Help Instruction File:

Soda Ash Module Overview

Provided by the Office of Surface Mining Reclamation and Enforcement (OSMRE), the Pennsylvania Department of Protection (PADEP), the U.S. Geological Survey's (USGS) and the West Virginia Department of Environmental Protection (WVDEP).

Soda Ash Module Overview

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1.0 Objective

The objectives of this overview are to: (1) Provide an understanding of the application of Soda Ash in mine drainage treatment and (2) Provide an overview of the Soda Ash Module to guide users in developing an estimate of the cost to construct, operate, and maintain Soda Ash treatment systems. The module can also be applied to reverse cost model an existing system to establish and evaluate future financial and investment decisions. The information is presented in two sections, **Overview and Application** and **Soda Ash Module Overview**.

2.0 Overview and Application

A basic understanding of the chemical and physical properties, the application, and equipment requirements of a soda ash treatment system are required to develop a treatment strategy using the AMDTreat software. These topics are discussed below before discussing the soda ash module interface and functionality to provide the necessary context. The Overview and Application section is organized into three parts: (1) Physical and Chemical Properties and (2) Benefits/Drawbacks, Equipment and Typical Treatment Configurations, and (3) Application and Financial Analysis.

2.1 Physical and Chemical Properties

Soda ash is an alkali consisting of a white anhydrous, powdered or granular material with a chemical formula of Na_2CO_3, which is sodium carbonate. It is soluble in water and occurs worldwide naturally and specifically in the minerals trona and nahcolite. It is an essential raw material in the United States used in the manufacturing of glass, detergents, chemicals and other industrial products. In terms of health and safety, any exposure to soda ash may cause skin and eye irritation; however, soda ash does not have the serious concerns compared to other treatment chemicals, such as hydrogen peroxide or caustic soda. Soda ash is manufactured by an industrial process, the Solvay process, or mined from natural deposits. The Solvay process produces soda ash from brine, as a source of sodium chloride [NaCl] and from limestone, as a source of calcium carbonate [$CaCO_3$]. The overall process chemical reaction is:

$$2NaCl + CaCO_3 \rightarrow Na_2CO_3 + CaCl_2$$

There are a number of chemical companies that manufacture soda ash. The delivery of soda ash typically comes in 50-lb bags when used for mine drainage treatment. Based on soda ash being administered via a dispenser, it is mostly utilized for low flow mine drainage discharges. Because soda ash is in a solid form and not pre-dissolved in a slurry mix (i.e. lime slurry) prior to adding to mine drainage, it is not ideal or cost effective for treating higher flow, high acidity discharges.

While soda ash treatment systems are simple, dependable, and able to achieve effluent standards, the dosing of soda ash briquettes directly into mine drainage in order to dissolve without mechanical mixing results in poor dissolution 'mixing' efficiency of the solid briquettes. Soda ash reacts with water, dissociating into carbonate [CO_3^{2-}] and sodium ions [Na^+] (equation 2). This reaction allows carbonate alkalinity to be available for acidity [H^+] neutralization (equation 3). With the solid briquettes having a relatively small surface area available for chemical reactions and dissolution to occur; the mixing or dissolution efficiency (or lack thereof) is one of the biggest disadvantages of soda ash. In addition, soda ash is considered a weak base compared to caustic soda [NaOH] or hydrated lime [$Ca(OH)_2$]; therefore, all the alkali ions [CO_3^{2-}] will not disassociate in the mine drainage, requiring more chemical addition.

$$Na_2CO_3 + H_20 \rightarrow CO_3^{2-} + 2Na^+$$

$$CO_3^{2-} + H^+ \rightarrow HCO^-$$

Typically, when determining to use soda ash as a treatment option, the only other option might be to use a caustic soda solution, in lieu of the soda ash. Therefore, treatment professionals must understand the relationship between neutralization capacity and unit cost between different reagents to make informed treatment decisions. Table 2 provides neutralization characteristics of commonly used caustic soda solutions relative to soda ash. The table shows that the caustic solutions have less neutralization capacity than an equivalent amount of soda ash. However, unlike caustic soda, soda ash is less soluble and requires placing briquettes in the mine drainage for dissolution of the solid soda ash particles. Thus, soda ash requires the continuous dissolution of the particles for CO_3^{2-} ions to be available for mine drainage neutralization. Looking at the 'lbs reagent/ton acidity' ratio for the soda ash vs 50% NaOH solution, they are comparable when accounting for a 60% mixing efficiency for the soda ash. In this regard, caustic soda has big advantage over soda ash. Caustic soda is highly soluble, quick reacting and requires little mixing in water. Simply dripping a caustic soda solution directly into turbulent flowing mine drainage provides sufficient mixing for treatment. A solution of caustic soda is denser than water so dripping into a pond or very slow-moving water may result in the accumulation of chemical at the bottom and result in decreased chemical efficiency (actual dose > theoretical dose).

