LIME FOR ENVIRONMENTAL USES

A symposium sponsored by
ASTM Committee C-7 on Lime
Los Angeles, CA, 25 June 1985

ASTM SPECIAL TECHNICAL PUBLICATION 931

Kenneth A. Gutschick, National Lime Association, editor

ASTM Publication Code Number (PCN)
04-931000-07

1916 Race Street, Philadelphia, PA 19103

Library of Congress Cataloging-in-Publication Data

Lime for environmental uses.

(ASTM special technical publication; 931)
"ASTM publication code number (PCN) 04-931000-07."
Includes bibliographies and indexes.
1. Lime as disinfectant—Congresses. 2. Flue gasses—Desulphurization—Congresses. 3. Environmental protection—Congresses. I. Gutschick, Kenneth A. II. ASTM Committee C-7 on Lime. III. Series.
TD192.4.L56 1987 628.4'45 86-32078
ISBN 0-8031-0499-5

Library of Congress Catalog Card Number: 86-32078

NOTE

The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

Printed in Ann Arbor, MI
February 1987

Foreword

The symposium on Lime for Environmental Uses was held in Los Angeles, California, 25 June 1985. ASTM Committee C-7 on Lime sponsored the symposium. Kenneth A. Gutschick, National Lime Association, served as symposium chairman and editor of this publication.

Related ASTM Publications

Hazardous and Industrial Solid Waste Testing: Fourth Symposium, STP 886 (1986), 04-886000-16

Masonry: Research, Applications, and Problems, STP 871 (1985), 04-871000-07

Manual of Protective Linings for Flue Gas Desulfurization Systems, STP 837 (1984), 04-837000-35

A Note of Appreciation to Reviewers

The quality of the papers that appear in this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

ASTM Committee on Publications

ASTM Editorial Staff

Contents

Introduction

It has been 16 years since ASTM Committee C-7 on Lime sponsored a lime symposium, which was published as *ASTM STP 472*. That symposium featured a variety of technical subjects dealing with many lime uses—from mortar to steelmaking, but also including information on research and new test methods. The present symposium centers on just one phase of lime—its environmental uses.

Why schedule a symposium on such a narrow subject? Well, in the last decade or so man has become acutely aware of the deterioration of his environment. Waterways have become polluted, acid rain has tarnished the atmosphere in many parts of the world, causing damage to forests, lakes, and buildings, hazardous wastes have degraded ground water supplies. Words like polychlorinated biphenyl (PCB) and dioxin have become common place in our vocabulary. Paralleling the degradation of our environment has been the realization that lime, in either oxide or hydroxide form, is one of the key chemicals to help solve or at least alleviate the problem of air, water, and land pollution. Lime's high alkalinity and pH, its high surface area coupled with its relatively low cost and ready availability has led to its steady growth in this important field.

The accompanying graphs underscore this recent development. Figure 1 shows that the environmental uses of lime have grown steadily, reaching 3.5 million tons in 1984, representing a sevenfold growth since 1960. These environmental uses now comprise 23% of the lime market, a far cry from the 6% used in 1960. Figure 2 shows the three elements that constitute environmental uses: water treatment and sewage and industrial waste treatment have grown steadily during this period, declining only during the recent recession, whereas lime for scrubbing sulfur dioxide from power plant gases has grown rapidly since the inception of lime scrubbing in the mid 1970s. Continued growth is certainly expected, paralleling the increase in treatment required for the environmental cleanup. The growth will undoubtedly explode if and when acid rain legislation is passed in the next year or two. But the substantial increase will not occur until the early 1990s.

