SUCCESSFUL DEWATERING EXPERIENCE AT HYPERION WASTEWATER TREATMENT PLANT

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ABSTRACT

The City of Los Angeles has developed a diversified sludge management program since cessation of the ocean disposal of sludge in November 1987. At the heart of this program is the centrifugal dewatering of digested sludge at the Hyperion Wastewater Treatment Plant. The experience gained from the dewatering process includes: centrifuge startup problem solving, optimization of the dewatering process, polymer testing, struvite monitoring and control, and waste activated sludge dewatering parameter development.

KEYWORDS

Sludge; dewatering; centrifuge; digestion; waste activated sludge; polymer; struvite; startup; mannich; emulsion

INTRODUCTION

The objective of this paper is to share the experience gained through the history of sludge dewatering at the Hyperion Treatment Plant (HTP). This experience should be useful for others implementing dewatering processes or upgrading and optimizing an existing operation. The discussion will specifically address centrifugal dewatering of municipal wastewater sludge, although some of the fundamentals addressed pertain to all mechanical thickening and dewatering of sludges.

The City of Los Angeles' HTP treats approximately 370 MGD of raw sewage with advanced (chemical addition) primary treatment with more than half the flow currently receiving conventional activated sludge secondary treatment. The primary and secondary sludges are codigested in conventional completely mixed high-rate anaerobic digesters. The City of Los Angeles, under Federal Court Order, ceased ocean discharge of sludge at HTP in November 1987. This resulted in a need to establish diversified means of sludge disposal. Presently, the disposal methods include: energy recovery, chemical fixation and reuse as landfill cover, land application and, as a last resort, landfill disposal. A key to the permanent cessation of ocean discharge of sludge at HTP has been the dewatering process. The method used to dewater the sludge at HTP is horizontal, continuous feed, solid bowl centrifuges.

At HTP, as in most municipal wastewater treatment plants, sludge disposal is a significant portion of operating costs. A one percent increase in cake solids translates to an approximate annual savings of one million dollars in disposal costs. This potential for cost savings has necessitated the development of optimized sludge dewatering process control strategies integrated into the routine operation of the facility.

HTP spends over two million dollars annually on polymer to aid in the dewatering process. The current type in use is a cationic liquid mannich polymer. Plant staff have developed
an extensive quality control program for this polymer which continues to be upgraded. Ferrous chloride is added to the raw and digested sludges to protect against magnesium ammonium phosphate (struvite) precipitation. Recently, HTP ran some successful pilot tests with CO$_2$ addition to the digested sludge lines to help prevent struvite formation downstream of the centrifuges.

This paper will discuss routine "trials and tribulations" in the dewatering process, as well as present an overview of some unique experiences at HTP; from the physical startup of the centrifuges to pilot dewatering of undigested thickened waste activated sludge (TWAS).

HISTORY

The City of Los Angeles has been dealing with the issue of sludge management since the early 1950s. The sludge facilities of that time included anaerobic digestion, elutriation, vacuum filter dewatering, heat drying in flash dryers, and bagging of the dried product for sale as a soil amendment. Marketing attempts for the dried product were unsuccessful and alternatives were investigated. As a result of these studies, a seven mile outfall for the discharge of digested sludge into the ocean was constructed and began operating in 1957.

Sludge disposal again became an issue in June 1971, when the Environmental Protection Agency (EPA) imposed a requirement for the City of Los Angeles to stop discharging sludge to ocean. A year later the State Water Resources Control Board (SWRCB) adopted a "Water Quality Control Plan for Ocean Waters of California" which also directed the cessation of ocean discharge of sludge. Shortly thereafter, the EPA and the SWRCB issued directives requiring the City of Los Angeles to discontinue the discharge of sewage sludge to the ocean by December 1976.

The City undertook a study known as the Hyperion Interim Sludge Project (HIS) which recommended centrifuge dewatering the sludge and landfilling the concentrated solids. Under this project eight Ingersoll-Rand centrifuges were purchased in December 1976. Litigations and landfill difficulties put this project on hold and the centrifuges were shelved soon afterwards.

In the meantime, a team of consulting engineers was retained by the City of Los Angeles, and Los Angeles and Orange County Sanitation Districts to study the region’s sludge problems and recommend alternatives. This study, known as the LA/OMA Project, was the basis for the creation of the Hyperion Energy Recovery Systems (HERS). Included in the HERS Project was the centrifugal dewatering of sludge. Five additional Ingersoll-Rand machines were purchased for a total of 13 units (model no. 290). In December 1988, three large capacity Humboldt centrifuges (model S6) with a capacity of 500-600 gpm were bought and installed to increase dewatering capacity.

