Technical Information For Fighting Acid Mine Drainage

BY TIFF HILTON

It has been several years since I first spoke to you about the Magic of Water Treatment but like elephants, Charlie Miller and the Task Force don't forget. Since they know I can't even say hello in the allotted time for these presentations, they scheduled me as the last speaker for the day so you can get up and leave whenever you are ready. Since that first talk on the Magic, few things have changed in the course of water treatment with the exception of the awareness of the problem and potential liabilities. This is due, in part, by the increased activity of the environmental community in it's efforts concerning acid mine drainage. Many coal operators are having a tough time understanding this growing wave of concern because they felt the pendulum had already gone to the other side. When they question me concerning these renewed efforts by the GREEN groups, I paraphrase a quote by Winston Churchill concerning the fire bombings over Germany during World War 11. The first of these bombings were so severe that several asked him if this would end the war. To their question he replied that-concerning the bombing with respect to the war --"This was not the end - Nor was it the beginning of the end - but the end of the beginning. " I feel that the environmental resurgence within the last few years is, as Sir Winston said, - "The end of the beginning." Based on my observations, the pendulum is just getting ready to swing towards that other side and I hope that before it passes the center we can come to an agreement with the Environmentalists that yes, there is a lot that needs to be done but more damage than good can be done if common sense escapes this swing. Since my last talk, I have formed a consulting company (on the side from my duties at Leckie Smokeless Coal Co.) and have had the opportunity to work throughout the state and surrounding states on many different water treatment problems. What I have observed is that the majority of Coal companies are not the demons they are made out to be. Most all companies I have worked for truly have an environmental conscience and want to do the right thing. This may blow your mind, but I have found that most of them don't know what that right thing is. Something as simple as water treatment really is mystical and magical to a lot of companies. Their human reaction to this lack of knowledge sometimes is to appear as if they want to do nothing. It might surprise you to know how many inspectors with the West Virginia Division of Environmental Protection know little or nothing about water treatment and related environmental issues. Should we condemn the Coal Companies and the Inspectors for their lack of knowledge in these areas or do something to help? This windy opening brings me to the reason for my being here today. We have spent the last years qualifying and quantifying acid mine drainage but have failed to teach all concerned the fundamentals for treating the problem. I realize the best way to prevent it is not to cause it and I feel that strides are being made in that direction but there is an enormous amount of acid mine drainage out there not being properly taken care of due to a lack of knowledge in the fundamentals. This reminds me of the same situation that we parents see our children going through in the present day school systems. I am appalled when I sit down to help my three boys with their homework and hear the problems they are having. You know what? These problems are what we were taught as children merely concerning the fundamentals of READIN-RITIN-AND RITHMATIC. It's no wonder

our children have the problems they do and likewise, it's no wonder that we have the problems we do concerning the treatment of acid mine drainage. I have actually seen operators intimidated by their lack of what to do concerning a water treatment problem. They want to do the right thing but what is it? I feel that part of the problem is that most people don't understand that like the rest of the country, the Coal industry is being revitalized by a different generation and one that is truly concerned about the environment. Presently, there is a spirit of condemnation of Coal operators created in part by the Environmental community to further their causes concerning the environment. Yes, I understand we gave them good ammunition, but what I am also saying is that we Coal operators are also changing with the times and could use some understanding and help without the constant criticism. What do I mean by help? As I stated earlier, most operators don't understand how to evaluate their water problems with respect to the proper method of treatment. Do you realize that the West Virginia Division of Environmental Protection, Water Resources branch has a program that teaches individuals how to evaluate water quality in the area they live and gives them free water test kits to do so? I just recently learned that there is an individual near Leckie that monitors streams running through our properties for chemical and benthic properties. I know this would really be absurd --- but what about giving this same type of training to the coal operators or better yet, require them to attend a training and certification course in water evaluation and treatment. We require our mine foremen, surface foremen, surface blasters, etc., to be certified. Why should it be any different for those involved in the care of our environment? As I stated, a lot of the problems and unfortunate situations that arise are simply due to a lack of knowledge. A case in point is ammonia. There have been cited situations involving the use of ammonia as the culprit. I have no doubt in my mind that this was correct. Why? First of all, most likely the operator did not fully understand the implications nor the manner in which ammonia must be used. Secondly, if you can believe this, the State of West Virginia does not EVEN give it's inspectors an ammonia test kit to check those of us with ammonia treatment systems. What is the answer? Put the coal operator in jail, hold him personally responsible for the situation, and make ammonia illegal to use. "NOT" That's the normal way we have handled things which accounts partly for our present situation. The right thing to do would be to require the operator to be certified in the use of all treatment chemicals and systems. In conjunction with this, require the WVDEP inspectors to likewise be certified and provide them with the necessary tools to perform their job. Making ammonia illegal to use or passing new limits that might as well make it illegal to use would take a cheap an effective tool away from the operator. This might not affect the large operator but would certainly affect the small to mid-size companies. So what? Well, what if this company can't afford to use the alternate method of treatment and goes out of business? Then you are left with a real problem of no treatment at all resulting in a real environmental situation. This scenario is based on the fact that this site was environmentally suited to use ammonia. The point I am trying to make is that I feel a new and different approach needs to be tried concerning the existing problems we have. Instead of always condemning, let's try to help those that don't know - I know you won't believe this but one operator got upset with me after I helped him install a treatment set-up and he had to begin cleaning the sludge out of his ponds. He said" What's wrong, I never had to clean this pond before we started to treat it?" Now some of you are thinking to yourselves, this dumb hick, what hollow did he crawl out or. It might amaze you to know that there are many individuals who don't realize the end results of water treatment and it is your type of thinking that has us in trouble today. Secondly, this was one of the major Coal companies in the industry. I give this