To cover the subject of this symposium, we have a number of technical papers to present. The first paper will give an overview of the many en-

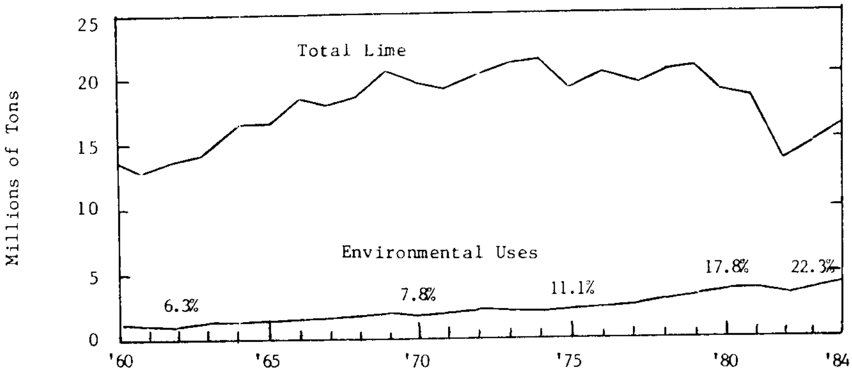

FIG. 1—*United States lime production versus environmental uses, 1960–1984.*

vironmental uses of lime, but in addition discuss various lime types and engineering considerations in the design of lime handling systems. Scrubbing of both carbon dioxide (CO_2) and sulfur oxides (SO_x) will be covered in three separate papers, the first dealing with a fascinating new use in preventing damage to apples during storage. The two papers on SO_x removal will demonstrate how research and development have led to the rapidly growing use of lime, particularly of thiosorbic quicklime.

Papers on hazardous waste will be presented by two authors, with one covering a large project in New Jersey where the waste was solidified with quicklime and lime kiln dust for burial. Another author will cover the growing use of lime and fly-ash for stabilizing scrubber sludges produced

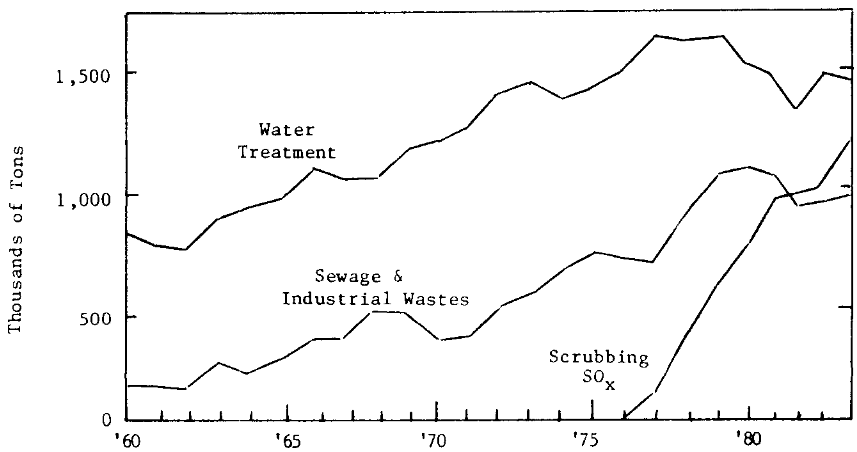

FIG. 2—*United States environmental uses of lime.*

in wet scrubbing installations at more than 20 power plants in the United States, thereby permitting safe disposal of the waste. Research on the use of lime for stabilizing sewage sludge for land fill disposal will be also discussed; this use of lime is effective not only in dewatering the sludge but also in causing bacteria removal and tying up of heavy metals. Another paper will cover the neutralization of calcium and magnesium calcium hydroxides through the use of carbon dioxide.

Finally there will be three papers on lime stabilization of expansive clays and silty clays for use in earth dams, irrigation canals, levees, etc. One paper will deal with dispersive soils which have caused considerable erosion damage of earth dams, particularly in the southern and southwestern parts of the United States. Another paper will demonstrate how lime stabilization has solved the problem of slides occurring in an irrigation canal in California; the stabilized canal lining has performed well for more than 12 years, even resisting erosion from wave action. The third paper will cover the use of lime in overcoming a serious problem with collapse-susceptible soils used in housing areas in an arid climate.

The sponsoring committee of this symposium hopes that the papers presented will stimulate additional research and development work on the use of lime for this growing environmental field. ASTM Committee C-7 would like to thank the authors for their diligence in preparing the many fine papers, and I personally would like to thank the members of the sponsoring committee who helped work up this fine program. In addition, the great assistance of the ASTM headquarters staff in presenting this symposium is appreciated.

