is based on extracting salt, by adding chemical substances, from water in an undissolved form (sediment), which is removed from water by precipitation or filtration. Lime, soda, sodium hydroxide, phosphoric acid salts, etc. are used for chemical softening. The most commonly applied procedures are the decarbonization of water with lime, which is achieved with milk of lime:

$$Ca(HCO3)2 + Ca(OH)2 \rightarrow 2CaCO3\downarrow + 2H2O$$

$$Mg(HCO3)2 + Ca(OH)2 \rightarrow MgCO3\downarrow + CaCO3\downarrow + 2H2O$$

Water softening using the lime-soda process is achieved by removing salts insoluble in water after the action of lime (precipitation and filtration):

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$$

$$MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCO_3$$

However, water-soluble salts remain in the water, which can be removed in the reaction with soda (chlorides, sulfates) by the following reactions:

$$CaSO_4 + Na2CO_3 \rightarrow CaCO_3\downarrow + Na_2SO_4$$

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2NaCl$$

Today, one of the widely used ways of softening water is ion exchange. The following reaction takes place on the grains of the ion exchange material:

$$Ca^{2+} + 2Na - R = Ca - R_2 + 2Na$$

$$Mg^{2+} + 2Na - R = Mg - R_2 + 2Na$$

When the ion mass is saturated, it is necessary to regenerate it. The regeneration process is achieved using a saturated solution of table salt or acid for cationic masses, while anionic ion masses (anions are removed) are regenerated with sodium hydroxide according to the following scheme.

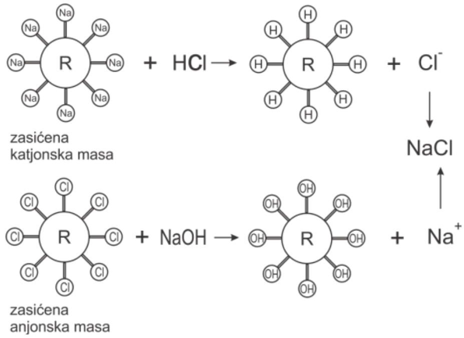

Figure 1. Scheme of cationic and anionic ion mass regeneration

Results and discussion

We designed and built a mobile device for softening and preheating water with a simple construction and low cost that can be used in small food industry plants where washing processes with hot and demineralized water are necessary. Such devices can also be used in other branches of the economy. The device has four components: a water softener, a boiler for heating water, a control cabinet and a mobile platform on which the equipment is fixed. Industrial wheels installed on the underside of the platform allow the device to be easily moved from one location to another along all production lines. For the operation of the device, it is necessary to supply it with alternating current 220V, 50Hz and a supply of drinking water.

The device works as follows. Inlet water of drinking water quality, with increased hardness, enters via valve V1 and candle filter Fs1 into the column with ionic mass KO, where transient water hardness (mainly bicarbonates of calcium and magnesium) is removed. When the water passed through the column, i.e. softened through the ionic mass, it exits through the filter candle Fs2. The production of softened water and the regeneration cycle are managed by an automatic valve head (AVG). The automatic valve head controls the operation of the water softener and determines the start of regeneration based on the measured volume of produced softened water (e.g. after 20 m^3), but in both cases the regeneration, which lasts about eighty minutes, is carried out at 2am (in the case of a single softener) when it is assumed that there is no need for softened water. Regeneration can also be started manually at any time.

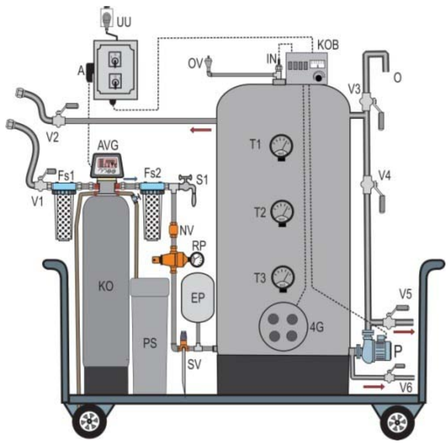

Figure 2. Drawing of a mobile device for softening and preheating water

The ionic mass column is usually made of composite material (polyethylene container reinforced with glass fibers and polyester). Inside the container, there is an ion exchange mass about 75% of the volume of the column. At the top of the column there is a nozzle for the entry of raw unsoftened water, and at the bottom a lower nozzle for the output of softened water (Figure 3).

