DENSE SLUDGE PROCESS FOR REDUCED AMD SLUDGE DISPOSAL

by

Robert L. Zick, Michael H. Leon, and Daniel C. Finn
Chester Engineers
Pittsburgh, PA 15108

Abstract. Dense sludge is an innovative and improved method for treating acidic metal bearing streams in a manner which minimizes volumetric generation of sludge for disposal. In the Dense Sludge process, the alkali source is combined with recycled sludge before being introduced into raw water influent, thus forming metal particles with a low affinity for water. The sludge density of clarifier underflow has in some cases increased from the usual 1-2% to nearly 35% solids. This paper will describe installation and operating data from a 9,000 gpm Dense Sludge AMD Treatment Facility at a coal mine in Northern West Virginia.

Additional Key Words: acid mine drainage, sludge

Introduction

The High Density Sludge Process was originally developed by Bethlehem Steel Corporation for use on acid mine drainage and diluted waste pickle liquor discharges requiring continuous chemical treatment systems. This work began in the early 1970s and was first put into practical use around 1973. To date there are approximately 15 operating systems which have been installed on mine drainage in the United States, and another 10 systems worldwide.

Dense Sludge is an innovative and improved method for treating acidic metal bearing streams in a manner which minimizes the volumetric generation of sludge for disposal. The technology utilizes a sludge recycle process which forms particles that have a low affinity for water, unlike conventional metal hydroxide solids which contain tightly bound interstitial waters. Typical acid mine drainage streams contain high sulfate concentrations which combine with calcium ions in lime based treatment systems to form gypsum crystals. The physical form of this gypsum is radically altered when the Dense Sludge process is utilized compared to the form generated in conventional lime treatment systems. The characteristics of the metals particles are also changed in this process, as the metal hydroxides are converted to metal oxides. Slides No. 1 and No. 2 show scanning electron micrographs of conventional and densified sludges illustrating these differences. The magnification used was 300X. The dense sludge particles settle faster, dewater more readily, are more easily pumped, and hold much less water than conventional precipitates. In some cases, because the metal content of the sludge is more concentrated, it can be economically recovered.

In general, the conventional and Dense Sludge treatment processes are very similar. The changes required to implement the Dense Sludge process are minor, and typically much of the existing equipment is utilized. The net results of the process are reduced operational costs associated with sludge generation, improved process control (particularly pH control), reduced gypsum deposition (i.e., less scaling) on system components, and reduced sludge generation resulting in less return water for treat-

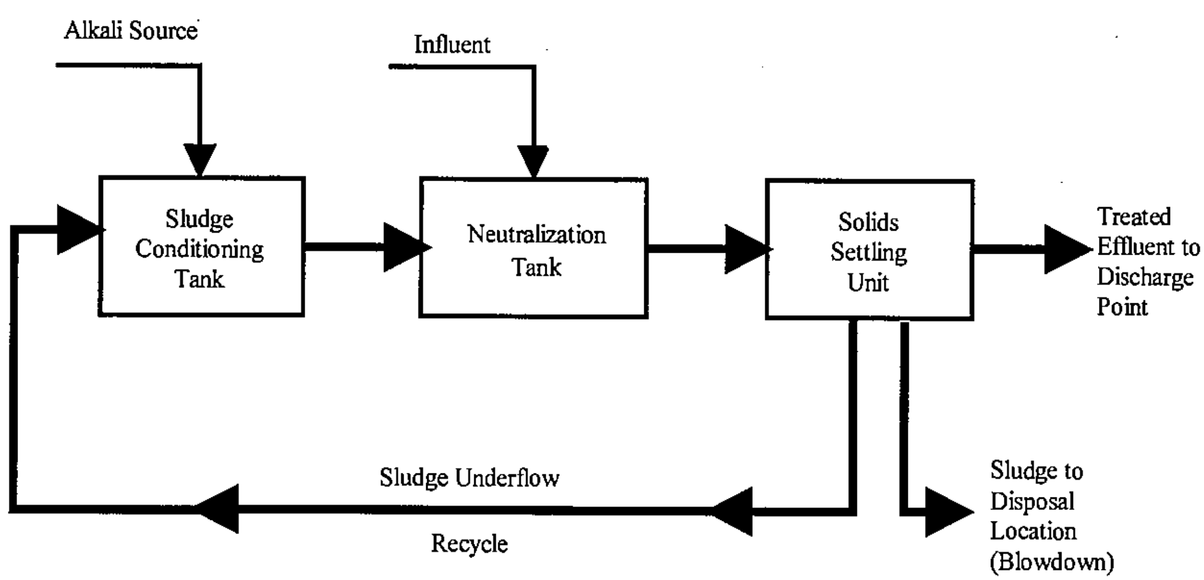

Figure 1. - Simplified Schematic of Dense Sludge Process

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ment. Despite the relative simplicity of the process, the application of the technology requires careful discrimination and the "experience factor" for implementation is an important consideration which should not be overlooked.

