ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

Factsheet:

Softening, coagulation and flocculation with alternative by-products

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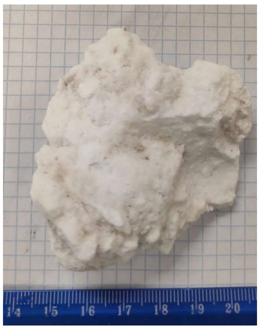
Softening, coagulation and flocculation with alternative by-products



Unique selling points:

- ✓ Removal of both hardness and organic matter
- ✓ Reuse of local by-products
- ✓ Increase of materials symbiosis between industry and utility
- ✓ Reduction of waste disposal

Description of the technology

Hard water is any type of water that contains more minerals than average tap water. Mostly it has to do with elevated levels of calcium and magnesium. Hence, water softening is a process in which the ions of calcium and magnesium are removed (Ordonez et al. 2012).

When treating water with a high hardness, a softening process could also reduce the conductivity of the water, avoiding reaching very high values of conductivity after the coagulation phase (Ordonez et al. 2012). Chemical precipitation is one of the more common methods used to soften water. Chemical additives such as lime or soda induce the formation of insoluble precipitates that are readily discharged from the water to obtain soft water (Wang et al. 2019):

$MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2\downarrow + CaSO_4$

$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3\downarrow + Na_2SO_4$

These precipitates are then removed by conventional processes of coagulation/flocculation, sedimentation, and filtration.

In this application, industrial by-products will be tested and used as softening agents or coagulants:

1. Sodium Carbonate (Na_2CO_3): off-specification waste material of the "Soda Solvay Light" produced and commercialized by Solvay.
2. Precotto: partially cooked calcareous rocks produced by Solvay
3. Iron and alum sludge from drinking water treatment plants

Sodium Carbonate and Lime have been used in softening/coagulation/flocculation processes, mainly to reduce hardness in wastewater streams. A softening step to remove impurity ions (i.e., Ca2+ and Mg2+) from hypersaline coal chemical wastewater used Sodium Carbonate with a dosage of 1.3 g/L Na_2CO_3 (Chen et al. 2021). Similarly, a combination of coagulation, softening and flocculation was applied to treat the concentrated stream of a reverse osmosis unit. Different polyaluminium chlorides and one ferric salt were used as coagulants, lime was added as softener, and two polymers (anionic and cationic polyacrylamides) were tested as flocculants. In this case, thanks to Lime dosage conductivity was reduced through the removal of Ca^{2+} and Mg^{2+} (Ordonez et al. 2012).

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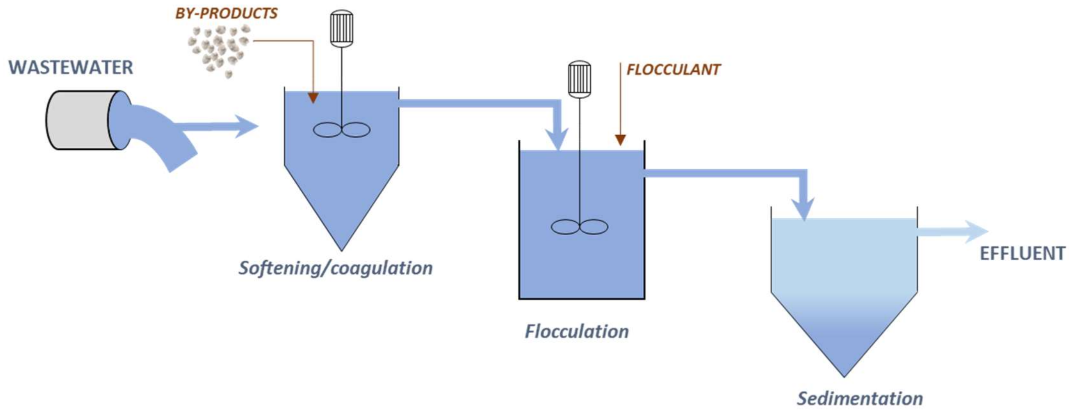
Sludge is a residual of the drinking water treatment processes, which could be reused for wastewater treatment. In particular, alum-based sludge (AbS) contains a large portion of insoluble alum hydroxides, and the possibility to reuse alum-rich sludge may be a practical solution to reduce the problems associated with its handling and disposal (Foroughi et al. 2018). Alum rich coagulation sludge could be used in soil amendment, in construction industry, in constructed wetland, for phosphate removal and for cement production, while Iron rich coagulation sludge could be used for soil amendment, in construction industry, in constructed wetland, as raw material for clay brick and cement production and potentially also for sulfide control in sewers and digester (Pikaar et al. 2022). Water treatment sludge has already been successfully used to improve the removal efficiencies of suspended solids (SS) and chemical oxygen demand (COD) in wastewater as well as to enhance the removal of natural organic matter (NOM) in surface water (Xu et al. 2016; Foroughi et al. 2018). In a further application, combinations of water treatment sludge with fresh coagulant proved to obtain a substantially higher COD removal compared to the removal obtained by fresh coagulant alone during wastewater treatment (Nair & Ahammed 2015).

Flow scheme of the technology



Synergetic effects and motivation for the implementation of the technology

- ✓ **Recovery of industrial by-products**

The application of this technology in Aretusa case study has the purpose to increase the sustainability of the wastewater treatment process by maximizing the circularity of reagents and materials used in the plant. In this way, in fact, residuals of the local industrial production cycle are reused in the Aretusa plant to increase the quality of the treated wastewater and, consequently, the sustainability for the water reuse by Solvay Industry. Moreover, the Aretusa plant is located in the same area of Solvay plant, and this fact contributes to further reduce costs and impacts for material transportation and production. Finally, finding a useful application for these residuals will save costs for disposal and will reduce the waste production.

- ✓ **Removal of both hardness and organic matter**

Requirements of the technology and operating conditions

A typical softening/coagulation/flocculation process involves three treatment steps that require different reaction times and mixing velocity. Coagulation and softening are usually

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short in time and have high mixing velocities, while lower mixing velocities are applied during flocculation to avoid the breakage of the formed flocs.

Tab. 1 Typical ranges for operating parameters

Parameter	Units	Min	Max	Reference
Coagulation time	min	1	5	Sher et al. 2013; El-Gohary & Tawfik 2009
Coagulation mixing velocity	rpm	100	600	El-Gohary & Tawfik 2009; Ordonez et al. 2012; Foroughi et al. 2018
Softening time	min	2		Ordonez et al. 2012;
Softening mixing velocity	rpm		200	Ordonez et al. 2012;
Flocculation time	min	20	30	Sher et al. 2013; El-Gohary & Tawfik 2009
Flocculation mixing velocity	rpm	20	50	Ordonez et al. 2012; El-Gohary & Tawfik 2009; Foroughi et al. 2018
Sedimentation time	min	30	60	Ordonez et al. 2012; El-Gohary & Tawfik 2009

Key performance indicators

Tab. 3 Key performance indicators

Parameter	Units	Value	References
Hardness and Cod removal compared to commercially available material	%	TBD	
Reduced waste production	kg/ton	TBD	
Chemical sludge production compared to commercially available material to obtain similar treatment performance	%	TBD	

Links to related topics and similar reference projects

Process/technologies	Reference

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