National Lime Association

LIME

The Versatile Chemical

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"Lime Facts" bulletin
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ENVIRONMENTAL USES

The use of lime to address environmental problems is one of the fastest-growing markets for lime products. As explained in more detail below, lime has found key uses in almost every area of pollution prevention and abatement, including treatment of air emissions, treatment of both drinking water and wastewaters, and remediation of hazardous wastes. Lime's unique characteristics, coupled with its low cost, make it an attractive choice for these applications.

Flue Gas Treatment

Lime is used to remove acidic gases, particularly sulfur dioxide (SO_2) and hydrogen chloride (HCl), from flue gases. Lime is more reactive than limestone, and requires less capital equipment. SO_2 removal efficiencies using lime scrubbers range from 80 to 99 percent (at electric generating plants). HCl removal efficiencies using lime range from 30 to 50 percent (at municipal waste-to-energy plants).

Lime reacts with sulfur dioxide to form calcium sulfite:

$$SO_2 + Ca(OH)_2 \rightarrow CaSO_3 + H_2O$$

The sulfite can then be air-oxidized to form calcium sulfate dihydrate, or gypsum:

$$2CaSO_3 + O_2 \rightarrow 2CaSO_4$$

$$CaSO_4 + 2H_2O \rightarrow CaSO_4 \bullet 2H_2O$$

The overall reaction of lime with hydrochloric acid is similar:

$$2HCl \text{ (hydrochloric acid)} + Ca(OH)_2 \rightarrow CaCL_2 \text{ (calcium chloride)} + 2H_2O$$

There are two main methods for the removal of acidic gases: wet scrubbing and dry scrubbing. Both methods are used for cleaning flue gases from the combustion of coat to produce electric power.
Dry scrubbing is also used at municipal waste-to-energy plants.

Wet Lime Scrubbing - In wet scrubbing, lime is added to water to form a slurry that is sprayed into a flue gas scrubber. The sulfur dioxide is absorbed into the spray and then precipitated out as calcium sulfite. Wet scrubbing is used primarily for high-sulfur fuels and some low-sulfur fuels where high efficiency sulfur dioxide removal is required. Wet scrubbing is a primary use for magnesium-enhanced lime (containing 3-6% magnesium oxide) for SO_2 removal, because it provides high alkalinity that increases SO_2 removal capacity, and provides for low scaling potential.

Dry Lime Scrubbing - In dry scrubbing, hydrated lime is injected directly into flue gas to remove SO_2 and HCl. There are two major processes, one in which dry hydrated lime is injected, and a second in which a lime slurry is injected.
Both methods yield a dry final product. At electric generating plants, dry scrubbing is used primarily for low-sulfur fuels. At municipal waste-to-energy plants, dry scrubbing is used for removal of SO_2 and HCl. Dry scrubbing methods have improved significantly in recent years, resulting in excellent removal efficiencies.

Mercury Removal - Many different methods for controlling mercury emissions are being evaluated in the U.S. One control technology being evaluated combines hydrated lime with activated carbon.
Other researchers are evaluating calcium-based sorbents as a cost-effective alternative for combined sulfur dioxide and mercury control in electric utility applications.

Drinking water treatment

In terms of annual tonnage, lime ranks first among chemicals used in the treatment of potable and industrial water supplies. It is used by many municipalities to improve water quality, especially for water softening. Indeed, the American Water Works Association (AWWA) has issued standards that provide for the use of lime in drinking water treatment.

Softening - In water softening the function of lime is to remove "carbonate" hardness (caused by bicarbonates and carbonates of calcium and magnesium) from the water, which is normally reduced by treatment with hydrated lime. Hardness caused by other calcium and magnesium salts, called "noncarbonate" hardness, is generally treated by means of the lime-soda process, which entails the precipitation of magnesium by lime. The co-produced calcium salt reacts with the soda ash to form a calcium carbonate precipitate.

pH Adjustment/Coagulation - Hydrated lime is widely used to adjust the pH of water to prepare it for further treatment. Lime is also used to combat "red water" by neutralizing the acid water, thereby reducing corrosion of pipes and mains from acid waters. The corrosive waters contain excessive amounts of carbon dioxide (carbonic acid). Lime precipitates the CO_2 to form calcium carbonate, which provides a protective coating on the inside of water mains.