Overview of the Dense Sludge Process

Figure 1 presents a simplified process flow diagram of the Dense Sludge process. The most significant change between Dense Sludge technology and conventional metals treatment is the method by which the alkali source is added. In conventional treatment systems, the alkali is added directly into the influent to achieve a desired pH setpoint. Generally, that setpoint is the pH at which the minimum solubility occurs for the target metal(s), or at the pH where discharge limitations can be reliably met. In the Dense Sludge process, the alkali source is combined with recycled sludge before being combined with the influent. The alkali source can be lime, caustic, ammonia, or any other neutralization agent which reacts readily and can be continuously metered.

The sludge particles react with the alkali to provide attraction sites for the removal of metals and cause the gypsum crystals to grow. The continued recirculation of sludge ultimately converts the metal hydroxides to oxides through a series of steps.

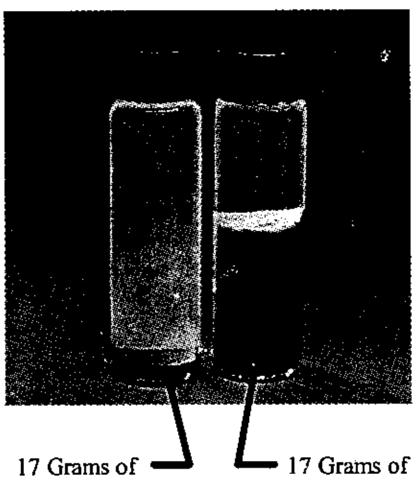


Figure 2 - Sludge Characteristics

The method of feeding the alkali (proportioning valve, proportioning weir box, or metering pump) is the same for both conventional and dense sludge systems. In some cases we have found that the pH setpoint can be lowered with the Dense Sludge system and still maintain optimum metals precipitation. The sludge for recirculation is withdrawn from the solids settling unit and pumped to the sludge conditioning tank where it combines with the alkali source. The resultant mixture of sludge and alkali is then directed to the neutralization tank where it combines with the influent. The demand for alkali depends upon the system pH setpoints and a probe in the Neutralization Tank provides continuous measurement and feedback to the proportioning device. Many operators of treatment plants which have been converted to the Dense Sludge process report a savings in alkali consumption.

The sludge generated in the solids settling unit is recirculated constantly at a rate sufficient to meet the constraints of the dense sludge process. In addition to continuous recycle, a certain quantity of sludge is removed from the system each day to maintain the equilibrium of the system. For best results this blowdown stream should be designed to handle the maximum anticipated loadings on a continuous basis and then it can be operated intermittently to maintain the density of the recirculated sludge or to keep this density within a target range, say 15 to 25% solids. For acid mine drainage derived from coal mining sites, we have found that 20% solids or less provides a good working density with lime alkali and ultra high molecular weight (UHMW) cationic polymer used as a settling aid. For applications involving other metals, 20 to 30% solids in the underflow from a clarifier/thickener is achievable. There are, of course, exceptions to these situations. One facility, which has high iron and sulfate loadings, uses no polymer and achieves underflow solids in the 35% range with lime.

Because the chemicals used and unit operations all remain the same with the Dense Sludge process, implementation of the process typically requires only the installation of small tanks, mixers, pumps, piping, flow meters, and valves. No new major equipment is required. Using the Dense Sludge process to eliminate the interstitial water in sludge particles, the solids in the sludge are denser and will settle more rapidly. This improvement in the characteristics of the sludge directly correlates to increased percent solids achieved in the sludge blanket in the thickener/clarifier and a decrease in the quantity of waste sludge generated. The percent solids ranges discussed previously compare to a typical range of 1-3% solids with conventional systems. The difference in the sludge characteristics is illustrated by Figure 2.

