

Accelerated seeded precipitation pre-treatment of municipal wastewater to reduce scaling

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Received 13 July 2007; received in revised form 21 January 2008; accepted 22 January 2008

Available online 6 March 2008

Abstract

Membrane based treatment processes are very effective in removing salt from wastewater, but are hindered by calcium scale deposit formation. This study investigates the feasibility of removing calcium from treated sewage wastewater using accelerated seeded precipitation. The rate of calcium removal was measured during bench scale batch mode seeded precipitation experiments at pH 9.5 using various quantities of calcium carbonate as seed material. The results indicate that accelerated seeded precipitation may be a feasible option for the decrease of calcium in reverse osmosis concentrate streams during the desalination of treated sewage wastewater for irrigation purposes, promising decreased incidence of scaling and the option to control the sodium adsorption ratio and nutritional properties of the desalted water. It was found that accelerated seeded precipitation of calcium from treated sewage wastewater was largely ineffective if carried out without pre-treatment of the wastewater. Evidence was presented that suggests that phosphate may be a major interfering substance for the seeded precipitation of calcium from this type of wastewater. A pH adjustment to 9.5 followed by a 1-h equilibration period was found to be an effective pre-treatment for the removal of interferences. Calcium carbonate seed addition at 10 g l^{-1} to wastewater that had been pre-treated in this way was found to result in calcium precipitation from supersaturated level at 60 mg l^{-1} to saturated level at 5 mg l^{-1} . Approximately 90% reduction of the calcium level occurred 5 min after seed addition. A further 10% reduction was achieved 30 min after seed addition.

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Keywords: Calcium; Interference; Phosphate; Effluent; Water reuse; Irrigation

1. Introduction

The world's growing human population is increasingly drawing upon our planet's fresh water resources. It is estimated that many capital cities in Australia will not have sufficient water supplies to meet their growing populations (Horticulture Australia Limited, 2006). Recycling and reuse of water is therefore becoming an increasingly important water management option.

Treated sewage effluent (commonly known as wastewater, recycled water or reclaimed water) is a water resource

that has been under-utilized in Australia. About 94% of Melbourne's sewage ($855 \times 10^3 \text{ m}^3 \text{ d}^{-1}$) is treated at two main treatment plants (Melbourne Water, 2007a). Less than 10% of this water resource is treated and utilized. The remainder is discharged to the environment (Horticulture Australia Limited, 2006).

Treated sewage plant wastewater contains considerable quantities of nutrients, making it an attractive option for its use in irrigation. It also, however, contains considerable quantities of salt. Approximately 45% of the salt in sewage that flows to one of Melbourne's sewage treatment plants comes from industry and about one-quarter comes from households. Salt in its various forms is widely used in manufacturing processes and is a by-product of many operations (Melbourne Water, 2007b).

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The treated wastewater from Melbourne sewage treatment plants typically contains approximately 1050 mg l^{-1} total dissolved solids (TDS). Investigations have shown that the most appropriate and sustainable uses of recycled water require a salinity level of less than 550 mg l^{-1} TDS (Melbourne Water, 2007b). Therefore salinity reduction is required before sewage treatment plant effluent can be used in unrestricted irrigation applications.

Technologies for desalination include membrane processes, thermal distillation and ion exchange. Membrane and thermal distillation processes are the most commonly applied technologies in large desalination plants. Membrane based desalination processes are increasingly becoming accepted as the method of choice for a wide range of applications. Reverse osmosis (RO) for brackish water desalination is the most utilised method in Australia (Baron, 2006).

One of the major impediments to the widespread use of membrane based processes is the fouling of membranes, leading to higher energy requirements and irreparable damage to the membrane. This fouling can be caused by colloidal material (Lee et al., 2004), microorganisms such as bacteria (Park et al., 2005), organic material such as humic acids (Tang et al., 2007) or inorganic material such as mineral salt scale (Sheikholeslami, 2003).