example only to illustrate the result of my observations over the last few years. To this extent I propose that we utilize the resources we have to instruct all concerned in the proper management of our environmental resources and respond in a mature manner in the attainment of this goal. As an example as to how part of the course or training would be established, I have provided an outline of the normal manner in which I approach a water treatment consulting assignment.

GENERAL PROCEDURES IN EVALUATION OF ABC COAL COMPANY--USA -

Upon arriving at ABC Coal Co. there are standard site parameters that must be evaluated with regards to choosing the right method of water treatment for this particular site. They are:

SITE LOCATION	SOURCE FOR TREATMENT
AVAILABILITY FOR POWER	DISTANCE FROM SOURCE TO POND
WATER QUALITY	NPDES LIMITS
ENVIRONMENTAL ASSESSMENT	SITE STATUS
FLOWRATES	POND RETENTION TIME

SITE LOCATION

What type of access is there to this treatment site? Can a tractor trailer reach the site? If not, can a straight truck access the area or is the only way in by four wheel drive? If there is absolutely no access to the point of treatment, one will have to be provided. I guarantee you that if someone has to walk down to the bottom of a valley fill there is a 99 % chance that the site will not be constantly monitored. I have also seen sites where the absence of an access to the site has determined the type of chemical to be used resulting in $40,000450,000 more be spent on treatment, where $ 10, 000 of road work could have allowed for a different treatment scheme and with the associated savings. Another consideration about site access involves pond cleaning and bulk delivery of chemicals. How do you clean a pond that has no access or poor access? You say you don't because your pond never fills up? NOT! You spend a lot of money in pumps and labor trying to do what would normally be cheap and effective if you could reach the site. What is the price difference in accessing the site with bulk delivery of chemicals? As it turns out, ABC Coal Co. could save $16,000 in year in ammonia if it were able to take tanker deliveries of ammonia instead of customary $.28/lb. deliveries for 1,000 gallon tanks.

POWER AVAILABILITY

Is power available? If not, this automatically eliminates some forms of treatment. The installation of a short power line may make the difference in treatment costs by as much as 60%-80%. One of our industries biggest problems is looking only at the cost of a specific treatment chemical based on existing conditions rather than evaluating different methods because of required capital expenditures. This type of thinking costs the Coal industry millions of dollars annually. In the case of ABC Coal Co., the closest power to the site is 500' away at a transformer location located for the purpose of a maintenance shop. Three phase, 440 volt power is available at the shop if needed. Based on current costs of $10.00/foot for powerline installation, the cost would be $5,000.00 to supply the Liberty Branch refuse area with power.

WATER QUALITY

What is the raw water quality? How severe is the problem? If the raw water quality is too bad this will usually eliminate the passive type treatment systems such as wetlands and bioremediation. However, anoxic drains may still be considered as a pretreatment step to reduce acidity values. The quality and flow may be such that certain chemicals because of their nature may be environmentally unsuitable for the receiving streams. Ammonia sometimes falls into this category. Acidity, iron, aluminum, and manganese need to be evaluated to determine the extent of the problem. For example, if a water analysis reveals that iron is absent leaving manganese as the sole culprit, you can expect to have potential retention time problems. This may sound crazy, but the presence of a small amount of iron will help to precipitate the manganese quicker and actually reduce the sludge volume which ultimately determines the frequency of clean-outs.

ENVIRONMENTAL ASSESSMENT

What is the nature of the surrounding areas with regards to wildlife habitat, receiving streams, and human population? These three things can affect your decision based on toxicity effects and even liability associated with vandalism.

FLOWRATES

What are the flowrates? Are they consistent or are they prone to extreme swings due to precipitation events? If flows are consistently high, the choice of some treatment techniques may prove to be too burdensome relative to materials handling. High flowrates will also usually eliminate the use of passive treatment systems due to the required area for such systems based on loading per square foot criteria. Flowrates are critical in choosing the storage size of the device which holds the chemical to be used in treatment. Too small of a holding facility will require daily deliveries of chemicals. This causes a logistics problem with most companies and can be eliminated with proper planning based on results of the titration tests in conjunction with projected average flows. Personally, I try to plan for my holding facilities to provide at least two weeks of materials for treatment. This allows for delivery truck breakdowns, weather problems, and doesn't tie your personnel up in constant deliveries to the site.