Table 1: Neutralization characteristics of various caustic soda solutions compared to other common alkali treatment reagents.

	NaOH 20%	NaOH 25%	NaOH 50%	Soda Ash
mg of $CaCO_3$ /mL reagent	306.0	399.8	959.0	2,396
lbs of $CaCO_3$ /gal reagent	2.55	3.34	8.00	19.9
lbs of $CaCO_3$ /lbs reagent	0.25	0.31	0.63	0.94
gallons reagent/ton acidity ($CaCO_3$)*	783	599	249	100.5
lbs reagent/ton acidity ($CaCO_3$)*	8,001	6,401	3,200	2,128 (3,530)

* Represents the amount of reagent required to neutralize a ton of acidity ($CaCO_3$)
Soda ash adjusted [60% mixing efficiency, (3,530)].

The purity of soda ash (% Na_2CO_3 by wt.) used in mine drainage treatment is approximately 99% pure. Soda ash is produced in various forms depending on the application and is mostly sized as briquettes (1" to 2 1/2"). The soda ash dispensers are typically 55-gallon barrels containing the soda ash product with holes cut into it to allow mine drainage to flow through and dissolve the briquettes (Figure 1). Slightly more sophisticated soda ash dispensers can be used, which consist of cone shaped metal bin with a flume feature that dispenses the soda ash into the mine drainage (Figure 2).

Similar to other chemical treatment (i.e. caustic soda or pebble lime) the motivation to directly add soda ash into mine drainage is mostly due to a lack of electricity at a site and the nature (i.e. low flow) of the mine drainage. Generally, sites with no electricity are forced to use caustic soda (NaOH) or soda ash due to their ability to be manually dispensed and passively mixed. However, given the very low capital cost for dispensing soda ash, minimal health and safety concerns and low operation and maintenance with soda ash, an operator may choose to treat the mine drainage with soda ash compared to caustic soda.

2.2 Benefits/Drawbacks, Equipment and Typical Treatment Configurations

This section summarizes some of the benefits, drawbacks, equipment, and treatment configurations for using soda ash at mine drainage treatment sites.

2.2.1 Benefits

The major reason why soda ash is popular is because of its simplicity, low operation and maintenance and low capital cost. The benefits of using soda ash as a mine drainage treatment chemical include:

1. Can be placed in flow path of mine drainage (i.e. toe-of-spoil seeps, collection ditch) and allowed to dissolve;
2. Dosing can be performed without electricity or the use of a metering pump;
3. Very small footprint of soda ash dispenser (i.e. 55-gallon drum);
4. Low operation and maintenance and low capital cost;
5. Relatively stable chemical allows for long-term storage in instances of ephemeral or periodic treatment;
6. No serious safety concerns with handling and storage;
7. Provides a good temporary treatment option until long-term treatment is evaluated.

2.2.2 Drawbacks

The drawbacks of using soda ash as a mine drainage treatment chemical include:

1. Poor 'Mixing Efficiency' due to using solid briquettes, making soda ash inefficient for higher flow mine drainage;
2. Soda ash is a weak base, requiring additional chemical to be added in order to treat high acidity mine drainage.
3. Based on the unit cost of soda ash, it is not cost-effective to treat high-flow mine drainage compared to other alkaline chemicals.

2.2 Equipment and Typical Treatment Configurations

The soda ash treatment systems are the simplest setup of all the passive or active treatment systems. As mentioned, soda ash has only really been utilized in remote situations where operators have to treat an impacted seep or low flow mine drainage. . In these remote scenarios where there is no electric available that may be required for other active chemical treatment options and/or there is insufficient real estate available to construct a passive treatment system is where soda ash is feasible. Soda ash may be utilized as temporary treatment while long-term treatment options are evaluated. Therefore, operators place a soda ash dispenser in the flow path of the mine drainage in order to increase the alkalinity and neutralize the acidity of the mine drainage.

Soda Ash Dispenser

It is recommended that soda ash dispensers, similar to Figure 2 be utilized for soda ash dispensing with mine drainage. These dispensers have a flume type base that allows for the mine drainage to make contact with the soda ash briquettes allowing for dissolution of the Na_2CO_3. This allows for fresh briquettes to continuously enter the mine drainage as briquettes dissolve, compared to placing the briquettes into a barrel all at once (Figure 1) and the briquettes lose their reactivity over time, requiring personnel to manually add additional chemical and possibly stir up the less reactive material.

