

I'm not a robot



ion exchange resin is a special kind of material that can help make water clean. it is used in many places like water treatment plants and factories. but after some time, it starts to lose its ability to do its job properly. this is called exhaustion. to fix this problem, we need to regenerate the ion exchange resin. regeneration is a way to make the resin work again. it involves using special chemicals to replace the old ions with new ones. this makes the resin good as new and ready to do its job properly. there are many different types of ion exchange resins, each with its own special regeneration method. some of them use sodium chloride or hydrochloric acid to remove the bad ions from the water. others use sodium hydroxide or ammonia solution to make the water clean. when to regenerate is important. if we don't do it on time, the resin will break down and the water will become dirty again. some signs that we need to regenerate include high levels of total dissolved solids in the water, reduced water flow rate, or decreased ion removal efficiency. to know when to regenerate, we can use special tools like conductivity sensors, hardness test kits, and pressure gauges. these tools help us detect changes in the resin's performance and determine the best time to regenerate. there are different types of ion exchange resins, including cation exchange resins, anion exchange resins, and mixed bed resins. each type has its own regeneration method, which is explained below. cations and anions ----- cation exchange resins remove positively charged ions like calcium and magnesium from the water. they are often used in softening processes to make water softer. anion exchange resins, on the other hand, remove negatively charged ions like chloride and sulfate from the water. they are often used in deep water treatment to purify water quality. mixed bed resins contain both cationic and anionic resins and are used in polishing processes that require extremely high water quality. backwashing ----- backwashing is the first step of the regeneration process. it helps remove particulate matter from the resin bed and redistributes the resin particles evenly. regeneration process ----- the regeneration process involves several steps, including backwashing, cleaning, and rinsing. these steps help restore the exchange capacity of the ion exchange resin and make it ready to do its job properly. the regeneration of ion exchange resins is a crucial process in maintaining the effectiveness of water treatment systems. this process involves several stages, including backwashing, chemical agent injection, displacement flushing, and fast flushing. resin performance and regeneration effects, especially when it comes to regular maintenance and testing. Regular checks can help identify potential issues early on, allowing for timely adjustments to optimize regeneration operations and extend the lifespan of the resin. water hardness ----- Why We Need Resin? Excessive water hardness will cause a lot of inconvenience for example in domestic water to much water hardness will reduce the taste of drinking water and in serious cases will affect human health. in boiler water supply, hardness ions in the water will also generate boiler scale in the boiler which not only wastes fuel but also causes explosions. In the field of seawater desalination, there is a lot of Na+, K+, Cl-, CO32-, and SO42- but also a high concentration of Ca2+ and Mg2+, without any treatment, will precipitate a lot of precipitates and cause irreversible scaling inside the system, reducing the recovery rate of water and the stability of operation, thereby increasing operating costs. Therefore, whether from the perspective of domestic water safety or desalination system anti-fouling and scale inhibition, it is inevitable to control the water hardness within a certain range. Ion Resin Softening & Regeneration Process The exchangeable ions carried on the cation resin used for water softening are generally Na+ and H+, which can react with Ca2+ and Mg2+ in the solution. Na-type cation exchange resin, for example, in the solution at room temperature and low concentration, due to the stronger affinity between Ca2+ (or Mg2+) and cation exchange resin, the reaction to the right, Na+ in the resin is continuously replaced by Ca2+ (or Mg2+) until the reaction equilibrium; when the concentration of Na+ in the solution is greater (i.e., the resin is added to saturated saline or HCl solution), the whole reaction is carried out to the point where the concentration of Na+ in the solution is greater (i.e., saturated saline or HCl solution is added to the resin), the whole reaction will proceed to the left, i.e., Ca2+ (or Mg2+) in the resin is continuously desorbed to regenerate the ion exchange resin. Softening and regeneration of Na- exchange resin Resin Regeneration Cycle Calculation The resin regeneration cycle refers to the time used when the exchange resin gradually loses its adsorption capacity after a period of use and reaches the saturated state. The regeneration cycle is influenced by many factors such as water flow, total water hardness, resin selection, etc. According to the volume of the water softener tank, calculate the volume of resin filling, which is generally 60% to 90% of the height of the water softener tank. We can find the regeneration cycle as follows: Periodic water production can also be obtained as: H - Regeneration cycle (hour) Qc - Periodic water production (m3) V - Resin volume (m3) C - Working exchange capacity (mmol/L) Q - Inlet flow rate (m3/h) W - Total water hardness (mmol/L) Recycled Salt Consumption The resin needs to be regenerated with the corresponding salt, acid, and alkali after failure to restore its working capacity, and the regenerant consumption and regenerant ratio are generally used to measure the regeneration capacity of the resin. Regenerant consumption = Regenerant ratio x Molar mass, so Cycle salt consumption = Regenerant ratio x Molar mass (g/mol) x Working exchange capacity (mol/L) x Resin filling volume (L). Temporary hardness in drinking water is caused by dissolved bicarbonate minerals (calcium bicarbonate and magnesium bicarbonate), which contain calcium and magnesium cations that make the water hard. However, unlike permanent hardness caused by sulfate and chloride compounds, temporary hardness can be reduced through boiling or lime softening. Boiling promotes the formation of carbonate from the bicarbonate and precipitates calcium carbonate out of solution, leaving softer water upon cooling. Permanent hardness is generally difficult to remove by boiling and is usually caused by the presence of calcium sulfate/calcium chloride and/or magnesium sulfate/magnesium chloride in the water. Ions causing permanent hardness can be removed using a water softener or ion exchange column. Calcium is the most abundant mineral in the human body, playing vital roles in structure and function, but high levels have been linked to colorectal, gastric, and breast cancer. Magnesium is an essential component in bones and muscles, but excessive supplementation can lead to symptoms of toxicity. Several technologies are available for removing water hardness, including electrochemical processes, enzyme catalysis, nanofiltration, electro-dialysis, ultrasound, ultra-filtration, ion exchange, membranes, and pulsed spark discharge. The two major methods used for removing hardness from water are lime soda softening and ion exchange softening. However, lime soda softening has a high operating cost due to the production of large volumes of sludge, excessive use of chemicals, and pH adjustment with acids. In contrast, ion exchange softening is primarily used for residential purposes and can result in higher sodium levels in softened water compared to municipal water. Adsorption using low-cost sorbents offers a promising alternative for this purpose. polymer sulfonate absorb metal ions via functional groups. Polyacrylic acid and its derivatives are used as adsorbents for metal ion removal [18]. Ion exchange resins can be classified as cation exchangers with positively charged mobile ions or anion exchangers with negatively charged ions. Both types of resins are produced from the same organic polymers. In the early 1900s, scientists discovered the ion exchange process. Cation exchangers were first synthesized in the United States, and the industry was born. Ion exchange resins are widely used for water treatment applications. Water softening and demineralization are the most significant applications. Gans used sodium aluminosilicate materials to soften water in 1905. These materials can absorb calcium or magnesium cations and liberate sodium ions. Zeolite softeners are occasionally used for any cationic exchange resin. In 1944, cationic exchange resins were developed based on polystyrene cross-linked with divinylbenzene. The anion exchange analog was developed in 1948. Using these two resins in sequence allows the complete demineralization of water. Water softening has been practiced commercially for a century or more, using natural and synthetic products. Demineralization has only been practiced since the discovery of synthetic anion exchange resins in the 1920s. The use of ion exchange technology is considered economical and environmentally sustainable for removing hardness [21]. The theory behind the process is to exchange positive and negative ions with hydronium and hydroxide ions. When water passes through a bed, positive metallic ions are exchanged with H+, while others are replaced by OH- [22]. The role of zinc and copper [27] in water treatment is a vital aspect of maintaining potable water. The ion exchange method, widely employed in the industry, offers an effective solution for purifying and separating various chemical compounds from contaminated water. Typically, IX polymer resin made of organic structures [21] is used as the medium. The deionization process includes three main steps: backwashing, regeneration, and rinsing. The regeneration process can restore only 60-80% of the resin capacity, leaving some ions and hardness on the resins. During service, these ions may leach off into the treated water effluent, known as leakage [36]. To address this, the regeneration cycle continues until the ions removed from the feed water during service are recovered or meet the allowable limits. Monitoring the electrical conductivity of water after each washing cycle can help track the progress of the regeneration cycle. It is expected that the electrical conductivity will decrease until it reaches distilled water levels [37]. The brining process uses a sodium cycle to soften water, where concentrated NaCl is passed through the bed to remove calcium and magnesium ions. However, this may lead to lowering the resin capacity if iron ions are present, as they can oxidize and block exchange sites on the resin. To minimize this issue, more frequent and quick regeneration can be performed to prevent iron oxidation [38]. Mixing sodium bisulfate with sodium chloride can also enhance the process by reducing insoluble ferric ions to their soluble form [38]. Deionized water has various applications, including cooling mediums and laboratory testing. In this work, tap water is deionized using HCl and NaOH as regeneration agents for the cathodic and anodic resins, respectively. The CE 300 Ion exchange demonstration unit is used in this study, which features cation and anion exchangers with strong and weak basic or acidic contents [39]. The apparatus allows for testing related to water softening and demineralization. The unit layout is illustrated in Figure 2. The CE 300 enables water deionization using both cation and anion exchangers. Raw water is pumped from the tank into the top of the cation exchanger, which then flows back into the collecting tank during the softening process. To desalinate the raw water, it passes through