

Lime Softening

Lime softening is often used to reduce the hardness of water and sometimes to enhance clarification prior to filtration. Hardness is the sum of all multivalent ions, which for typical water treatment applications are mainly of calcium and magnesium. Water is considered to be hard if it contains 150 mg/L as CaCO_3 or more [1].

1.0 Applicable Contaminants

Lime Softening is an EPA BAT for the following contaminants arsenic, barium, beryllium, chromium (for Cr III only), copper, fluoride, lead, mercury, cadmium, nickel, and radionuclides.

2.0 Description of Technology

The origin of lime softening dates back to 1841 when lime was added to Thames River water to reduce bicarbonate hardness by precipitation of calcium alkalinity as calcium carbonate and magnesium alkalinity as magnesium hydroxide. Modern day lime softening, referred to as the cold lime process, operates under the same principle.

The softening process typically includes pretreatment, softening, recarbonation, and filtration steps.

Pretreatment Pretreatment consists of either aeration or presedimentation. Aeration is necessary with waters that have high CO_2 concentrations, such as ground water. Presedimentation is used with very turbid surface waters, in order to create a more consistent feed water quality.

Technology Description In the softening step, the first chemical addition is quick lime, or CaO , which combines with H_2O to form calcium hydroxide, or $\text{Ca}(\text{OH})_2$. The calcium in the water then reacts with CO_2 to form a calcium carbonate (CaCO_3) precipitate. The optimum pH for this process is about 10.3. Magnesium precipitation in the form of magnesium hydroxide, $\text{Mg}(\text{OH})_2$, requires a pH of 11.0 to 11.3. This pH can be obtained by using additional lime.

Solids contact clarifiers combine mixing, flocculation and sedimentation in a single basin and are commonly used for lime softening. Raw water and chemicals mix with previously formed lime slurry in a centrally located draft tube with impeller. Quick lime is usually in the form of pebbles, which need to be slaked with mixing equipment. Slaking creates a mixture of 2 parts water and 1 part lime slurry in a separate facility, which is then fed to the solids contact clarifier along with the addition of a coagulant. The coagulant could be iron based (ferric sulfate, ferrous sulfate) or aluminum based (aluminum sulfate or sodium aluminate). Sodium aluminate is the preferred coagulant if the feed water contains high sulfate concentrations. The water depths in solids contact clarifiers usually range from 14 to 19 ft, and contact time is typically 15 to 30

min.¹ Surface loading rates typically range from 1.0 to 1.75 gpm/ft². If coagulation for turbidity removal is required the surface loading rate is usually on the lower end of this range.¹

The water then passes through distinct zones within the basin for reaction, flocculation and clarification. Clarified water is collected in radial effluent launders which direct the flow to an effluent discharge pipe. Solids in the clarification zone settle to the bottom of the basin and are moved to the center by a rotating sludge rake.

Effluent pH from the lime softening process is around 10 to 11. A pH adjustment is required to reduce the pH to around 8. The pH adjustment is particularly important when using MF membranes since high pH water may induce scaling on membrane surfaces. The pH adjustment is performed by injecting sulfuric or hydrochloric acid into the effluent stream with a metering pump. Sulfuric acid is preferred over hydrochloric due to the lower dosages and costs required.

Soda ash (Na₂CO₃) can then be added to remove non-carbonate hardness, in a process known as second stage softening, which is prior to filtration as well.

Recarbonation

After softening is complete, the water must be recarbonated with CO₂ in order to stabilize the water and bring the water up to a minimum calcium hardness. This is performed prior to filtration, and the typical target concentration of bicarbonate alkalinity is 40 mg/L.¹

Filtration

Conventional media filters are traditionally used after lime softening to capture remaining suspended solids in the lime softening effluent. However, membrane technology is rapidly gaining popularity as an alternative to media filters due to their higher removal efficiencies of microorganisms. The lime softening process typically produces a 1% lime sludge waste stream.

Maintenance A routine check of chemical feed equipment is necessary several times a day to prevent clogging and equipment wear, and to ensure adequate chemical supply. All pumps, valves, and piping must be regularly checked and cleaned to prevent buildup of carbonate scale, which can cause plugging and malfunction. Similar procedures also apply to the sludge disposal return system, which takes the settled sludge from the bottom of the clarifier and conveys it to the dewatering and disposal processes.

Waste Disposal The solids content of the sludge produced by the lime softening process is about 2% to 15% by weight. Dewatering of the sludge must take place in order to properly dispose of the solids. The dewaterability of the sludge depends on its magnesium hydroxide content. A low magnesium hydroxide content sludge can be dewatered to 60% solids, but a high magnesium hydroxide content can only be dewatered to 20 to 25% solids.

The total amount of dry weight solids that is produced by the excess lime softening process is about 2.5 times the hardness that is removed, and 2.0 times for the straight lime process.¹ Some lime sludges may be recycled by reclamation if the sludge is of sufficient quality². The lime sludge can be permanently lagooned, landfilled after dewatering, or used for fill in strip mine areas or borrow pits².

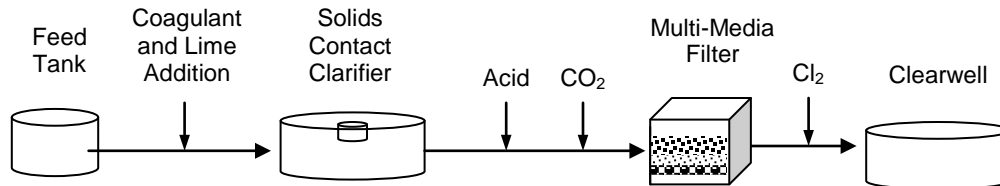
Benefits

- Reduces dissolved minerals and scale forming tendencies
- Removes heavy metals, such as arsenic
- Removes radium 226 and 228
- Removes certain organic compounds and NOM
- Removes inorganic compounds such as: silica, iron and manganese
- Reduces turbidity
- A proven and reliable treatment process
- Little or no pretreatment required

Limitations

- Operator care required with chemical handling
- Produces high sludge volume
- Filtration is usually required after lime treatment
- Waters high in sulfate may cause significant interference with removal efficiencies

3.0 Example Treatment Train



4.0 Safety and Health Concerns

- Chemical storage and handling (acids, bases, lime, etc.)
- Sludge production hazards (base)

5.0 References

1. American Water Works Association, and American Society of Civil Engineers. Water Treatment Plant Design. Ed. Edward E. Baruth. Fourth ed. New York: McGraw-Hill Handbooks, 2005.
2. Corbitt, Robert A. Standard Handbook of Environmental Engineering. Second ed. New York: McGraw-Hill Handbooks, 1999.
3. Perry, Robert H., Don W. Green, and James O. Maloney. Perry's Chemical Engineers Handbook. Seventh ed. New York: McGraw-Hill, 1997.

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