The module allows for the user to enter and/or adjust the default unit cost for the soda ash dispenser. The default cost for the dispenser is $1,500. No other equipment items are included with the treatment setup of soda ash; however, any additional items can be included in the 'Other Capital Items' section of the module.

2.3 Application and Financial Comparison

The following is a quick cost assessment between soda ash and caustic soda for a low-flow acidic mine drainage source; whereby, no electric would be available, and an automated caustic soda system would not be an option. Table 2 includes the parameters that are used for the assessment, table 3 provides the estimated chemical consumption and annual chemical costs for both soda ash and a 20% caustic soda solution.

Table 2. Summary of mine drainage and chemical parameters used in comparison.

Mine Drainage Flow	Mine Drainage Acidity	Soda Ash Purity / Mixing Efficiency	Caustic Soda Purity / Mixing Efficiency	Soda Ash Unit Cost	Caustic Soda (20%) Unit Cost
10 gpm	100 mg/L as $CaCO_3$	99% / 60%	99% / 100%	$0.15/lb	$0.70/gal

Table 3. Monthly chemical consumption and annual chemical costs.

Soda Ash 50-lb bags per Month	Soda Ash Annual Chemical Cost	Caustic Soda gals/month	Caustic Soda (20%) Annual Chemical Cost
13	$1,230	145	$1,321

There are some assumptions in selecting the default values in both the soda ash and caustic soda assessment; however, based on evaluating a scenario with a low flow source and no electric available, soda ash is comparable to the 20% caustic soda solution despite the lower mixing efficiency of soda ash. As the flow may increase and/or net acidity increase, it will likely become more cost effective to consider caustic soda and a stronger solution (25% or 50%) of caustic soda. Additional variable(s), other than the capital costs, that would need to be considered might be labor costs. For example, the soda ash would require approximately thirteen 50-lb bags per month; but if the flow is variable the caustic soda drip valve may need adjusted manually to ensure proper dosage. Again, soda ash is most likely utilized in low flow conditions and/or on a temporary basis until a more permanent treatment system can be designed and constructed if mine drainage treatment is required on a long-term basis.

3.0 Soda Ash Module Overview

3.1 Layout and Workflow

In general, inputs are on the left-hand side of the module and calculated outputs are on the right. The module inputs on the left-hand side are arranged into six sections: (1) Water Quality and Flow Input, (2) Soda Ash Information, (3) Annual Cost Input, (4) Other Capital Items, and (5) Other Annual Items. The workflow for the module is for users to start at the top left-hand side. Enter the *Typical Flow* and *Net Acidity* and AMDTreat calculates the annual acidity loading. Then, within the Soda Ash Information section the cost of the soda ash dispenser is specified. Also, the user selects the *purity* and *mixing efficiency* of the soda ash and selects the method to estimate the soda ash consumption (*Stoichiometric, Titration, or User-specified*). Please note, the 'Mixing Efficiency' is used in the calculations for the Stoichiometric and Titration options, but not for the User-Specified method (see Section 3.2.3.1 and 3.2.3.2). AMDTreat uses this information along with the calculated acidity load to estimate the annual soda ash consumption. The *Annual Cost Input* section allows the user to specify the unit cost of soda ash. Finally, users can specify additional capital and annual costs not considered by the module under the *Other Capital Items* and *Other Annual Items* sections.

Module output is provided on the right-hand side. Module outputs are arranged into four sections: (1) *Sizing Summary*, (2) *Capital Cost*, (3) *Annual Cost*, and (4) *Net Present Value*. The *Sizing Summary* section provides estimates of chemical consumption in lbs/year and the number of 50-bags/year for the dispenser. The estimated cost to construct and operate a soda ash treatment system is provided under the *Capital Cost* and *Annual Cost* sections. Lastly, users can opt to conduct a Net Present Value (NPV) analysis to obtain the total cost to operate and maintain a soda ash treatment system for a defined time period.

A general overview of the module input and output sections is presented below, however, users are directed to the numerous tool tips located in the module that provide additional detailed information, such as definitions of terminology. In most cases, the tool tips are accessed by clicking on the information icon ( ) in each of the subheadings in the module.

3.2 Module Inputs

3.2.1 Water Quality and Flow Input: The Water Quality and Flow Input section is where users specify the Typical Flow and Net Acidity values for the source of mine drainage. These values are used to (1) estimate the annual chemical consumption and (2) potentially estimate the size or cost of a soda ash dispenser.