SOURCE FOR TREATMENT

What is the source for treatment? Is it a flowing stream of water or is the water entering the pond by subsurface means? There is nothing more difficult to treat than water entering a pond from below the surface. However, this happens quite frequently and is usually associated with valley fill rock cores terminating at the pond. In this case, ammonia is the best and sometimes the only chemical that is successful in treating the water due to it's unique properties. In this particular case, a baffle would be installed across the entrance end of the pond with a window cut near the surface to allow water to flow through. An ammonia injector would be situated on the fill side of the window and calibrated to treat to the appropriate pH to meet effluent standards. The source of treatment is also especially important in reducing costs and the use of chemicals. Often I see operators treating the water in the entrance of the pond which is normally as it should be. However, there are cases where the water being treated emanates

from several different areas and all of these different streams of water may not need treatment. If this is the case (and I have seen it time and time again) then you are way over treating and spending a lot of money unnecessarily. Check all of the different water sources and treat only what needs to be treated.

DISTANCE FROM THE SOURCE TO THE POND

What is the distance from where the mine drainage first appears to the treatment pond? Sometimes there are distinct advantages to treating just prior to entering the pond relative to oxidation. I once examined a site where the specific location of treatment made a 40% difference in the cost. The parameters being treated for should be examined carefully to determine the best location for treatment. Also, some chemicals require that there is a certain amount of ditchline available prior to entering the pond for adequate solubilization and mixing. Calcium oxide sometimes falls into this category as does trapzene.

NPDES LIMITS

What are the NPDES limits? Is this an instream structure requiring less than 1ppm of manganese? Does this site have water quality based or technology based effluent limits? The effluent limitations really set the tone not only for the type of chemical to be used but for the entire scheme of treatment. If you are so unfortunate to have both aluminum and manganese limits, you are immediately thrust into a multiple treatment system. The first phase of treatment will be for aluminum removal with subsequent ponds being utilized for the elimination of manganese. If you don't mind I want to take a brief moment to rant and rave about manganese limits. This is one area where I believe we are all missing the boat, especially the environmental community. I know all the tales about manganese limits with respect to EPA and in some cases these could be true. However, there are hundreds, perhaps thousands of cases out there where the operator has no iron, the pH is 7-7.5, and his manganese content is 10 mg/1 or less. Some of the companies I have dealt with have only a 4-5 mg/l of manganese with no iron and a good pH and are pouring the chemicals in to get rid of 2-3 mg/1 of the deadly and subversive manganese. I really believe that this is one of the indications that the pendulum is swinging and everyone is having such a good time on the ride that common sense or any sense at all has completely left them. I STRONGLY feel that in these particular types of circumstances where the manganese is probably coming from siderite dissolution rather than acidity, we are doing an enormous amount of harm by throwing in all these different chemicals. I CAN'T SAY ENOUGH ABOUT HOW COMPLETELY LUDICROUS IT IS THAT WE ARE TREATING FOR MANGANESE IN THESE TYPE OF CIRCUMSTANCES. SHAME- SHAME-ON US. WHAT ARE WE THINKING OF? Come on Environmental community, use your intelligence and resources for the optimum benificiation of our resources. We need your help. Well, back to the paper. Sorry about that, but I see this circumstance all the time and wonder "WHY?"

SITE STATUS

Is this an active site? Is someone there daily to check the water? If not, how often is this site checked? Certain chemicals demand more attention than others and actually, 0 treatment sites should be checked at least twice daily. I know of no chemical or system irregardless how elaborate, that can be utilized without daily checks to insure continuous treatment relative to

changes in flowrates and quality. Also, active mine sites do not lend themselves well to passive type systems due to fluctuating flows, quality, and the inundation of suspended solids.

POND RETENTION TIME

This can be the most important parameter of all. I don't care what method or system you use, IF YOU DON'T HAVE ENOUGH RETENTION TIME THOU SHALT NOT MEET THE EFFLUENT LIMITATIONS. This is where about 90% of us royally screw up. We never build water treatment ponds. Instead, we build sediment structures designed on a .125 acre ft. criteria. There is a world of difference in a sediment pond and a treatment pond. Retention time is critical for the effective removal of metals, especially manganese and sediment structures rarely offer the optimum amount of time. Well, since we are stuck with these ponds or ditches, what do you do? BAFFLE-BAFFLE-BAFFLE Baffles are the cheapest and most effective method in optimizing the theoretical retention time of a pond. There are numerous types of baffles depending upon your application and there are times when you will use several of these types in the same pond.

How does ABC Coal Co. stand relative to all the categories?

SITE LOCATION--The Liberty branch refuse area pond is an instream structure with poor access. Road construction could be performed for approximately $ 10, 000 that would upgrade the classification for tanker or bulk deliveries and obviously reduce clean-out costs.

POWER AVAILABILITY--Power is available within 500' and could be taken to the site if needed for $5,000.00.

WATER QUALITY--The water quality of this site is close to a 3 pH, 2500 mg/1 acidity, 1500 mg/l iron, 250 mg/l manganese, and .2 mg/l of aluminum.

ENVIRONMENTAL ASSESSMENT- The receiving stream of the refuse area is a trout stream and has a healthy benthic community.

FLOWRATES--The flowrate of the trout stream is 30,000 gallons per minute versus the discharge from the treatment pond of 175 gallons per minute.

SOURCE FOR TREATMENT--This particular pond is fed by an underdrain and emerges as a subsurface flow.

DISTANCE FROM SOURCE TO POND -The distance from the source to the pond is 0 due to the underdrain.

NPDES LIMITS -pH is 6-9, manganese is < 1mg/l, and iron is 3-6 mg/l..

SITE STATUS -The site is an active refuse area.

