Memorandum

From: Robert Weil, Assistant City Engineer (Water Utility)

To: Matt Newell, Public Works Director
Paul Caswell, City Engineer
Keith Alexander, Water Production Manager

Date: March 25, 2024

Subject: Lime Treatment Alternatives

Background

This memo is to provide additional background information to assist the City Council in weighing the costs and benefits of upgrading the existing pebble lime system versus upgrading to the new hydrated lime technology. CMT prepared a technical analysis of both options in December 2022 and found that the hydrated lime system was less costly over the life cycle of the system. This memo provides further justification for the switch to hydrated lime, based on operational and risk considerations.

I would like to thank David Cox, the area sales representative for Mississippi Lime Company for reviewing a initial draft of this memo and providing input to the final version.

Analysis

As discussed at the City Council study session on September 25, 2023, there would be significant advantages to upgrading the chemical feed system for lime (calcium oxide, CaO) to a new technology.

The current design, which was first used for water treatment in 1841, uses calcium oxide (CaO), commonly referred to as pebble lime or "quicklime". Pebble lime is a highly reactive chemical grade product that is used in a water treatment application as a water softener by removing calcium and magnesium ions and raising the pH level. Through this process, quicklime is mixed with water, which is referred to as "slaking", at which time a chemical reaction that produces heat in upwards of 170-185° F.

While historically and widely used, pebble lime is not popular with water treatment operators due to the safety risks, high maintenance and challenges associated with monitoring and controlling the chemical reaction. The amount of calcium oxide produced by the lime slaker depends on a range of factors that are difficult to account for, including the quality of the pebble lime, water temperature, and efficiency of the chemical reaction. If one of the factors changes, the process can become imbalanced and unstable due to excessive heat being generated. To recover, the equipment usually requires a shutdown, and a standby lime slaker has to be brought on-line. This can be a time-consuming process in which it is not uncommon for systems to be out of service for a period of time without dosing and treating water resulting in overall water quality being supplied.

Safety and maintenance are also large contributing factors associated with a slaking process of quicklime. During this process, the chemical reaction produces elevated temperatures which come with various safety concerns if not properly managed along with propensity for lime burns if exposed to human skin or eye contact. During this process, quicklime is made into a slurry liquid at which limestone fines called "grit" will fall out of suspension and settle in the slaker equipment and distribution feed troughs. The distribution feed troughs and slaking equipment regularly requires cleaning of the grit deposits and discarded accordingly. Over time, the limes form heavy, hard scale deposits (much like you would see in an underground cave or cavern), to which abrasive cleaning and chipping is required to remove the deposits. All of these activities increase the chances of human contact that has the potential for injury or burns.

To summarize the intensive maintenance associated with pebble quicklime, the following actions are required of a plant operator during the course of shift work. As pebble lime is discharged into the system, constant monitoring of temperatures, grit, and build up are a critical function that at any time could result in plant shutdown and cleaning. Feed troughs and slaking equipment are constantly monitored and scraping of grit is required to keep the feed systems operating. Slakers are to come on- and off-line for as needed, maintenance, cleaning and repair due to the abrasive nature of the grit in the distribution systems. And lastly, full system chipping of scaling can be expected annually which requires labor-intensive maintenance.

Due to these safety and maintenance challenges, the water industry is seeing a growing interest and adoption of water treatment engineers designing and recommending the use of hydrated lime through a high-density slurry make down system. With a high-density system, water treatment plants can benefit in having less safety risk and operational expense associated with the grit removal processes and required maintenance. With high density systems typically being a relatively closed loop system, the risk associated with chemical burns can be reduced.