Lime is used in conjunction with alum or iron salts for coagulating suspended solids incident to the removal of turbidity from "raw" water. It serves to maintain the proper pH for most satisfactory coagulation conditions. In some water treatment plants, alum sludge is treated with lime to facilitate sludge thickening on pressure filters.

Effect on Pathogen Growth - By raising the pH of water to 10.5-11 through the addition of lime and retaining the water in contact with lime for 24-72 hours, lime controls the environment required for the growth of bacteria and certain viruses. This application of lime is utilized where "phenolic water" exists, because chlorine treatment tends to produce an unpalatable water due to the phenol present. This process is called "excess alkalinity treatment," also removes most heavy metals.

Removal of Impurities - One of the most common methods of removing silica from water is the use of dolomitic lime. The magnesium component of this lime is the active constituent in silica removal. Lime is used to remove manganese, fluoride, and to a lesser extent iron from water supplies. Oftentimes supporting chemicals are required. In softening it also removes organic tannins from the water.

Wastewater Treatment

Lime is also extensively used in the treatment of municipal wastewaters, as well as industrial liquid wastes.

Municipal Wastewater Treatment - In more advanced wastewater treatment plants, lime precipitation is employed in tertiary processes in which phosphorous is precipitated as complex calcium phosphates along with other suspended and dissolved solids. Often supplementing lime precipitation is activated carbon treatment for final clarification of the effluent before discharge. Due to the high pH of 10.5-11 maintained by lime, the stripping of nitrogen, another nutrient, is facilitated. Thus, the removal of phosphorus and nitrogen helps prevent eutrophication (algae build-up) in surface waters.

When alum and ferric chloride are employed for coagulation, lime is used to counteract the low pH induced by these acid salts and to provide the necessary alkalinity for efficient nitrogen removal.

In sewage plants where sewage sludge is removed by vacuum or pressure filtration, lime and ferric chloride are employed as fitter aids in the conditioning of the sludge and for final clarification of the effluent.

Industrial Wastewater - In steel plants, sulfuric acid-based waste pickle liquors are neutralized with lime in which the iron salts are precipitated. Lime is also a neutralizer and precipitant of chrome, copper, and heavy metals in processes for treating discharges from plating plants.

Lime is also used to neutralize sulfuric acid wastes from rayon plants and to neutralize and precipitate dissolved solids from wastes of cotton textile finishing plants (dyeworks).

Vegetable and fruit canning wastes can be clarified with lime alone or with supporting coagulants as an alternate to lagooning of the liquid waste. In citrus canning, lime assists in clarifying wastewaters and in the processing of citrus pulp by-products used for cattle feed by neutralizing acidity and reducing corrosion to processing equipment. Further, this application serves as a calcium supplement to the cattle and as a dewatering aid.

The most efficacious method of solving the waste treatment problem of beet sugar plants is to clarify the wastewater with lime for reuse in the process. Water is conserved, and it is also possible to recover secondary sugar residues of value.

Acid Mine Drainage - Highly acidic drainage from active or abandoned mines is frequently neutralized with lime. Further clarification of the discharge is achieved by precipitation of iron contained in this pyretic leachate. Coal washing plants use lime to neutralize the acidic waste or process water to reduce corrosion on steel equipment and to recover the water for reuse.

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Sludge Treatment

Sewage Biosolids - Quicklime and calcium hydroxide have been used to treat biological organic wastes for more than 100 years. The treatment of human wastewater sludges (i.e. biosolids) by lime treatment is specifically prescribed in U.S. EPA regulations (40 C.F.R. 503). There are many examples of wastewater treatment systems using lime stabilization. In 1996, more than 450,000 metric tons of lime were used for biosolids treatment in the U.S.

Lime treatment controls the environment needed for the growth of pathogens in biosolids and converts sludge into a usable product. Lime stabilization is a cost-effective option that generally has lower capital costs than alternative treatment options.

The mechanism of lime treatment of biological wastes is based on several chemical reactions:

- Calcium hydroxide is an alkaline compound that can create pH levels as high as 12.4. At pH levels greater than 12, the cell membranes of harmful pathogens are destroyed. The high pH also provides a vector attraction barrier, preventing flies and other insects from infecting the treated biological waste. Because lime has low solubility in water, lime molecules persist in biosolids. This helps to maintain the pH above 12 and prevent regrowth of pathogens, allowing achievement of EPA's Class B requirements.
- When quicklime (CaO) is used, an exothermic reaction with occurs. This heat release can increase the temperature of the biological waste to 70°C, which provides pasteurization that can meet EPA's Class A requirements.
- The high pH also will precipitate most metals present in the waste and reduce their solubility and mobility. Lime will also react with phosphorus compounds.
- The solubility of calcium hydroxide also provides free calcium ions, which react and form complexes with odorous sulfur species such as hydrogen sulfide and organic mercaptans. Thus the biological waste odors are not "covered over" but actually destroyed.
- The addition of lime also increases the solids content of the waste, making it easier to handle and store.