POND RETENTION TIME--There is one large round pond at the base of the refuse area, which, by calculation has enough theoretical retention time to handle the flows.

After reviewing this list of site parameters, the selection for the proper ameliorant w made from the following list:

LIQUID SODIUM HYDROXIDE	POTASSIUM PERMANGANATE
SODA ASH BRIQUETTES	SODIUM ALUMINATE
ANHYDROUS AMMONIA	DUBOIS 200,220,300,ETC
NALCO-7883 ULTRION	MAGNESIUM HYDROXIDE
STOCKHAUSEN-CM 190,191,196, ETC.	SODIUM METASILICATE
HYDROGEN PEROXIDE	ELECTRICITY
ALUM	CALCIUM OXIDE
POTASSIUM HYDROXIDE	TRAPZENE
WETLANDS	BIOREMEDIATION
ANOXIC DRAINS	ANIONIC FLOCCULENTS

Since the Liberty Branch refuse area is currently active it would appear that the present treatment system would exclude passive options and rely on chemical treatment for the time being, With that in mind and to save time in writing this paper I am simply going to tell you that your options are Trapzene, Sodium Hydroxide, Ammonia, and Calcium Oxide. Trapzene is the most expensive to use and Calcium oxide is the cheapest. Each one of these chemicals would have site specific applications and to this extent, they will be used for titration testing of the Liberty Branch Refuse leachate. --A side note about calcium oxide-- Although Calcium Oxide has been around almost forever, it has only been within the last two-three years that a device was invented making it usable in almost any acid mine drainage situation. Mike and Milford Jenkins, a couple of Coal operators themselves, invented and constructed a device called a water wheel feeder to treat their own water. The machine worked so well that they have since patented the machine and are in full scale production. As a matter of fact, I have one of his wheels at Leckie and have derived tremendous savings from it's use. Without sounding like an advertisement for the AQUA FIX water wheel, I just can't say enough good things about it. Although the results of the titration testing will be closely evaluated it would already appear that ammonia will be chosen for Liberty Branch simply due to the subsurface flow from the underdrain. As far as I am concerned, nothing compares to ammonia for treating subsurface flows.

LIBERTY BRANCH REFUSE AREA TITRATION TESTING

CHEMICAL	FLOWRATE	AMOUNT/GAL.	COST/GAL	ANNUAL COST
TRAPZENE	175 GPM	.001396 LBS	$.000784	$ 72,125.00
NA HYDROXIDE	175 GPM	.001275 GALS	$.000638	$ 58,683.00
AMMONIA	175 GPM	.OO2174 LBS	$.000609	$ 55,985.00
CAL OXIDE	175 GPM	.002810 LBS	$.000281	$ 25,848.00

You are saying to yourself that this guy is crazy to have chosen ammonia based on the cost of calcium oxide but you must remember that everything in water treatment is site specific. We are assuming that there is no way to presently get to the subsurface flow entering the pond and we are presently under a consent order concerning effluent limitations. Ammonia is the only answer and except for calcium oxide, is the cheapest. Based on our survey of the site parameters, it will be acceptable environmentally and will require a minimal of capital

expenditures to begin it's use quickly. The only thing holding ABC Coal Company up at this point is modification of the permit to allow for the use of ammonia as a treatment chemical. WELL, I could go on for about 3-100 pages concerning this subject but I will merely say that if you are presently obtaining a new permit, be sure and include any conceivable change to the permit that might ever happen, including changes in water treatment chemicals if you want to seethe change prior to final release of the permit. (Really this applies more to other areas more so than NPDES changes but I wanted to let off some steam) Back to the task at hand. Perhaps with the obvious savings of Calcium Oxide over Ammonia, the owner of ABC Coal Co. will figure out a way to get to that subsurface flow in order to reduce his cost even further. Until that time, Bill, Hill., and Al, partners in ABC Coal Co., can rest easy in the knowledge that they approached their problem in a common sense manner considering all the options and chose the appropriate method to treat their problem. However, to be totally honest, at the Board of Directors meeting Bill and Al voted for the most expensive solution saying something about the fact that money was no problem but Hill. must own the most stock in the Company since her vote was for ammonia and that is what is being used today.

I realize that I have only touched on the surface with regards to many of the issues in this paper but as with my previous paper you are probably now asleep from trying to finish or forget what was on page one. Actually, I hope that this didn't sink in too well and that you will continue to call me for consulting work as I am now financially destitute from investing my earnings in ABC Coal Co.. I wonder who that Hill. lady is and what she did with my money.

NOTE: The titration graphs included with this paper are actual titrations conducted with the specified chemicals on water obtained from one of my clients.

NOTE 2: Client, if your are out there I am sure you will notice that I used a portion of your report for this paper and want to say thanks.