The definitions for *Typical Flow* and *Net Acidity* can be found in the tool tip for this section. Click on the information icon ( ) on the right side of the Water Quality and Flow Input subheading. In short, *Typical Flow* is the flow rate "typically" experienced at the site (e.g., median flow). This flow rate is used to calculate the annual chemical consumption so one must take careful consideration to calculate this value.

Net Acidity represents the acidity released and neutralized when the base is added to achieve the desired treatment pH. For eastern coal mine drainage, the acidity producing species will be the hydrolysis of Al^{3+}, Fe^{2+}, Fe^{3+}, and Mn^{2+}, the precipitation of $CaCO_3$, and the deprotonation of H_2CO_3 and HCO_3^-. For treatment pH > 10, the hydrolysis of Mg^{2+} and hydroxylation of cations must also be considered.

3.2.2 Soda Ash Information

: The user can enter the cost of *soda ash dispenser* and adjust this capital cost as needed. The *purity* and *mixing efficiency* can also be adjusted. Typically, the purity of soda ash is very high (~99%); however, the mixing efficiency is poor compared to other chemicals (i.e. caustic soda). Based on setups that utilize soda ash for treatment, there is essentially not any 'mixing' of the soda ash briquettes, but rather, the soda ash briquettes are placed in the flow path of the mine drainage allowing them to dissolve as the AMD flows through the dispenser. Therefore, the mixing efficiency default is set relatively low at 60%, and the user can adjust this value based on the site-specific conditions. Next the user can select a method, either *stoichiometric*, *titration*, or *user-specified,* that calculates the soda ash consumption and is discussed further in Section 3.2.3.

3.2.2.1 Soda Ash Dispenser: The default cost of a soda ash dispenser is $1,500. The user can adjust this value based on the type of dispenser that is chosen or already existing at a site. A metal cone-shaped hopper with a retrofitted flume channel to allow mine drainage to flow through the soda ash is assumed with this cost (Figure 2). This hopper-style dispenser will allow the soda ash to be self-feeding as the soda ash dissolves in the flowing mine drainage. However, it should be noted this will still require personnel to check periodically that no plugging or dysfunction of the dispenser has occurred. For example, the unreacted or coated soda ash briquettes may need removed or broken up on a consistent basis in order for fresh briquettes to enter the mine drainage flow.

Since soda ash is not highly reactive, all the soda ash may not react (i.e. disassociate) in the mine drainage; therefore, mixing efficiency is a parameter that can be adjusted and is used in the calculations for the stoichiometric and titration methods.

3.2.3 Chemical Consumption

: The *Chemical Consumption* section offers the user three methods to estimate the annual chemical consumption, *Stoichiometric, Titration, and User-Specified Quantity*.

3.2.3.1 Stoichiometric – This method estimates the annual chemical consumption by using the user-specified information under the *Water Quality & Flow Input* and *Soda Ash Information* sections. This method uses the values for *Typical Flow* and *Net Acidity* to calculate the annual acidity loading in Calcium Carbonate Equivalents in the following equation:

$$A.L. = \left(Flow\ \frac{gal}{min}\right) \times \left(Acidity\ \frac{mg\ CaCO_3}{L}\right) \times \frac{3.785\ L}{gal} \times \frac{1\ g}{1000\ mg} \times \frac{60min}{hr} \times \frac{24\ hr}{day} \times \frac{365\ day}{yr} \qquad (1)$$

Where:
A.L. = Annual Acidity Load in g $CaCO_3$/yr
Flow = Typical Flow in gal/min
Acidity = Net Acidity in mg/L as $CaCO_3$

After the Annual Acidity Load is determined, the program uses the stoichiometric relationship between $CaCO_3$ and Na_2CO_3 to re-express the acidity load in terms of Na_2CO_3.

$$Na_2CO_{3_L} = \left(A.L\ \frac{g\ CaCO_3}{yr}\right) \times \frac{Mole\ CaCO_3}{100\ g} \times \frac{2\ Mole\ H^+}{1\ Mole\ CaCO_3} \times \frac{1\ Mole\ Na_2CO_3}{2\ Mole\ H^+} \times \frac{105.9\ g}{1\ Mole\ Na_2CO_3} \quad \textbf{(2)}$$

Where:
$Na_2CO_{3\,L}$ = Annual Acidity Loading in g/yr expressed as Na_2CO_3

Finally, the program uses the designated purity and mixing efficiency to determine the annual amount of soda ash required to neutralize the acidity load.

$$Na_2CO_{3_{lbs}} = Na_2CO_{3_L} \times \frac{1kg}{1000g} \times \frac{2.2046lbs}{1kg} \times \frac{1}{\frac{Mix\ E}{100}} . \times \frac{1}{\frac{Purity}{100}} \quad \textbf{(3)}$$