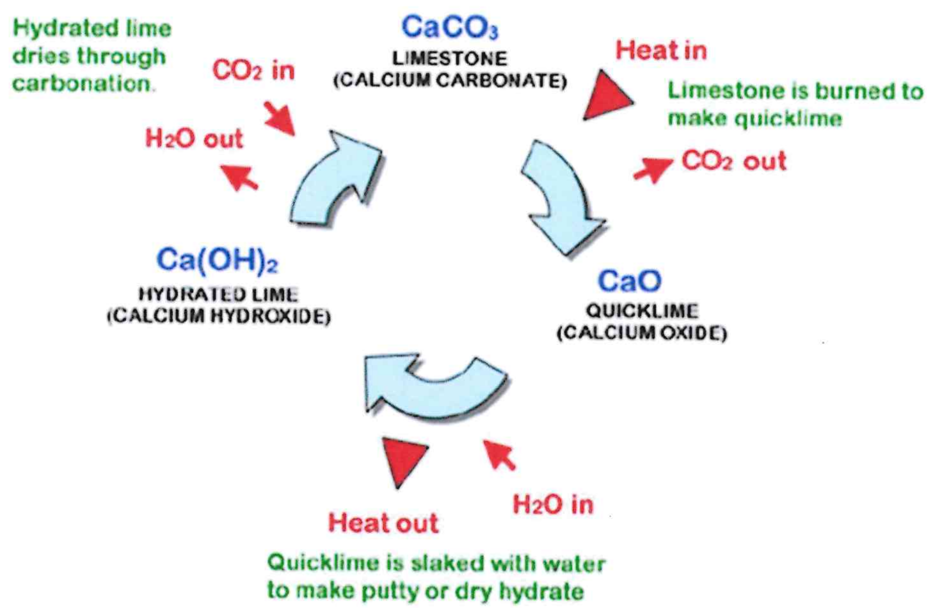
Hydrated lime $Ca(OH)_2$ (or calcium hydroxide) is a powder form of chemical lime that is derived from taking quicklime, adding water in a controlled environment called a "hydrator" to which a highly pure form of lime is produced. The hydration process takes place at the lime suppliers' facility where they have quality assurance and equipment in place to monitor, sample and test the reaction process to produce a finished product to within required specifications to be provided to end user customers. Through the hydration process, just the right amount of water is added for the chemical reaction to be achieved by which the impure "grit" is removed leaving a more pure and concentrated form of calcium hydroxide.

When a high-density slurry system is in place, hydrated lime is delivered to the water treatment plant and offloaded into a silo much like the quicklime application. From there, the hydrate is fed into the high-density mixing equipment where water is mixed to the right consistency which is measured by % of solids as designed by the water treatment engineer. From there, the slurry (which takes the form of a thick milk shake like consistency) is the finished product and can either be pumped to a day reservoir tank or directly into the treatment tanks at recommended dosing levels. While lime still has the propensity to scale and build up over time, a high-density system scales at a much slower rate than slaked lime and is able to be flushed out on a regularly occurring basis with various cleaning chemicals to maintain flow rates and reduce build up compared to the manual efforts associated with quicklime.

There are many benefits associated with hydrated lime when it comes to safety and maintenance cost as outlined above, which does come at an increased initial cost. To guide the decision about whether to upgrade to the new technology, an analysis of costs and benefits was prepared during preliminary design. See attached. In summary, for hydrated lime alternate has higher capital costs (about $2 Million) and slightly higher material costs (about 4%) but lower electrical usage, part replacement, contracted repairs and labor. After accounting for all of the above, the 20-year life cycle costs were estimated to be $3,356,000 lower for hydrated lime than for replacing the current pebble lime system in kind.

Although the life-cycle cost analysis presents a solid case for hydrated lime, staff decided to defer the decision on alternates until contract award. This enabled us to make our recommendation to Council based on actual cost rather than estimates. Our engineering consultant, CMT, agreed to prepare the plans for both options, and included those services within the contract limits that had already been approved. The alternate bid represents the cost saving if the Council decides to keep the existing pebble lime design rather than upgrading to hydrated lime."

The below pictorial gives a good visual of the hydrated lime process.



Recommendation

If the alternate bid item represents a cost reduction of less than $3,500,000, it is recommended that the Mayor and City Council award the base bid, which would move forward with the upgrade to the safer, more reliable hydrated lime system.

Attachments:

1. Design Summary Memorandum from Crawford, Murphy and Tilly

DESIGN SUMMARY MEMORANDUM (DSM)

CLIENT:	City of Decatur **City Project Number: 2022-02**
Project Name:	**Project 3 – Chemical Feed System Improvements**
Facility:	South Water Treatment Plant 1155 South Martin Luther King Jr Dr., Decatur, IL
Consultant/Engineer:	Crawford, Murphy & Tilly, Inc. (CMT) CMT Project Number: 22004438.00
CMT Project Manager:	William H. Peffley, P.E. Direct Telephone: 217-572-1053 e-mail: wpeffley@cmtengr.com
Subject	**Bulk Lime Storage and Feed System**
Distribution:	**City:** Decatur Project Staff **CMT:** WHP, WAB, RTB, Others upon request or identified by City's/CMT's Project Managers

Introduction:

The purpose of this Design Summary Memorandum (DSM) is to outline and discuss the general pros and cons (as they only apply to bulk Lime storage and feed system) for the WTP to:

a) Convert and upgrade the 1988 constructed bulk pebble lime storage and slaked lime feed system to a bulk hydrated lime storage and onsite high-density make-down and lime feed system, or
b) Continue using the bulk pebble lime storage silos, replace the current slakers in kind and thus, continue to slake pebble lime onsite into a low-density lime slurry.