LIBERTY BRANCH TITRATION CURVES

The following titration curves were generated from my sophisticated laboratory in the kitchen sink. Lot's of times, people are intimidated about the thoughts of titrating but it's as simple or actually more simple than trying to build a pinewood derby for Cub Scouts. I generally use a 2,000 ml sample depending on the quality and dispense . 1 ml at a time of whatever liquid chemical I am using. If the chemical is a powder such as calcium oxide or trapzene, I weigh out samples generally in the range from .01 grams to .1 grams again depending on the quality. If you are not fortunate enough to have a magnetic stirrer, a blender or even a spoonahand works great. This may sound very simple and basic but you must remember that there are very few places in actual field applications where the chemical entering the treatment stream is well mixed. Comparison of my sink tests and field results have been compared to the accuracy of the laser or at least reliable enough to do budgets with. I have seen various methods that certain labs use and am not sure that I totally agree with their methods. The sink test tends to more closely assimilate what you are actually looking at in the field with all the imperfections that you find in nature itself. The results of the four titrations are somewhat off the standard differences you normally see between the four chemicals used. By difference I mean the percent difference between the annual cost of the four. Again for your review:

TRAPZENE ----------$ 72,125.00

20% SODIUM HYDROXIDE ----------$ 58,683.00

ANHYDROUS AMMONIA ----------$ 55,985.00

CALCIUM OXIDE ----------$ 25,848.00

TRAPZENE----------$ 72,125.00

20% SODIUM HYDROXIDE----------$ 58,683.00

ANHYDROUS AMMONIA----------$ 55,985.00

CALCIUM OXIDE----------$ 25,848.00

The difference I spoke of is the amount more that trapzene is than sodium hydroxide and the fact that calcium oxide is not lower than it is. Calcium oxide will almost always be between 70 % -80 % cheaper to use than sodium hydroxide. As it turns out, part of the differences in these titrations was related to the iron content and the minimal amount of ditchline (mixing) ahead of the pond. Sometimes when the iron content is extremely high and the mixing is minimal, the iron will coat some of the oxide and trapzene before it has a chance to dissolve and basically renders it useless. The extent to which this happens can be evaluated by the variation in percent differences between the titrations at the specified delivered costs of:

TRAPZENE ----------$ .60/POUND

20% SODIUM HYDROXIDE ----------$.50/GALLON

ANHYDROUS AMMONIA ----------$ .28/POUND

CALCIUM OXIDE ----------$ .10/POUND

TRAPZENE----------$ .60/POUND

20% SODIUM HYDROXIDE----------$ .50/GALLON

ANHYDROUS AMMONIA----------$ .28/POUND

CALCIUM OXIDE----------$ .10/POUND

This represents fairly average pricing and is subject to change pending site specific parameters such as the ability to receive volume shipments. A case in point for ABC Coal Co. would be the installation of an 8,000-10,000 gallon ammonia tank. I cannot confirm this but I would imagine that the ABC could probably get the ammonia for at least $.20/lb. and perhaps less. What does this do? That price reduction just slashed $ 16,000.00 from the annual treatment costs. However, likewise, if ABC could ever figure a way out to reach the water in the core with calcium oxide and a water wheel, the cost of oxide might go to $.05/lb. by taking 26 ton tanker loads and dispensing from a silo. This just cut the annual treatment cost when using calcium oxide by 50%. Is any of this making any sense to you? Are you starting to understand how one might be able to spend money to save money? The conclusion of this report was that ABC would

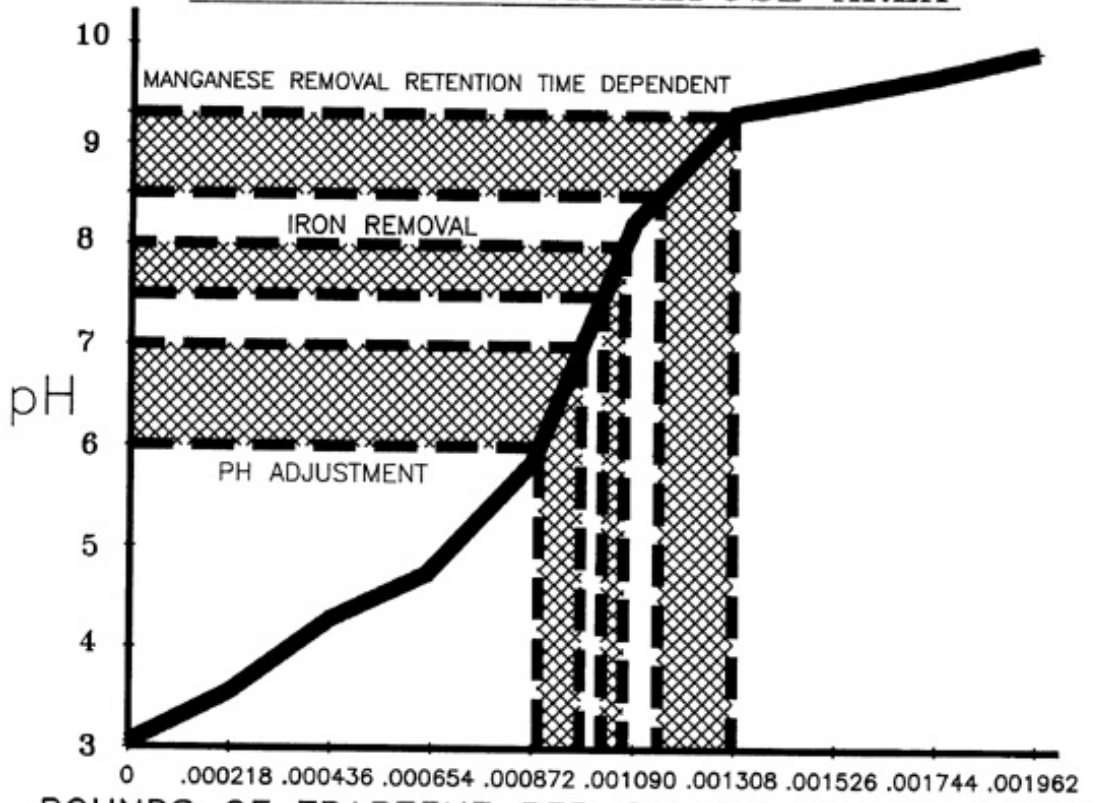
spend $ 55,985.00a year in treatment but as we have just seen, with a little imaginative thinking, it might be possible to get this down to $ 12,924.00 by using calcium oxide. What does all of this have to do with titration curves? Nothing. As usual I got off the point I was trying to make and that is --titration curves can tell you many things about the water you are treating without having any idea of the raw analysis--. Often you can see sodium hydroxide move slowly through water containing high acidity, while ammonia busts right on up to it's buffering point of a 9.2 pH. The ammonia titration curve in this report is an excellent illustration of why caution should be taken when using ammonia for manganese removal. In this test, it took twice as much ammonia to go from a 9.2 to a 9,9 as it did to go from a 3 to a 9.2 pH. On the other hand, that quick jump to a 7 pH is why nothing can compare to ammonia for use in preparation plants. Titration curves are interesting and to a certain extent like photographic profiles. If you really think hard, I bet you'll remember seeing some of my curves on the wall at the post office.