Application of Dense Sludge Process

The Dense Sludge process is generally suited for acidic waste streams containing soluble metals. Although there is no strict guideline for pH characteristics, the wastewater must contain metals in the soluble form. In some cases, as with ferric iron, this dictates an influent pH below 3.5. When evaluating the process for use with acid mine drainage, if an appreciable amount of ferric iron could be present in the influent and the pH is low enough for it to be present in a soluble state, a two-stage neutralization system should be utilized to optimize the Dense Sludge process. With other metals (e.g., nickel, chromium, cadmium), a pH less than 7 would suffice. Because of the chemistry of the process, metals that are insoluble when they reach the process cannot be densified, since they have already been precipitated.

Although the process was originally developed for acid mine drainage, Chester has also installed the Dense Sludge process in the following industries:

- Acid pickling (carbon and stainless steel)
- Electrogalvanizing (steel)
- Aluminum conversion coating
- Printed circuit board manufacturing

In addition to the above industries, other candidate industries include:

- Electroplating
- Semi-conductors
- TV picture tube manufacturing
- Aluminum anodizing

Mining Case History

The following section describes the installations and provides operating data from an AMD treatment location in northern West Virginia. At this site two Dense Sludge systems have been installed and the new larger system is currently operating. The older system is a conventional treatment plant which was retrofitted with Dense Sludge technology. It is currently not operating, but held on standby. Both of these systems are located on a site which is part of a large mine complex that operates on Freeport seam coal.

Retrofit

Dense Sludge technology was retrofitted to the existing AMD treatment plant to prove the merits of the system. Construction activity began in August 1994, and start-up of the entire system incorporating the retrofit components began during late December 1994. This plant has capacity to treat approximately 2000 gpm of influent which is collected in a storage pond. The water flowing into this pond is combined surface runoff and leachate from an old refuse disposal area, and artesian flow. A representative influent analysis and effluent discharge permit limitations are listed below.

Influent Data

Flowrate	2000 gpm
pH	≤5.0
Acidity as $CaCO_3$ equivalent	1900 mg/L
Aluminum	175 mg/L
Iron, Total	300 mg/L
Ferrous Iron	200 mg/L
Manganese	9.0 mg/L
Sulfate	2500 mg/L

Effluent Permit Limitations

pH	6-9
Iron, Total	1.6 mg/L
Manganese, Total	1.1 mg/L
Total Suspended Solids	35 mg/L Average Monthly
Total Suspended Solids	70 mg/L Maximum Daily

Operating information from the retrofit system which helped justify use of the Dense Sludge technology at the new facility is presented below.

- The sludge density of the clarifier underflow increased from 1-2% to approximately 15% solids by weight.
- The blowdown pump used to dispose of sludge to the borehole was reduced in size from 400 gpm to approximately 100 gpm, resulting in a subsequent reduction in pump horsepower from 100 to 30.
- The sludge disposal pipeline size was reduced from 6-inch to 3-inch.
- Actual sludge volume for disposal was reduced by approximately 90% because the blowdown pump was operated intermittently for less than half of the time the plant was treating water.
- Projected clarifier size for the new facility was reduced by approximately 25 feet of diameter compared to conventional sizing. Due to the very low effluent limits at the site, a larger size reduction could not be justified.
- Since the lime delivery system had been modified just prior to installation of the Dense Sludge system, no data comparing usage was available. Most operators from other Chester-installed systems report an approximate 10% reduction in lime usage with the Dense Sludge system.
- Observations over time by our client has shown that the Dense Sludge process provides control of gypsum deposition on internal components of the system. The requirement for less frequent pH probe cleaning was one measurement of the phenomena. The process does not eliminate gypsum deposition completely, but it provides a considerable reduction minimizing the maintenance requirement.

New Facility

A new Dense Sludge AMD treatment facility was constructed at the site and operations began in November 1996 with a capacity to treat up to 9000 gpm of influent. Except for the large increase in flowrate, design parameters were very close to those used for the retrofit system. The facility can treat combinations of flow from the storage pond and two deep well pumps operating on mine pool water. The capacity of each deep well pump is 4500 gpm, so depending upon the flow volume originating from the storage pond, the plant operator decides how many deep well pumps can be operated without exceeding the capacity of the system. Thus, under a very high runoff situation no deep well pumps are operated. At times this new facility has handled flow rates in the 11,000 gpm range.

To assist us with this paper Chester Engineers contracted with Mr. Tiff Hilton of Working on People's Environmental Concerns (WOPEC) to do a treatability study with raw water samples taken on January 24, 1997 at the new AMD treatment facility.