Where:
$Na_2CO_{3\,lbs}$ = lbs/yr of Na_2CO_3 to Neutralize the Annual Acidity Loading
Mix E = Mixing Efficiency %
Purity = Purity %

3.2.3.2 Titration – The titration method allows users to input the results of field or bench acidity titrations that empirically determine the required dose of a chemical to achieve the desired end point (e.g., treatment pH). Users must enter the results of the titration data in terms of pounds (lbs) of soda ash required to treat a gallon of mine drainage. Since the soda ash purity is inherently contained in the titration input value, AMDTreat does not use a value for *Purity* when the Titration method is selected. However, users can adjust the *Mixing Efficiency* value if they feel the actual mixing efficiency will differ from the efficiency experienced during the titration.

$$Adj.Na_2CO_{3_{lbs}} = \left(Flow\ \frac{gal}{min}\right) \times \left(Titration\ \frac{lbs\ Na_2CO_3}{gal\ AMD}\right) \times \frac{60min}{hr} \times \frac{24\ hr}{day} \times \frac{365\ day}{yr} \times \frac{1}{\frac{Mix\ E.}{100}} \quad (4)$$

Where:
Mix E. = Mixing Efficiency
Adj. $Na_2CO_{3\,lbs}$ = Annual Soda Ash Consumption adjusted for Mixing Efficiency

3.2.3.3 User-Specified Quantity - This method allows users to specify the annual soda ash consumption. This method is typically selected when AMDTreat is being used to evaluate long-term water treatment liability using the *Net Present Value* calculations or if the quantity of soda ash is known for an existing system.

3.2.4 Annual Cost Input: The user can adjust the unit cost, or price per pound, of soda ash. The default value for soda ash is $0.15 per pound and is assumed that a bulk order consisting of a pallet(s) of soda ash is purchased. In addition, this unit cost does not include delivery, so the user should consider the delivery cost based on the site location. The default unit cost is estimated based on pricing in 2019-2020; but similar to other chemicals, the unit cost can fluctuate and the user should adjust this value accordingly by checking prices with local suppliers.

3.2.5 Other Capital Items: The *Other Capital Items* section allows users to capture the capital cost of equipment and other items that are not included in this module. For example, if someone wanted to invest in an automated dispenser, this additional feature could be included in Other Capital Items. Since this is uncommon it was not included the cost module, however, users who want to include this capability can input the cost into the *Other Capital Items* section to capture the capital cost.

3.2.6 Other Annual Items: The *Other Annual Items* section allows users to capture the annual cost of equipment and other items that are not included in this module. For example, users could include the annual electric cost of an automated soda ash dispenser in the *Other Annual Items* section.

3.3 Module Outputs

3.3.1 Sizing Summary: The Sizing Summary section displays important calculated module outputs, such as the estimated soda ash consumption in pounds per year and total number of 50-lb soda ash bags per year.

3.3.2 Capital Cost: This section provides the estimated costs for the various user-specified components and the total estimated cost to install the soda ash system. Users can opt to estimate the installation cost by specifying it as a percentage (cost-multiplier) of the capital cost or by entering a user-specified installation cost.

3.3.3 Annual Cost: The annual cost section provides an estimate of the annual cost to operate and maintain the soda ash treatment system. Users can select to have AMDTreat estimate the annual chemical cost or specify a known annual chemical cost. Specifying an annual chemical cost is often used when AMDTreat's Net Present Value calculations are being used to estimate water treatment liability. The annual operation and maintenance (O&M) for the soda ash treatment system can either be user-specified or estimated as a percentage of the capital cost. The latter method assumes the more expensive a system the more costly it is to maintain.

3.3.4 Net Present Value: The Net Present Value (NPV) section determines the cost to operate a treatment system component over a specified time period. The NPV calculates the present-day financial investment required to generate the income to pay for future operation and equipment/materials replacement costs. Both **Financial Variables** and **Cost Categories** are required to calculate the NPV.

3.3.4.1 Financial Variables - The *Term of Analysis*, *Inflation Rate*, and *Rate of Return* are three variables used in the NPV calculations. The default values for these terms are shown under the *Net Present Value* section of each module. Users must access the *Net Present Value* menu at the top of the main user interface to change the default values as they would apply to all modules used for an entire treatment system. While NPV is determined for each AMDTreat module activated by the user, the goal is to determine a total NPV for an entire mine drainage treatment system project (a collection of cost estimates for individual modules creates a treatment system project in AMDTreat). Therefore, a single value for *Term of Analysis*, *Rate of Return*, and *Inflation Rate* is applied to all modules and cannot vary between modules.