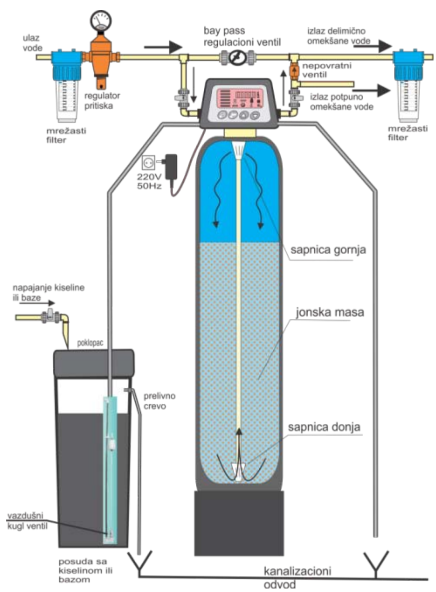

Figure 3. Single-column water softening unit with a brine

A container for making a saturated salt solution is called a brine (Figure 2). The volume of the brine is determined according to the volume of the ionic mass in the column. Tableted table salt is poured into the brine up to half of the container. There should be several centimeters of water above the salt tablet. At the bottom of the brine there is an inlet, ie. perforated bottom so that the water entering the container passing through salt tablets is saturated and as saturated (300 g/l) passes through the perforated bottom.

During the ionic mass regeneration process, a concentrated table salt solution is drawn from the bottom of the vessel with an ejector so that 120 to 200 g of table salt are consumed per liter of regenerated ionic mass. After that process, the same amount of fresh water is added to the brine so that the solution level in the brine is always the same. During the operation of the device, it is necessary to supplement the brine manually with salt tablets. There are five basic water softener cycles. The first cycle is normal operation when it produces softened water. Cycles from the second to the fifth cycle are types of regeneration.

The technological calculation of the capacity of the ion exchanger shows how much water can be softened in one working cycle, i.e. before it enters the regeneration process. If we have 75 l of ionic mass in the column and if the softening capacity is 4000 l/°dH, then the total capacity of the softener is calculated: 4000 x 75 / 17 = 17600 l.

After the cumulative flow through the column of 17600 l of softened water, the regeneration process must be activated, which is achieved by programming the softener head. If the incoming water has a hardness of 17 °dH. We set the desired output water hardness on the water softener. All functions of the device (regeneration, rinsing) are regulated by the built-in automation.

The ion exchange water softener works fully automatically and is programmed according to the following parameters:

1. required flow of softened water of 500 liters per hour continuously during all 24 hours and
2. according to water hardness of 17 °dH (German degrees).

The condition for optimal operation of the softener is the optimal pressure in the pipeline for its supply, which is around 3 bar. The maximum pressure to which the column is certified is 10.5 bar. The automatic valve head works properly if the pressure is up to 6 bar.

The softener feeds the boiler with a volume of 500 l of water. The water heater has dry electric heaters and proper protection so that they cannot be switched on if there is no water in the water heater. The boiler has a double set of thermostats that turn the heaters on and off to reach the optimum temperature. The water heater also has a recirculation pump that is turned on at the same time as the heaters are turned on in order to ensure a uniform, i.e. equal, temperature throughout the entire height of the water heater. Three thermometers are installed on the boiler at different heights in order to measure the temperature along the entire length of the boiler.

On the top of the boiler tank there is an IN level indicator that does not allow the boiler to start working until the water level reaches the top of the tank. If the water heater tank is not completely full, the water heating process will not start, so the signal lights on the control cabinet of the water heater KOB will not turn on. There is a thermostat button on the control cabinet of the KOB boiler, which is used to set the desired water temperature. After turning on the heater, the process of heating 500 liters of water lasts from 4 to 6 hours, depending on the temperature of the incoming water and the temperature of the environment. In the event of an increase in pressure over 6 bar, the safety valve SV opens and the pressure inside the vessel is relieved.

Conclusion

A prototype of a mobile water purification device with a boiler was installed in the PIK Oplenac winery in Topola in the bottling plant, where it is intended to soften and heat water for packaging washing. The device has been in operation for a long period of time and has met the expectations of investors. The device is periodically washed with an acid-based process and then disinfected so that, in periods when it is not working, algae and bacterial pollution do not occur. It is recommended that, after each wine filling and bottling season, the device is washed, disinfected, and the water heater completely emptied of water. The automatic valve head is programmed to regenerate and disinfect the column regardless of the fact that the water was not softened during that period. Since the device has proven to be reliable and provides quality water, we can recommend its use not only in wineries but also in other branches of the food industry and economy.

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