Results from Mr. Hilton's work are presented as follows.

- Table 1 - Raw Water Analysis
- Table 2 - Incremental Titration Results Using Lime
- Figure 3 - Incremental Plot of Titration Results

Table 1 Chester Engineers Client Water Sample Raw Water Analysis

Parameter	Analysis Results	Method
pH	2.83 STD. UNITS	4500
Specific Conductance	3,538.00 UMHOS/CM	2320
Total Alkalinity	<1.00 MG/L	2320
Total Hot Acidity	1,146.00 MG/L	2310 B
Total Suspended Solids	<1.50 MG/L	2540 B
Total Sulfates	1,050.00 MG/L	375.4
Total Dissolved Solids	3,333.00 MG/L	2540 C
Hardness	1,356.10 MG/L	2340 C
Total Calcium	332.00 MG/L	3111 B
Total Magnesium	128.00 MG/L	3111 B
Total Sodium	38.00 MG/L	3111 B
Potassium	10.80 MG/L	3111 B
Total Iron	190.80 MG/L	3111 B
Ferrous Iron	189.60 MG/L	--
Ferric Iron	1.20 MG/L	--
Total Manganese	16.30 MG/L	3111 B
Total Aluminum	50.60 MG/L	3111 D

The incremental titration results (Table 2) approximate the operation of a conventional type treatment facility that has been designed conservatively for aeration capacity and neutralization retention time to allow the chemical reactions to be completed and the lime to be fully utilized. The following observations can be made from the presented data.

- The manganese discharge limit of 1.1 mg/L could not be met with this water without maintaining a pH of over 9.3 in the reactor vessel.
- When the manganese limitation becomes the driving parameter forcing the pH to be maintained above 9.0, aluminum becomes increasingly soluble, thus, making it more difficult to remove in a conventional system. Site data indicates that the Dense Sludge Process controls these conditions by reducing the pH requirement to meet the manganese limits, thus minimizing the amount of aluminum that can come back into solution.

Additional information generated during this project shows benefits of the Dense Sludge process to be:

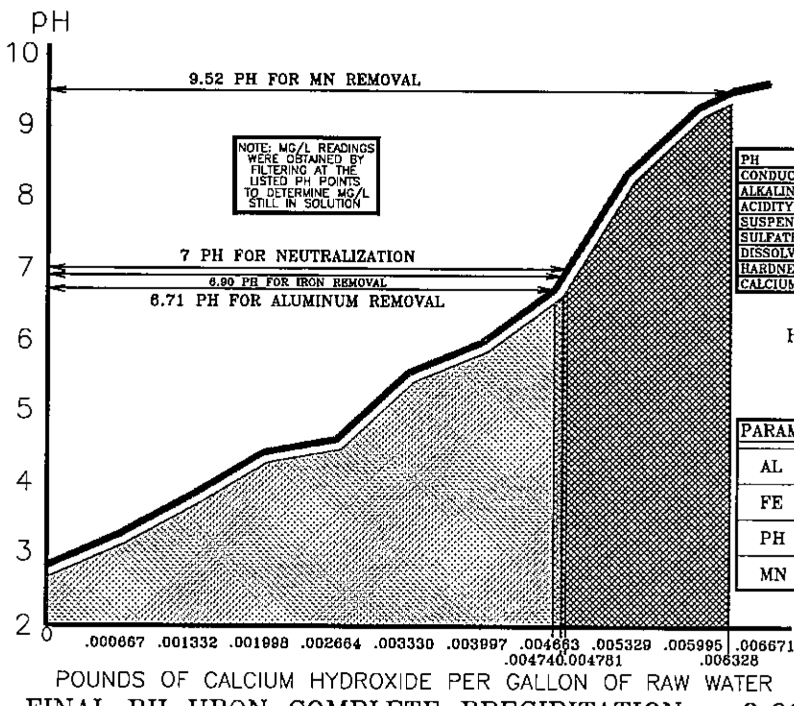
- Given the comparative sizes of the sludge disposal pumps required for a conventional treatment process versus the dense sludge process, the amount of water recirculated to the mine pool was reduced by approximately 1 MGD.
- The existing sludge disposal pipeline to the borehole, which is 3-inch diameter, was able to be utilized with the dense sludge process. An 8-inch sludge disposal pipeline which would have been required with a conventional process was eliminated. The length of this line is approximately 2000 ft.
- The system is utilizing lime very efficiently. Actual usage based upon lime delivery records is less than theoretical neutralization calculations, as opposed to conventional systems which use the lime less efficiently.
- There is very little pH fluctuation with the Dense Sludge Process. This tight operating range is less sensitive to any upset conditions which could occur.
- By utilizing a lower treatment pH, the final pH at the system outfall is also reduced, which is beneficial to the receiving stream.