- Term of Analysis: The time period used by the NPV calculation to determine the financial investment required to pay for all future costs of the treatment system.

- Inflation Rate: Represents the average price increase of goods and services over time. AMDTreat uses the inflation rate to calculate the future cost of the annual operation and maintenance (O&M) and recapitalization items.

- Rate of Return: Describes the expected profit on an investment.

3.3.4.2 Cost Categories - For each treatment module, AMDTreat provides a list of recommended equipment and materials that require recapitalization. In addition, AMDTreat provides recommendations (default values) for life cycle and replacement percentage. Users can click on the default values for *Life Cycle* or *Replacement Percentage* and use the +/- buttons to c0hange the default values. In addition, users can select *Custom Cost* and enter a new cost to represent the current cost of the equipment. Users can add new recapitalization items or deactivate/delete existing items for calculating the NPV.

An example of how the recapitalization variables are used to determine NPV is to consider the following hypothetical scenario. Assume a vertical turbine pump has a life cycle of 50 years but requires the pump motor to be rebuilt every 20 years. Assume the present-day cost to purchase the motor is $500,000, and the cost to remove, rebuild, and reinstall the pump motor is $20,000. Now assume we want to determine the amount of investment required today (NPV) to generate the income to pay for the future cost of rebuilding the pump motor over a 50-year *Term of Analysis*, which is also equal to the life cycle of the pump. Assume an *Inflation Rate* of 5.0% and *Rate of Return* of 8.1%. The goal is to place the money in a relatively secure investment vehicle to generate 8.1% annually. The NPV will calculate the size of investment required to generate income for future costs.

There are several ways to model the replacement cost. One way is to replace 4% of the present-day cost of the pump (4% of $500,000 = $20,000) with a life cycle of every 20 years. If the *Term of Analysis* is 50 years, then the entire pump would not require recapitalization since the life cycle of the pump is 50 years. However, the motor would require two replacements (50 years / 20 years = 2.5 rounded down to 2).

To determine the NPV to recapitalize rebuilding of the motor, AMDTreat calculates the future cost to rebuild the motor at each life cycle, 20 and 40 years. The program uses the *Inflation Rate* to inflate the present-day default cost to rebuild the motor in 20 and 40 years from now. While the present-day cost to rebuild the pump motor is $20,000, the future cost to rebuild the motor in 20 years at a 5.0% *Inflation Rate* is $53,065 and $140,799 in 40 years (Equation 5). Assuming an 8.1% *Rate of Return*, the 50-year NPV for the pump is $17,422. In other words, an initial investment of $17,422 is needed at an annual *Rate of Return* of 8.1% to generate the investment income required for the two motor rebuilds over the 50-year life cycle of the pump.

$$\textit{Cost to rebuild pump motor in 20 years} =$$
$$\textit{Present Day Cost} \times (100\% + \text{Inflation Rate})^{20} = \$20{,}000 \times (100\% + 5\%)^{20} = \$53{,}065 \qquad \textbf{(5)}$$

- Annual Operation and Maintenance Cost: By default, AMDTreat transcribes the annual O&M cost from the Annual Cost section to the Net Present Value section. The program assumes the module is being used to first estimate the annual cost for a treatment system component, so it automatically transcribes the annual cost to the NPV section. If this is not the case or the user wants to use some other annual cost, the “Use Custom” box can be selected to allow the user input of a different annual cost to utilize in the NPV calculation.

- Recapitalization Cost: Certain treatment system components, especially mechanical and water conveyance equipment, require periodic replacement. The recapitalization cost of an item is an estimate of the amount of money required to pay for future replacement costs for the item. In addition to the Financial Variables described above, three additional values are required to calculate the NPV of recapitalization costs, the Present-Day Equipment Cost, the life cycle, and the Replacement Percentage.

- Default Cost: This represents the current cost to purchase the equipment or material.

- Life Cycle: The time frame between equipment or material replacement is termed as its life cycle. Some equipment manufacturers provide recommended life cycles for their equipment to provide consumers with an estimate of how long the equipment is expected to be operational. Some life cycles, such as those used for treatment media (limestone), are based on best professional judgement. Some operators prefer to periodically purchase and replace equipment before failure to preserve the continuity of operations, while others wait until failure to replace an item.