Kenneth A. Gutschick
Technical director, National Lime Association, Arlington, VA; symposium chairman and editor.

Clifford J. Lewis[1]

Lime in the Environmental Program—An Overview

REFERENCE: Lewis, C. J., **"Lime in the Environmental Program—An Overview,"** *Lime for Environmental Uses, ASTM STP 931*, K. A. Gutschick, Ed., American Society for Testing and Materials, Philadelphia, 1987, pp. 4–9.

ABSTRACT: High-calcium quicklime [calcium oxide (CaO)] is presently the major chemical used for controlling environmental pollutants. Areas of application for water include domestic water, industrial waste water, including acid mine drainage, and sewage and hazardous wastes. Domestic water is included because lime can remove metals in source waters which might be considered as pollutants. The area of application in air pollution control is the reduction of sulfur oxides in the stack gases of coal-fired boilers or other operations producing sulfur dioxide as a potential air pollutant. While the foregoing do not cover all of the environmental uses for lime, they are the major ones, an understanding of which should be helpful in almost any environmental application of lime.

The behavior of lime in these applications is discussed. Reference is also made to the use of dolomitic lime [calcium oxide; magnesium oxide (CaO; MgO)]. The magnesium content of this material gives rise to special considerations—for example, the solubility of magnesium sulfate as contrasted with that of calcium sulfate. This paper also calls attention to materials which are competitive with lime as a chemical in the environmental program.

The discussions include lime as the chemical for pH control of the liquid phase in sewage treatment, as well as for sludge dewatering and sludge stabilization prior to ultimate sludge disposal. Waste acids which favor the use of lime are contrasted with those which do not. Potential uses for lime in stabilizing tailings and in the construction of barrier walls around hazardous waste dumps are called to attention. In the field of sulfur oxides control, both wet and dry lime scrubbing procedures are covered, including reference to direct lime or limestone injection into coal-fired boilers.

The paper concludes with a review of the more important engineering considerations which must be taken into account when designing lime handling systems. These include storage, lime slaking, and lime slurry transport.

KEY WORDS: calcium, sulfur, lime, environment, oxides, coal-fired boiler, stack gases

Lime is the most abundant and least expensive alkaline chemical in the world. It is a most versatile chemical, presently having at least 65 chemical applications of which I am aware. No doubt there are others.

[1]Director, Environmental Service, National Lime Association, Lakewood, CO 80215.

There are two types of commercial lime with their corresponding hydrates. These are high-calcium quicklime [calcium oxide (CaO)] and dolomitic quicklime (CaO; MgO), the latter being an equimolar mixture of calcium oxide and magnesium oxide. This discussion is concerned primarily with high-calcium lime, although reference will be made to the dolomitic material, as well as the naturally occurring parent limestone, where appropriate.

Lime Composition

While lime is a chemical and is so recognized by the American Chemical Society, it is not a pure chemical. The composition of lime will vary with the source of the parent limestone and the method of lime production, particularly the type of fuel being used to convert the limestone to quicklime. Impurities, which are generally less than 5%, include unburned limestone, silica, alumina, and sulfur. Also the reaction rates of limes, when being reacted with water to produce a water slurry of hydrated lime [$Ca(OH)_2$], will vary and so will the viscosity and particle size of the resulting slurries of hydrated lime. For reasons such as these, lime is frequently a misunderstood chemical because of a lack of knowledge on the part of purchasers, users, and those who design lime handling installations. ASTM recognizes this and has developed useful standards for evaluating lime in some of the use areas. Likewise, the National Lime Association has many publications on this subject. However, a discussion of the various chemical and physical parameters affecting lime usage is beyond the scope of this presentation.

In the U.S. environmental cleanup program, almost any factor which bears on the environment in any way is now considered of interest to the program. Such major areas of interest range from the treatment of domestic water, industrial wastes, acid mine drainage, and sewage to the control of air pollutants, hazardous wastes, revitalization of forest lands and control of hazardous waste landfills. Even the stabilization of soil for environmental control and the injection of lime into garbage dumps to control methane formation fall into the general categories of the environmental uses for lime. Only the more important of these will now be mentioned.