Mineral salt scaling can occur when ions such as Ca^{2+} , Ba^{2+} , CO_3^{2-} , SO_4^{2-} , F^- and PO_4^{3-} in the membrane concentrate stream are concentrated above the solubility limit of sparingly soluble salts (e.g. calcium carbonate, calcium sulfate, calcium fluoride, calcium phosphate, barium sulfate). This scaling leads to permeate flux decline, lower water recoveries and shortening of membrane life (Rahardianto et al., 2006). Although membrane elements can be cleaned using a variety of chemicals, this cleaning may require interruption of the desalination process and generates secondary effluent for disposal.

The composition of sewage treatment plant wastewater is subject to seasonal and yearly variation. The average levels of calcium in monthly monitoring trials of wastewater from one of Melbourne's sewage treatment plants has been reported to be approximately 35 mg l^{-1} (Southern Rural Water, 2006). This concentration would be expected to double in the concentrate stream of a membrane filtration process operated at 50% water recovery. Such an increase in calcium levels is expected to cause scaling at the membrane surface, leading to flux decline, higher power consumption and compaction of the membrane.

There are three main options to avoid or minimize the formation of scale: lowering the pH (for calcium carbonate or calcium phosphate scale), running the plant at lower water recoveries, and removing the calcium by seeded precipitation.

Treated wastewater from sewage treatment plants is often supersaturated with respect to calcium. However, supersaturation alone is not sufficient for commencement of precipitation in a solution. There must exist in the solution a number of seeds that act as centres of nucleation.

Accelerated seeded precipitation involves the addition of nucleating site for precipitation of ions from this supersaturated solution. The rate of accelerated precipitation depends largely on the degree of supersaturation and the number of nucleating sites added to the solution.

The use of accelerated seed precipitation to remove the scaling ions from the first stage RO concentrate, before feed to the next stage RO, can not only decrease the incidence of calcium scaling during desalination, but also allow greater control over the composition of the recycled water. If the water is recycled for agricultural irrigation, for example, it is possible to return some or all of the removed calcium and other ions to the (low salt) recycled water, thereby improving the sodium adsorption ratio and its nutrient value.

One of the difficulties associated with the use of accelerated seed precipitation for reduction of calcium in wastewater is the potential for interference by substances such as organics and phosphates present in the wastewater. These substances can interfere with calcium carbonate precipitation mechanisms (Sawada, 1997) by a variety of mechanisms that are not fully understood (He et al., 1999), which may involve adsorption and/or co-precipitation of the interfering substance onto the calcium carbonate lattice (House and Donaldson, 1986; Sawada, 1997). Concentrations of orthophosphate as low as a few μM have been found to significantly retard the rate of calcium carbonate crystal growth in seeded solutions (Lin and Singer, 2005, 2006).

For seeded precipitation of sparingly soluble salts that have a pH dependent solubility (e.g. calcium carbonate, calcium hydroxyapatite) it is often necessary to raise the pH of the wastewater. This increases the extent of precipitation due to the lower solubility of these salts at higher pH values, and increases the speed of precipitation due to the effective increase in the supersaturation of the solution.

In the current study, the feasibility of using seeded precipitation to lower the level of calcium in sewage treatment plant effluent is investigated. Treated sewage treatment plant (TSTP) wastewater was spiked with calcium to approximately 60 mg l^{-1} in order to simulate the increase in calcium concentration associated with membrane treatment. Due to the complex nature of this wastewater, the expected increase in concentration of the many other wastewater constituents was not simulated in this study.

2. Materials and methods

Analytical reagent grade calcium carbonate (Ajax Chemicals) was used as supplied for all experiments involving calcium carbonate seed addition.

One litre of TSTP wastewater was dosed with $500 \mu\text{l}$ of 100 g l^{-1} calcium (as calcium chloride) and 150 g l^{-1} carbonate (as sodium carbonate), thereby increasing the calcium concentration from the 25 to 75 mg l^{-1} (sample no. 1) or 31–81 mg l^{-1} (sample no. 2), and increasing the car-

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