- Replacement Percentage: The replacement percentage is an adjustment factor to the default cost to accommodate situations where the entire piece of equipment or all of the material does not require recapitalization. For example, a passive treatment component may be designed to contain enough limestone to neutralize the acidity load for 20 years, however, the accumulation of metal hydroxide precipitates within the void space of the limestone layer may require that 25% of the limestone be replaced every 7 years to prevent hydraulic failure such as plugging or short-circuiting. For this scenario, the initial cost of the limestone making up the limestone layer is discounted by 75% and assigned a life cycle of 7 years to determine the amount of money required to cover the cost of replacing 25% of the limestone layer every 7 years over the Term of Analysis.

3.3.4.3 Rationale for Recapitalization Recommendations:

Recapitalization recommendations are based on professional experience of the AMDTreat Team and may not apply to all situations. Users are encouraged to customize the recapitalization assumptions to their treatment scenario. AMDTeat Team members are located in Pennsylvania and West Virginia and have collective experience in design, funding, and/or operation/maintenance for over 100 passive and active treatment systems. The AMDTreat Team held discussions on personal experience to develop a list of recapitalization recommendations. Users may have different experience and opinions than those listed.

By default, AMDTreat includes a list of two recapitalization items. However, based on the items the user selects to include in the module will determine which ones are included in the NPV section. Users can delete or modify any of the default recapitalization items by either deselecting the item or by setting the replacement % to zero. If the item is deselected the total cost for the item will still be shown but the cost will be subtracted from the Net Present Value cost, shown in the Net Present Value section. For example, the default value for the lifecycle of a poly storage tank is 12 years due to degradation from ultraviolet light. However, users may opt to increase the life cycle if the poly tank will be housed in a building. Users are free to fully customize the replacement items, including adding new items or deleting default items.

Soda Ash Dispenser: The life cycle of a soda ash dispenser depends on the type of material (i.e. steel, poly) the dispenser is constructed. In almost all instances, these dispensers will be placed outdoors and exposed to weather. As a default, the AMDTreat team feels 20 years is an estimate as long as the dispenser is maintained. However, the user should consider adjusting this value based on the site conditions and dispenser quality. A longer or shorter life cycle may be appropriate if the dispensing unit is cleaned and painted when corrosion becomes visible or if the dispenser is constructed of a poly material.

3.4 Assumptions of Design Sizing and Costs

AMDTreat is a cost estimation model that uses assumptions to provide treatment sizing and both capital and annual cost estimates. While there are many assumptions in the program, the assumptions that follow are important for the soda ash module.

1. The Stoichiometric method used to estimate the annual chemical consumption relies on a properly determined value for Typical Flow and Net Acidity. Many people use the Standard Method 2310 (Hot Acidity) procedure to determine Net Acidity. In most instances, a Hot Acidity titration result will not accurately describe the base requirement to achieve effluent standards. A cold acidity titration is the best method to determine the Net Acidity encountered during treatment and for estimating chemical consumption.