Lime has been used for over 100 years in domestic water treatment to control hardness, precipitate metals, and reduce turbidity by flocculation and coagulation. Dolomitic lime is rarely used for this purpose and high-calcium limestone cannot be used because it is virtually insoluble and does not develop a sufficiently high pH.

Industrial Uses

In industrial liquid waste treatment, the major use for lime is acid neutralization, particularly sulfuric acid including acid mine drainage, and to a lesser extent phosphoric and hydrofluoric acids. Lime is rarely used to neutralize hydrochloric or nitric acids because of the solubility of the chloride and nitrate salts which then may result in an unacceptable effluent for discharge to public domain. Dolomitic lime can be used in some acid neutralization processes so long as the solubility of the magnesium salts can be tolerated. Likewise, high-calcium limestone can be, and is, used where it is not necessary to develop a pH much above pH 6. However, dolomitic limestone is rarely used in acid neutralization because it is simply nonreactive at any practical rate.

In municipal waste treatment, commonly referred to as sewage treatment, lime is used extensively to precipitate phosphates and heavy metals, to set the stage for nitrate removal, and to condition the waste sludge prior to disposal. These various applications and their position in the sewage treatment process depend largely on whether the operation involves primary, secondary, or tertiary sewage treatment. Lime, when added directly to the incoming sewage, will precipitate phosphates and metals, as well as aid in settling the primary sludge. In secondary treatment, lime may be used to control pH to thus enhance bacterial action, thereby reducing biochemical oxygen demand (BOD). In tertiary treatment, lime is used to control phosphates and nitrates.

However, the present high interest in lime in sewage treatment is pointed toward sludge disposal. Lime, when applied to otherwise untreated sewage sludge whether primary or secondary, destroys odors, fixes heavy metals by precipitation, and kills pathogens. In an Environmental Protection Agency (EPA) publication, it is stated that if the sludge is lime-treated to a pH of 12.2 and held at this pH for two hours, thereby killing pathogens, the sludge may be disposed of on the land. Obviously, limestone cannot be used for this purpose, and dolomitic lime is scarcely used because, at a pH of around 10, magnesium salts are precipitated by the high-calcium lime content of the dolomitic lime, thus necessitating excessive use of the lime.

Presently, there is a movement away from the use of a mixture of lime and ferric chloride as an aid for dewatering sewage sludge on rotary vacuum filters. The present trend is toward the use of polymers and belt filter presses, with the lime being added to the sludge on the belt as it comes off the filter.

Pollution Control Uses

In the area of air pollution control, both high-calcium limestone and high-calcium lime have proved to be excellent reagents for the absorption of sulfur dioxide resulting from fossil fuel combustion. The choice between these materials in wet scrubbing devices is a matter of economics based on such items as relative neutralizing values, freight rates, and handling costs. However, the use of lime is gaining over limestone due to the advent of the so-called dry scrubbing system and, more recently, to the interest in the dry injection processes.

Dry scrubbing for sulfur oxides control is a misnomer in that a water slurry of lime is atomized into a spray chamber. There, the slurry meets the hot sulfur-laden gases from the combustion of the fuel. The lime and sulfur gases have but a few seconds to react before everything becomes dry and the reaction products, together with unreacted lime and fly ash, sweep into a baghouse collector. Obviously, the baghouse discharge is practically dry and can be disposed of as a dry material rather than as a wet sludge from a wet scrubber. There are a number of dry scrubbers now operating satisfactorily on the lower-sulfur coals. In time, the system may be developed to meet sulfur dioxide removal requirements for the high-sulfur coals. To date, only high-calcium lime has been found satisfactory. At present, there is pending legislation which may result in less stringent requirements for removing sulfur oxides from atmospheric discharges, this legislation being based on the premise that it might be more desirable to remove 60% of the sulfur gases from practically all fossil fuel rather than 85 to 90% from a fraction of the fuel now being used. Should this type of legislation be enacted, the interest in dry scrubbing would increase dramatically, as would the development of dry injection processes.