I thought I ended this paper two pages ago. Sorry. See you in another three or four years.

ABC COAL CO. TRAPZENE TITRATION TEST

LIBERTY BRANCH REFUSE AREA

TRAPZENE DELIVERED = $.60/LB.



TITRATION BY WOPEC

.001306 POUNDS REQUIRED FOR MN REMOVAL

$.000784/GALLON OF RAW WATER FOR MN REMOVAL

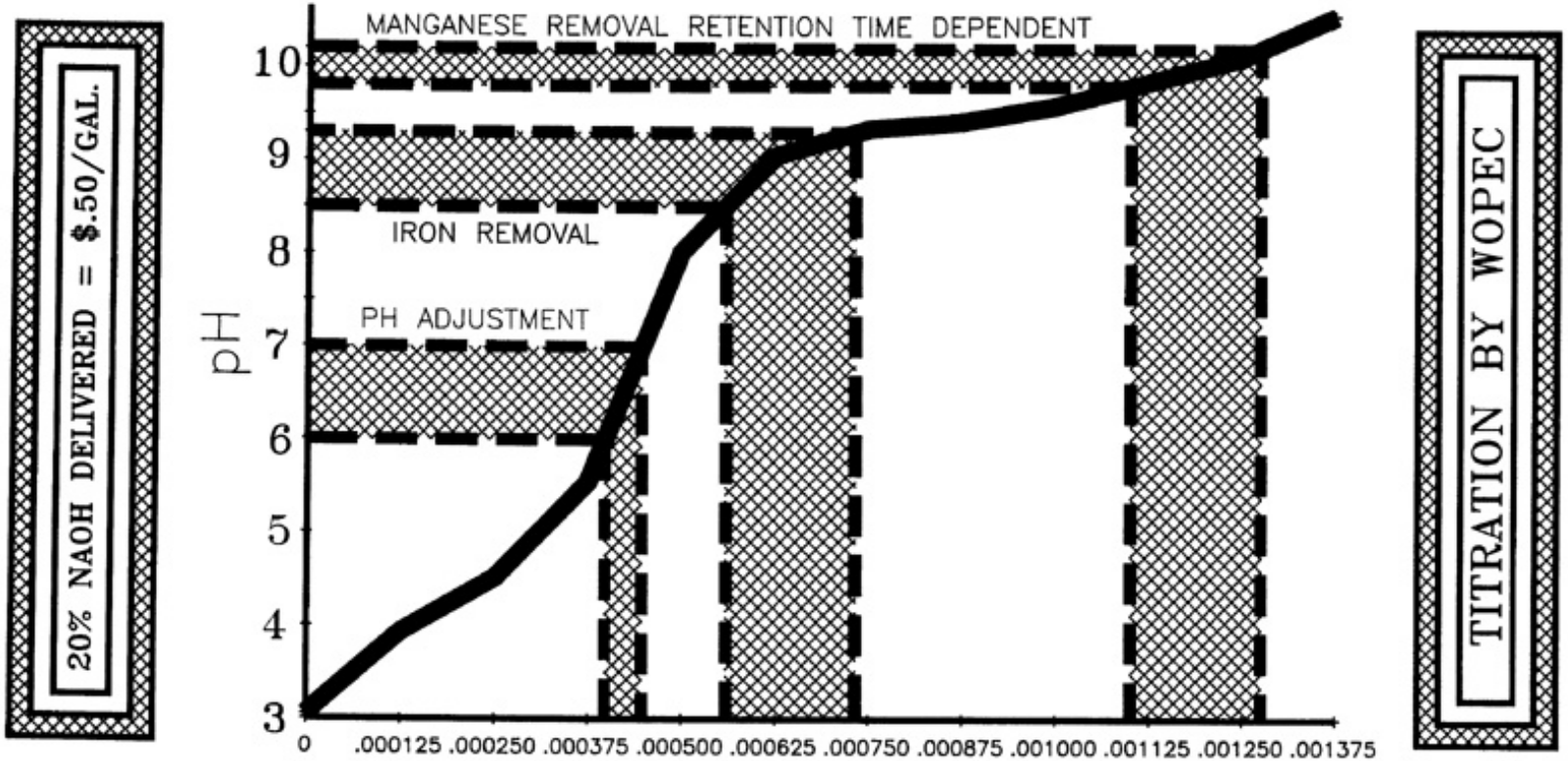
AVERAGE FLOW RATE = 175 GALLONS PER MINUTE