Conclusion

The Dense Sludge process is a waste minimization technique that can be effectively used when treating metal bearing wastewaters. In general, the technology can reduce waste generation considerably and also improve treatment system performance. It increases the solids handling capacity of existing systems and minimizes equipment requirements for new systems. In addition, the Dense Sludge process reduces costs for operating labor, the quantity of neutralization chemicals used, and sludge disposal. Since the process utilizes existing equipment to the maximum extent possible, modification of existing systems is not difficult and is generally cost effective because of the economic benefits realized by its installation.

Table 2 Chester Engineers Client Water Sample
Calcium Hydroxide — Incremental Titration Results

Lab ID	Sample ID	PH	AL	FE	MN	CA	MG	Hardness	K	NA
228161	Raw	2.83	50.60	190.80	16.30	332.00	128.00	1356.10	10.80	N/A
228378	#1	3.27	43.50	142.20	14.40	221.00	124.00	1062.50	N/A	N/A
228379	#2	3.82	42.80	117.20	14.30	279.00	122.00	1199.10	N/A	N/A
228380	#3	4.42	35.40	116.40	14.00	289.20	122.00	1224.50	N/A	N/A
228381	#4	4.60	16.00	109.60	13.00	293.00	109.00	1180.50	N/A	N/A
228382	#5	5.54	6.00	86.80	12.80	297.00	115.00	1215.20	N/A	N/A
228383	#6	5.96	1.80	45.90	11.70	386.00	117.00	1445.60	N/A	N/A
228384	#7	6.71	0.80	2.83	11.40	397.00	104.00	1419.60	N/A	N/A
228385	#8	8.34	3.60	0.08	6.20	402.00	105.00	1436.20	N/A	N/A
228386	#9	9.28	4.20	0.05	1.21	480.00	73.00	1499.20	N/A	N/A
228386	#9.5	9.52	9.60	0.05	0.52	564.00	80.00	1737.70	N/A	N/A
228387	#10	9.63	10.40	0.03	0.23	581.00	69.00	1734.90	10.01	15.00



FINAL PH UPON COMPLETE PRECIPITATION = 8.66

METAL	FERRIC IRON	FERROUS IRON	ALUMINUM	MANGANESE	FINAL PH=8.66
REMOVAL PH	6.90	N/A	6.71	9.52	FINAL MN=0.26
INFORMATION FOR CURVE PROVIDED BY: WOPEC TITRATION TEST					SLUDGE=0.07 GALS.
					SLUDGE % SOLIDS=.09%

Titration Evaluation By WOPEC

RAW WATER ANALYSIS

PH	2.83	MAGNESIUM	128
CONDUCTIVITY	3,536	SODIUM	38
ALKALINITY	<1.00	POTASSIUM	10.80
ACIDITY	1,146	IRON	190.80
SUSPENDED SOLIDS	<1.50	FERROUS IRON	189.60
SULFATES	1,050	FERRIC IRON	1.20
DISSOLVED SOLIDS	3,333	MANGANESE	16.30
HARDNESS	1,356	ALUMINUM	50.60
CALCIUM	332	FLOWS	9,000 GPM

HYDRATE LIME DELIVERED = $70/TON

GENERAL TREATMENT STATISTICS

PARAM.	#/GAL.	$/GAL.	GPM	AN.SLUDGE/GAL	AN.CHEM.COST
AL	.004663	$.000163	9,000	N.S.	$771,055
FE	.004740	$.000165	9,000	N.S.	$780,516
PH	.004781	$.000167	9,000	N.S.	$789,976
MN	.006328	$.000221	9,000	20,068,363	$1,045,418

NOTE:

This graph represents an actual titration test on a sample of acid mine drainage obtained from a Chester, client treatment site. Results will vary with changes in water quality due to a change in surface and groundwater flows, (quantity and/or quality.)

Figure 3 - Incremental Calcium Hydroxide Titration Test using Conventional Treatment