Lime-treated biosolids are safe and promote recycling. As EPA notes, "properly prepared biosolids provide a rich source of the essential fertilizer elements needed by plants to produce food." U.S. EPA, "Biosolids Recycling: Beneficial Technology for a Better Environment," (June 1994). Reuse of lime stabilized biosolids s not limited to use on farmland. Biosolids have also been used as a soil substitute for landfill cover, and in reclamation of mining-desabled land. Exceptional quality biosolids can also be sold for public use as a commercial fertilizer or soil conditioned.

Animal Wastes - An emerging issue in the U.S. is the environmental threat caused by animal wastes. Current management practices have begun to create environmental problems because of the consolidation of the livestock industry into much larger facilities, and the resulting concentration of waste-producing activities. Concentrated animal feeding operations for beef cattle, swine, and poultry can create numerous problems, including eutrophication of surface waters, groundwater contamination, pathogen release and offensive odors.

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Lime treatment is a potential solution that can address many of these environmental threats. Lime can be used to control the environment needed for the growth of pathogens, similar to the way that lime stabilization is used for human sewage sludges (biosolids). Lime can also be used to reduce the solubility of nutrients. Lime may also be used to control odors-hydrogen sulfide, in particular. Lime offers a practical and economic option for animal waste treatment, based on the favorable economics of biosolids treatment and the fact that lime is already used on farms in other ways (e.g., to create impermeable feedlot surfaces and for soil sweetening).

Industrial Sludges and Petroleum - Quicklime and hydrated lime can be used in the treatment of many diverse industrial sludges by correcting pH for further treatment, neutralizing acidic wastes, and removing or immobilizing contaminants. Specific examples include sulfite/sulfate sludges and petroleum waste.

Calcium sulfitelsulfate waste - Calcium sulfite and sulfate wastes from desulfurizing stack gases, lime neutralization of acid waste effluent, and waste accumulated in the manufacture of superphosphate fertilizers, when untreated, are totally lacking in bearing strength and are prone to leach objectionable amounts of the sulfate ion into the ground water. However, this material, when mixed with 2-3% lime and 15-30% pozzolan-such as fly ash, volcanic ash, pulverized slag, etc.-develops considerable bearing strength, erosion resistance and is non-leaching. The stabilized material can be used in constructing embankments and earth dams. In addition, a synthetic gypsum can be crystallized from sulfite sludges from wet scrubbers. The gypsum produced from hydrated lime in this manner is very white and is a saleable product.

Petroleum wastes - Restoration of waste oil ponds to environmentally safe land for beneficial uses has been achieved using either commercial lime (mainly quicklime) or lime kiln dust. Either material is used to dewater the oily waste to the extent that the dried sludge can be compacted and the pond area converted to useful land.

Hazardous Wastes

Lime is widely used to treat hazardous wastes - both currently generated process wastes and previously disposed or abandoned materials.

Under the U.S. EPA's land disposal restrictions regulations, currently generated hazardous wastes that are to be land disposed must be pretreated using the "best demonstrated available technology." For hazardous wastes containing metals, metals stabilization or metals precipitation is frequently required, and lime is identified by EPA as suitable to treat these wastes.
EPA also endorses lime stabilization as a key technology for hazardous waste site cleanups. In 1997, for example, EPA announced a proposed cleanup plan as part of the Anaconda Regional Water, Waste, and Soils Project for 14,000 acres in Anaconda, Montana. A key element of the plan is to treat arsenic-containing soils with lime and organics. Copper mining created environmental contamination in the 300 square mile area and concern about potential human exposures. EPA recommended in-place lime treatment over the option of excavating and treating the tailings and contaminated groundwater. (Nearby, the Warm Springs Pond is already being used to capture and treat water contaminated with metals-copper, zinc, and arsenic-that threaten the Clark Fork River. The contaminated waters are treated with a lime solution).