ANNUAL COST = $ 72,125.00

THIS GRAPH REPRESENTS AN ACTUAL TITRATION TEST ON A SAMPLE OF ACID MINE DRAINAGE OBTAINED FROM ABC COAL CO., SITE 1A-LIBERTY BRANCH REFUSE AREA. RESULTS WILL VARY WITH CHANGES IN WATER QUALITY DUE TO A CHANGE IN SURFACE AND GROUNDWATER FLOWS (QUANTITY & QUALITY).

ABC COAL CO. SODIUM HYDROXIDE TITRATION TEST

LIBERTY BRANCH REFUSE AREA



.001275 GALLONS REQUIRED FOR MN REMOVAL

$.000638/GALLON OF RAW WATER FOR MN REMOVAL

AVERAGE FLOW RATE = 175 GALLONS PER MINUTE

ANNUAL COST = $ 58,683.00

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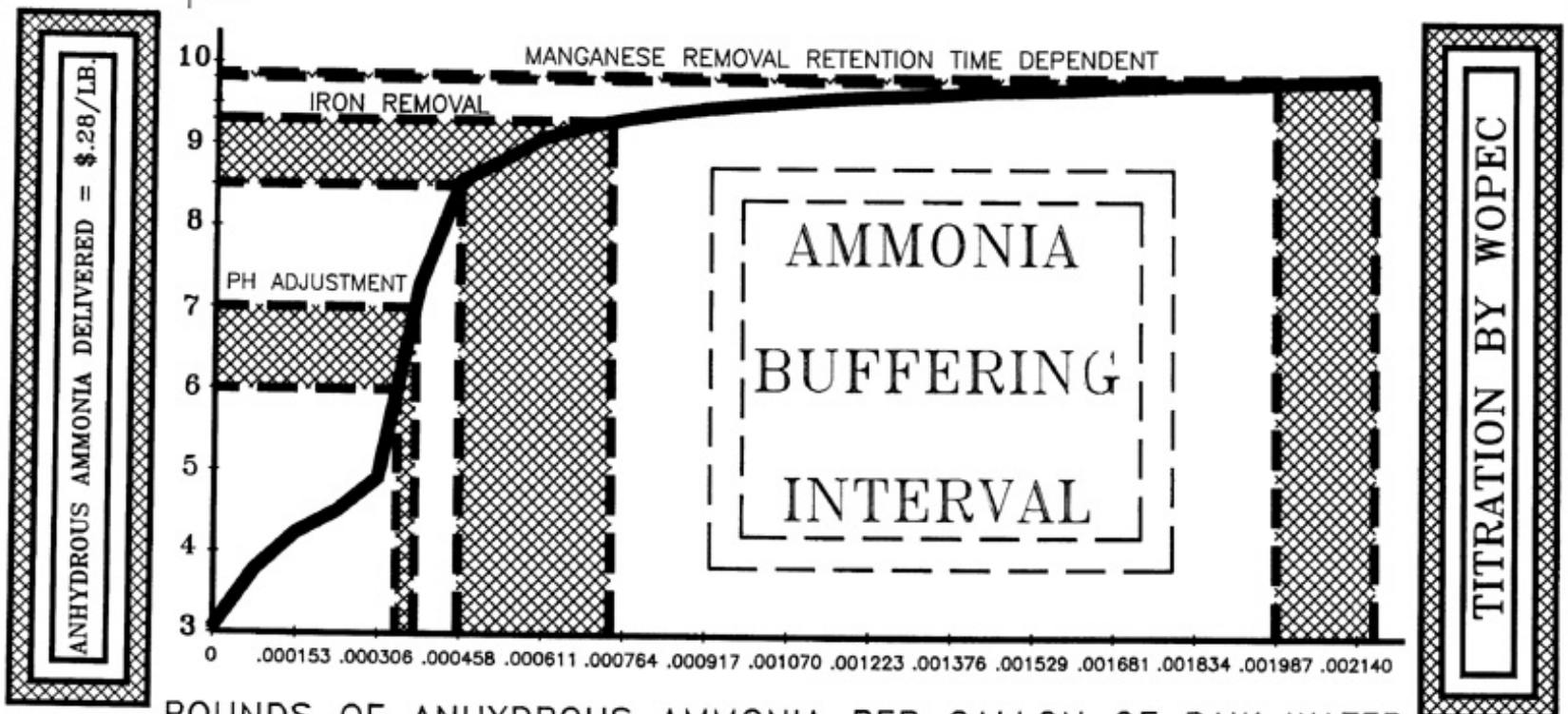
ABC COAL CO. AMMONIA TITRATION TEST