4.0 Figures

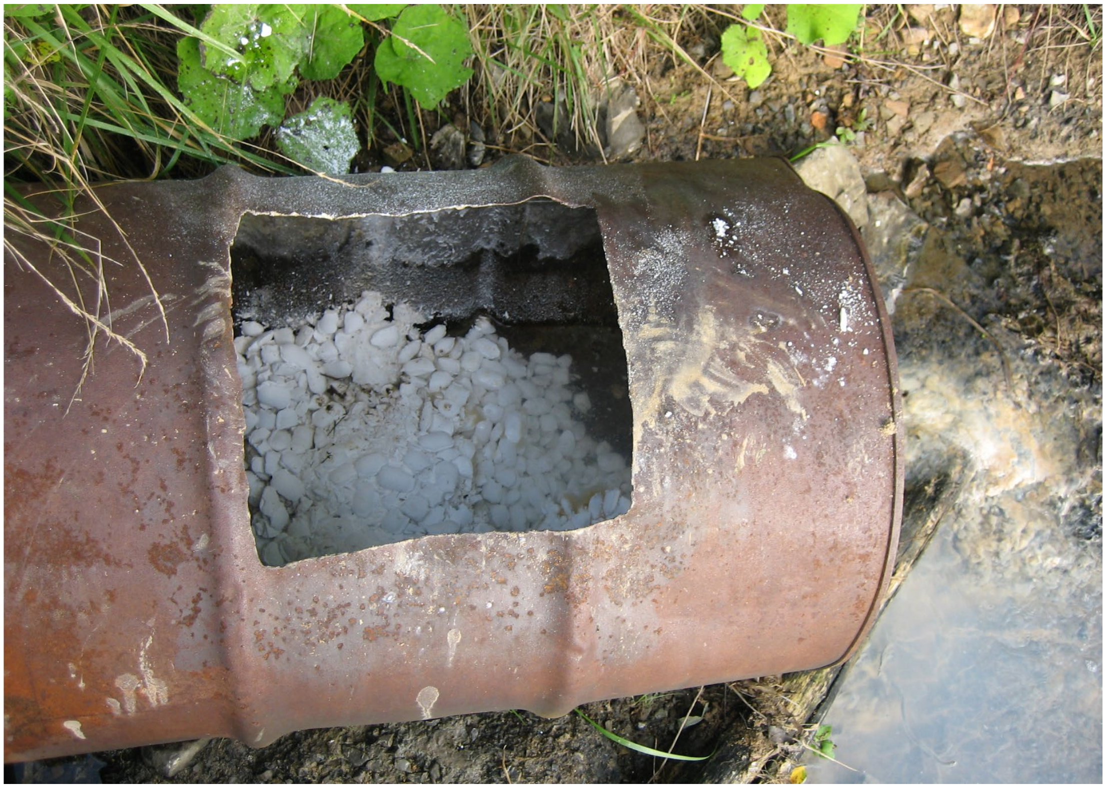

Figure 1: 55-gallon barrel with hole cut into it containing soda ash briquettes, with mine drainage flowing through each end of the barrel to allow dissolution of soda ash.

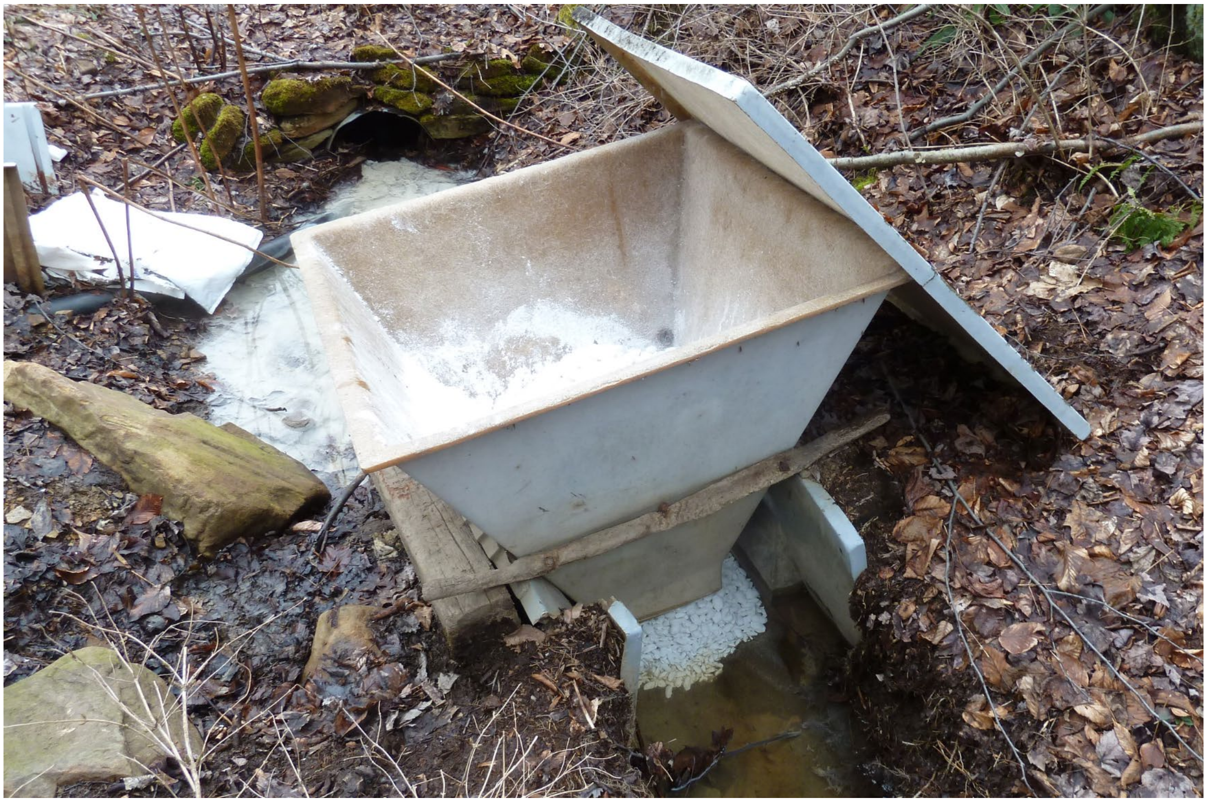

Figure 2. Photo of a soda ash dispenser with soda ash briquettes placed within mine drainage flow path.