the anion exchanger before entering the collecting tank. During regeneration, acid or caustic is fed into the ion exchangers from below using the same pump. The acid and caustic used are collected in the collecting tank. The flow rate of the pump can be adjusted, and is adjustable, with a conductivity sensor installed upstream of the inlet to measure values [39]. Tap water can be used as raw water. Commercial cation and anion exchangers were provided by Gunt Hamburg (Germany), including the MERCK 104765 cation exchanger IV and MERCK 104767 anion exchanger III. The set-up was prepared by opening/closing valves as described, with solutions of HCl and NaOH in distilled water used for regeneration. The cation tube was filled with a 5% HCl solution, while the anion tube contained a 0.1% NaOH solution, both holding 20 grams of polymeric resin. The process began by pumping hard water through the column and allowing it to pass through the outlet tubes until a steady flow occurred. At this point, the conductivity of the water at the outlet was recorded every 10 seconds. Once the pump turned off, the experiment continued with other concentrations of HCl and NaOH: 0.5 vol% increments for HCl and 0.1 vol% increments for NaOH. Furthermore, the process was repeated to study the effect of varying amounts of water treated by adjusting the concentration of HCl and NaOH in the cationic and anionic resins. The resin amount varied during each run as well. To reduce costs and minimize solid waste, the focus was on resin regeneration using different acid-base combinations at various concentrations. The resins are deionizing the passing water. It started off with a conductivity of 864 µS which is the conductivity of tap water and ended with a conductivity of 73.19 µS. When the volume increased to 2 L, the lowest conductivity was found to be 70 µS after 140 seconds have passed. On the other hand, when 3 L of water was added, 1.14 L of water was treated and the lowest conductivity was found to be around 77.2 µS; after this point, the conductivity increased again and that happened at 70 seconds (Figure 4). For the case of 4 L of water being added, an amount of 1.63 L of water was treated. The lowest conductivity was found to be 242 µS and then it started to increase at 70 seconds. This shows that as more water is being treated, the conductivity increases. Effect treated water on resin regeneration; resin amount: 20 g in both tubes; 5 vol% HCl—1 vol% NaOH. The effect of amount of resin used in cationic anionic resin tubes on deionization is also studied by putting different amounts of resins in each tube with different volumes of hard water as 3 using 5 vol% HCl in the cationic resin tube and 1 vol% NaOH in anionic resin tube. The results are shown in Figure 5. The case of 20 g resin is the same as the described in the previous section. When the amount of resin was increased to 40 g, the same trend was obtained as that of the 20 g resin. However, more water was deionized in this case because more resin was used. In other words, it required around 480 seconds to saturate the resin and to stop the deionization process. This shows that increasing the resin amount, helps in increasing the deionization efficiency. The resin amount was again increased to 60 g. The water was being deionized until 560 seconds were reached and a conductivity of 19.8 µS was obtained. After this point, the conductivity started to increase again indicating that the resin has been saturated. As the resin amount increased, the apparatus was able to give better results in terms of removing more ions from the water. For example, at 500 seconds the conductivity was found to be 38.6 and 20.4 µS for the 40 and 60 g, respectively. This shows that the amount of resin is related to the deionization efficiency. As the amount of resin increases, more ions are removed. Effect amount of resins on resin regeneration using 5-vol% HCl in cationic resin tube and 1-vol% NaOH in anionic resin tube. Water conductivity decreases with the increase in resins concentrations; the lowest conductivity is achieved when using 1-vol% NaOH and 5-vol% HCl in the cathodic and anodic resin tubes, respectively. The results of this work show that water conductivity increases with the increase in the amount of water being used. The amount of resin significantly impacts the deionization efficiency; more ions are removed as the amount of resin increases. The optimization implemented in this work is considered superior compared to other deionization techniques due to life time and efficiency of the reused resins. Using Ion Exchange Technologies for Water Treatment and Softening ===== The use of ion exchange technologies has become a crucial method for water treatment and softening in recent years. This process involves the removal of impurities from water using resins that can selectively capture specific ions or compounds, resulting in cleaner and softer water. Ion exchange resins gradually accumulate contaminants that decrease their ability to remove ions from solutions. Regeneration brings back resin capacity while reducing replacement costs and minimizing downtime. The regeneration method uses specific chemicals to reverse the ion exchange reaction, depending on whether the resin is cationic, anionic, or mixed-bed. ===== The calculation of the required hydrochloric acid mass involves using its molar mass and concentration in the given formula. The mass fraction of HCl is typically 15% for commercial solutions, while the density of HCl can be found from the provided table. Using the following formula, calculate the mass of the required hydrochloric acid: mHCl (kg) = m / ϕHCl * pHCl where: mHCl - mass of the required commercial hydrochloric acid - m - mass to be calculated ϕHCl - mass fraction of the hydrochloric acid solution (15%) pHCl - density of the hydrochloric acid solution (from table) The calculation of the regeneration agent for anion resin follows a similar process.