LIBERTY BRANCH REFUSE AREA



.002174 POUNDS REQUIRED FOR MN REMOVAL

$.000609/GALLON OF RAW WATER FOR MN REMOVAL

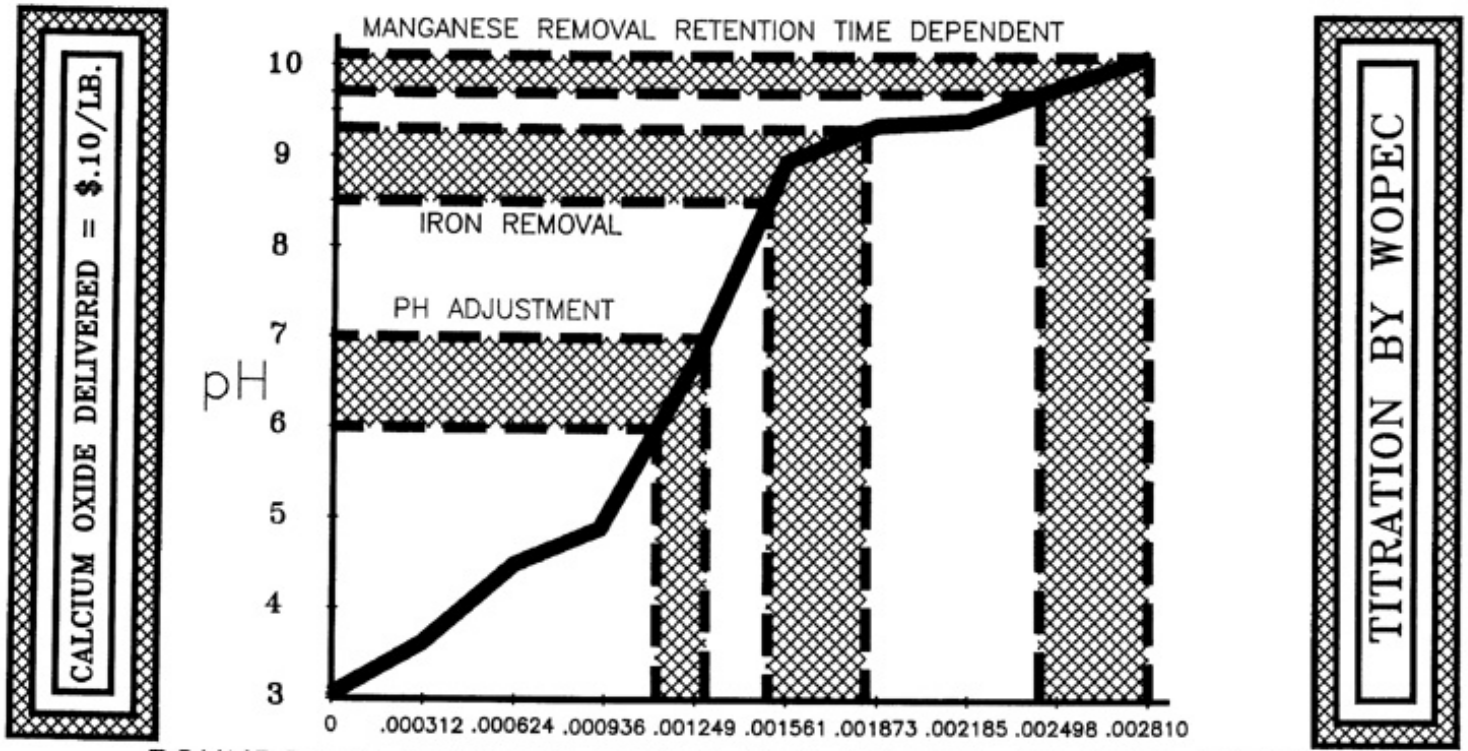
AVERAGE FLOW RATE = 175 GALLONS PER MINUTE

ANNUAL COST = $ 55,985.00

THIS GRAPH REPRESENTS AN ACTUAL TITRATION TEST ON A SAMPLE OF ACID MINE DRAINAGE OBTAINED FROM ABC COAL CO., SITE 1A–LIBERTY BRANCH REFUSE AREA. RESULTS WILL VARY WITH CHANGES IN WATER QUALITY DUE TO A CHANGE IN SURFACE AND GROUNDWATER FLOWS (QUANTITY & QUALITY).

ABC COAL CO. CALCIUM OXIDE TITRATION TEST

LIBERTY BRANCH REFUSE AREA



POUNDS OF CALCIUM OXIDE PER GALLON OF RAW WATER

.002810 POUNDS REQUIRED FOR MN REMOVAL

$.000281/GALLON OF RAW WATER FOR MN REMOVAL

AVERAGE FLOW RATE = 175 GALLONS PER MINUTE

ANNUAL COST = $ 25,848.00

THIS GRAPH REPRESENTS AN ACTUAL TITRATION TEST ON A SAMPLE OF ACID MINE DRAINAGE OBTAINED FROM ABC COAL CO., SITE 1A–LIBERTY BRANCH REFUSE AREA. RESULTS WILL VARY WITH CHANGES IN WATER QUALITY DUE TO A CHANGE IN SURFACE AND GROUNDWATER FLOWS (QUANTITY & QUALITY).