Summary of Recommendations:

This memorandum recommends to the City the following design criteria guidance:

- Decommission and abandon the existing pebble lime bulk storage and slaked lime feed system that produces a ten percent (10%±) low-density lime slurry, and
- Install and commission a new bulk hydrated lime storage and high-density (35%±) lime feed slurry system.

The proposed high-density option has the upside potential to provide a robust, low maintenance and process efficient lime feed system which will potentially reduce (on per million gallons treated basis) the amount of lime slurry residuals generated in either the existing two-stage treatment tarin and new single-stage treatment trains.

Should this design recommendation be accepted, it will be used in preparing the thirty percent (30%) preliminary design plans and associated opinion of probable construction cost. As the design process proceeds, specific design details may be revisited, revised and/or reaffirmed with the City.

Background and Objective:

The bulk lime storage and lime feed system equipment are located in the main Chemical Feed Room and they are a critical component of the South WTP operation. In addition to being the primary water treatment softening agent, the system should be one of the most reliable chemical systems onsite.

When the South WTP began operations in 1988, the originally installed bulk pebble lime storage and lime slaker feed system was considered "State-of-the-Art" for medium and large sized WTP facilities. Over the years, the original slakers were upgraded in-kind and today continue to produce a low-density lime slurry. In the mid-1990s, high-density lime slurry began to be introduced into small treatment facilities. With the passage of time, high-density onsite hydrated lime make-down systems have become a proven and reliability technology for use in water treatment. When a major lime feed system improvement project is being evaluated today for medium to large facilities, a high-density lime system has become a viable option to consider.

System Description & Pros and Cons:

For the proposed design improvements, the following two paragraphs summarize the system description and the pros and cons of the two bulk lime storage and feed systems options being considered.

A. <u>Bulk Pebble Lime Storage and Slaked Lime Slurry Feed System</u>:

   As mentioned above, the South WTP uses a pebble lime (quicklime) bulk storage and slaked feed system that produces a ten percent (10%±) low-density lime slurry. The pebble lime slaking systems are usually prone to issues such as:

   1. Depending on the source of supply, pebble lime will have different slaking characteristics.
   2. The slaking process is sensitive to the water to lime ratio and slaking temperature.
   3. Requires grit removal during the slaking process. Grit must be disposed of offsite.
   4. Slakers are not well suited to intermittent operation. They perform best when operated continuously. If raw water pumps are stopped, the lime lines must be flushed to eliminate plugging.
   5. When intermittent operation is required, slurry holding tanks and/or recirculation loops are required in most cases.
   6. Slakers are limited in the amount of turndown to accommodate changing and minimum facility water production while maintaining their optimum water to lime ratio and slaking temperature.

7. Requires more maintenance and cleaning than a high-density lime system.
8. Produces more slurry residuals that must be disposed of.
9. Scaling of the pipes, troughs, slakers, etc. is a big issue for pebble lime slaking systems.

B. <u>Bulk Hydrated Lime Storage and High-Density Lime Slurry Feed System</u>:

Hydrated lime is dry powder derived from pebble lime with which enough water is added to satisfy its chemical affinity for water under the conditions of hydration. During this hydration process, the grit and impurities are removed and hence the delivered product is essentially all (100%) active calcium hydroxide with high surface area. Onsite high-density liquid lime is derived from hydrated lime. Depending on the local characteristics of available hydrate's, finished water is added to make a 30% to 40% by weight high-density hydrated lime slurry suspension. Once fully wetted, this slurry can maintain its suspension for up to 14-days without additional mixing and can be directly fed into the primary solids contact softening clarifier. Hydrated high-density lime slurry suspension has the following advantages over low-density slaked pebble lime:

1. The high-density slurry system can be designed with as high as a 50 to 1 turndown ratio using a single size of feed piping and controls, for a wide range of water production.
2. The control process can be fully automated and monitored through the facility SCADA system.
3. The high-density lime slurry can be pumped one direction to the point of use. Operating and maintaining return slurry or recirculation loops are not required.
4. High-density lime slurry systems do not scale, which increases reliability and reduces maintenance costs while allowing the facility to maintain water quality.
5. The system can operate intermittently at any time without being concerned about plugging the slurry feed lines.
6. The metering pumps can be stopped for up to 3-4 days without flushing the system.
7. Aging high-density lime slurry increases chemical efficiency by increasing surface area through de-agglomeration.
8. If desired, the aging tank can be sized to hold a backup supply of high-density slurry to allow the facility to operate while maintenance is completed.
9. In general, pumps, piping, valves, and the aging tank can be greatly reduced in size, utilizing a smaller footprint.
10. Between 25% to 30% less plant water is needed to make up high-density lime slurry.
11. Since the grit and impurities are already removed, there is zero waste to dispose of or landfill.
12. A dry loss-in-weight feeder is typically used to monitor the slurry flow stream. In some cases, Coriolis mass flow meters have been used since scaling is not an issue.

Conceptual Budget & Present Worth Differential

The following combined "Conceptual Budget & Present Worth Differential" table lists the major and/or significant item differences between the bulk pebble lime storage/low-density slaked lime slurry feed and the bulk hydrated lime storage/high-density lime slurry feed systems where there is a conceptual and present worth budget costs difference between in the two systems.

Major and/or Significant Item	**Lime Feed Systems**		**Conceptual Capitol Budget Cost Differentials**
	Bulk Pebble Lime Low-Density Slaked Lime Slurry Feed	**Bulk Hydrated Lime High-Density Lime Slurry Feed**	
	Total	**Total**	
General Lime Demolition	Same costs for both systems.		Zero Differential
Silo Modifications			
Lime Slurry Equipment, 4-units FOB Job Site.	$1,330,800	$2,510,100	$1,179,300 higher for high-density slurry
Installation, Testing and Commissioning of Lime Equipment Systems	$1,638,953*	$2,445,998*	$807,045 higher for high-density slurry
Conceptual Budget Capital Differential	$2,969,753*	$4,956,098*	$1,986,345 higher for high-density slurry
20-Year Present Worth Values Used			
South WTP Maintenance Labor	5280-hours	312-hours	4,968-hours higher for slaked lime slurry
Power	43,948 kW-hrs	61,864-kW-hrs	17,916-kW-hrs higher for high-density slurry
Parts	$26,000	$4,000	$22,000 higher for slaked lime slurry
3rd Party Labor	$8,500	$1,000	$7,500 higher for slaked lime slurry
Lime Efficiency	-5%	+10%	15% higher for high-density slurry
Lime Costs	$312.23 per ton	$324.23 per ton	$12 higher for high-density slurry
Lime	5,000 tons	5,750 tons	750-tons higher for high-density slurry
Annual Inflation Adjustment	3% per year		Zero Differential
Initial Power Costs (3% inflation adjustment every 3-years)	$0.04684 per kW hour		
Total for 20-Year Present Worth Costs	$37,806,138*	$34,450,224*	$3,355,914 lower for high-density lime slurry
Totals Rounded	**$37,806,000***	**$34,450,000***	**High-Density Lime Slurry Lower By $3,356,000**
Note: * Includes a 20% construction contingency.			

Summary:

Based on the numerous advantages listed in the above "*System Description & Pros and Cons*" section, and the information presented in the "*Conceptual Budget & Present Worth Differential*" table, it is CMT's opinion that *if the budget allows*, the City should:

a) Decommission and abandon the existing pebble lime bulk storage and slaked lime feed system that produces a ten percent (10%±) low-density lime slurry, and
b) Install and commission a new bulk hydrated lime storage and high-density (35%±) lime feed slurry system.

References:

The following are publications and industry references consulted in preparing this Design Summary Memorandum.

- AWWA Standard B202, Quicklime and Hydrated Lime
- Bulletin 211 "*Hoover's Water Supply & Treatment*" National Lime Association
- Bulletin 213 "*Lime Handling, Application and Storage*" National Lime Association
- Handbook of Public Water Systems, 2nd Ed.
- Principles of Engineering Economy, 6th Ed.
- Vendor Information from:
    - Wallace & Tiernan (Evoqua)
    - Merrick Industries, Inc.

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End of Summary Memorandum