The dry injection process involves the introduction of a dry alkaline material with the coal, or separately from the coal, in some optimum area of the combustion zone. In theory, the alkaline material should react with the sulfur gases as formed so that the gas stream containing reaction products, unreacted reagent, and fly ash can sweep into a baghouse for dry collection. Among the reagent candidates for this process are soda ash, high-calcium limestone, high-calcium quicklime and hydrated lime and, surprisingly, dolomitic lime, both quicklime and hydrated. Research data on dry injection, now being generated at a rapid rate, suggest (1) that surface area of the injected reagent is a critical factor affecting efficiency of sulfur oxide (SO_x) removal, and (2) that there may be no adverse effect on boiler efficiency. In my opinion, there is not yet sufficient data to justify firm conclusions as to sulfur removal, but it does appear that dry injection will remove sulfur in the 60% to 70% range, and that pressure-hydrated dolomitic lime, because of its high surface area, may be a relatively superior reagent.

As for reactions involving soil, lime is presently used extensively in stabilizing clayey soils and base materials prior to the construction of streets, highways, airfields, etc. Also, lime in slurry form is injected deep into clay soils to stabilize building foundations and railroad beds. Indeed, sections of the Friant-Kern Canal in California have been stabilized with lime in areas where mud slides had occurred on the banks. (A separate paper in this volume (by L. L. Garver) reports on this canal project.) Also, the expansive clay soil at the Dallas-Fort Worth Airport in Texas was lime-stabilized prior to building the extensive system of runways and aprons. This use of lime has proved to be highly successful.

In the area of hazardous wastes and hazardous waste dumps, lime is just starting to be used, even though most of these wastes are of an organic nature and do not react directly with lime. In this application lime is used in conjunction with fly ash or with lime or cement kiln dusts to dry out the wet sludge and later solidify it following compaction.

Of course, the acid leachate from hazardous waste dumps can be neutralized with lime. Likewise, lime has been added during the cleanup operations of these dumps to neutralize acid conditions around material being removed.

Since lime reacts with many soil constituents, another opportunity in this area is deep injection or trenching with lime-stabilized clayey soils for the construction of impervious dikes around hazardous waste dumps. Research on this possibility is in its early stages.

Discussion

A few generalities may be made with respect to engineering lime handling systems. Lime is not corrosive toward common steel. The transportation of lime via trucks which have pneumatic unloading equipment is becoming ever more popular. Lime storage bins should be equipped with live bin bottoms, as well as dust collectors. Lime should not be transported pneumatically in horizontal pipes since pebble quicklime, in particular, tends to fall out of the air stream. Vertical or well-angled runs are preferred, as are sweep elbows when direction must be changed. This observation pertains to the relatively limited air volume and pressure of pneumatic truck loading. Horizontal runs are feasible when the necessary larger air volume and pressure are available. Limes should be evaluated not only in terms of chemical analyses and reactivity toward water, but also in terms of particle size of the lime slurry and slurry viscosity in terms of percent solids in the slurry. These latter two are becoming increasingly important because of more sophisticated end uses, such as dry scrubbing, dry injection, and deep soil injection.

Summary

In conclusion, I wish to call attention to a few areas which the American Society for Testing and Materials might consider for additional specification work. ASTM has already done a commendable job in outlining specifications for lime in such applications as mortar and plaster, soil stabilization, domestic water treatment, and slakability. However, I am not aware of any ASTM specifications covering lime in sewage sludge and industrial waste disposal, and surface area when used in dry scrubbing or dry injection. In my opinion, we need these specifications, as well as others, as lime moves into the more sophisticated use technologies.

Bibliography

Boynton, R. S., *Chemistry and Technology of Lime and Limestone*, 2nd ed., Wiley, New York, 1980.
"Chemical Lime Facts," Bulletin 214, National Lime Association, Arlington, VA, 1981.
"Effective Use of Lime for Flue Gas Desulfurization," National Lime Association, Arlington, VA, 1983.