STARTUP PROBLEMS

The physical startup of 13 Ingersoll-Rand dewatering centrifuges began in 1985 to meet a consent decree milestone for the cessation of ocean sludge disposal by the end of 1987. Eight of these machines were purchased in 1976 and, therefore, required retrofitting to state-of-the-art technology. One change was hard-facing the leading edge of the conveyor flights with tungsten-carbide to prevent wear and erosion. Another modification was the addition of hydraulic backdrive units designed to produce a torque sensitive differential speed which maximizes the solids inventory in the machine and minimizes the chance for plugging. Additional modifications became necessary once the machines began operation.

After 2500 hours of operating time, one of the machines was removed from service for routine maintenance and it was discovered that the cake discharge chutes were being eroded by the abrasive action of the cake. Additionally, the feed pipe bushing and the guide plates were also severely worn. A modification was made to line the cake discharge ports with a tungsten-carbide lined sleeve and to machine tungsten-carbide parts for the other worn parts. Another problem was encountered with the hydraulic hoses on the backdrive units. The continuous vibration of the machine resulted in the hoses wearing holes at points of contact. This problem was resolved by isolating the feed and return hydraulic hoses to prevent this wear from occurring.

The conveyor belts under the cake discharge chutes were experiencing some tracking difficulties. The rollers under the chutes were a high-maintenance item due to the cake dropping about six feet onto the belts. This was remedied by adding energy dissipators
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inside the cake chutes and adding additional impact rollers under the chutes.

Fig. 1. Concurrent Dewatering Centrifuge Ingersoll-Rand Model No. 280

The Humboldt units also required some modification upon startup. Their significant problem was excessive vibration. At times the vibrations exceeded 60 millimetres of displacement which eventually caused some auxiliary piping failures. The worst vibrations occurred during startup and shutdown. It was found that flushing water dampened these vibrations and, therefore, plant effluent for flushing these machines was integrated into the automatic startup and shutdown sequence. This modification, however, did not correct the vibration problem on one of the machines. When this machine was taken to a machine shop it was found there were 70 missing tiles on one flight and the entire scroll was out of specification for pitch and height. This conveyance assembly underwent extensive rebuilding which resolved the problem.

Leaking oil from the bearing housing was a continuous problem with all three Humboldt machines. This became a significant concern as these machines kept tripping off on low oil pressure and high temperature. Modifications were made including an additional ring round the labyrinth seal which fixed this problem.

Another major problem was that the design of the centrate line did not take into account the hydraulic capacity used up by the foam which is produced by the turbulence in the machines. Hydraulic relief lines were installed to prevent centrate backing up and degrading the cake concentration.

OPERATIONAL CONTROLS

One very successful part of sludge dewatering at HTP has been the daily operation of the centrifuges. A key to this success has been the flexibility built into this system with control capabilities that include: local, remote, manual and automatic functions. The controls are designed with a system of magmeters and control valves on each centrifuge for sludge and polymer feed which determine the demand of sludge and polymer by common variable speed pumps. All remote monitoring and control is done with a Westinghouse Distributed Processing Control System (WDPS).

The WDPS is designed to provide a system of microcomputer modules, known as "drops", each performing a basic function. The system is configured using a building block approach; each drop added to the data highway until all the tasks required for the specific application are accommodated. This building block approach allows flexibility in that any future automation is easily accommodated by the addition of drops and the modular startup of the new system. Since the drops function independently, problems or failure with one drop does not affect operation of the remaining system.

The data acquisition and control functions are combined in the Data Processing Unit (DPU) and share the same input/output. The data acquisition function includes processing input values, alarm checks, broadcasting values and sorting points for viewing at the operator console. The control function is maintained through the use of ladder diagrams or control
algorithms which allow the operator to monitor the process or change values as required to maintain the process. Also included are critical alarm points such as the backdrive hydraulic oil pressure. DPU programming allows this alarm to initiate closure of the affected centrifuge sludge and polymer valves. A second alarm point shuts down power to the centrifuge and backdrive motors. Such configuration protects critical plant equipment from damage while the operator is freed from routine monitoring to concentrate on process control.

The operator console features custom graphic displays of flow diagrams, system status, alarm points, trend graphs, etc. The console operator may modify the definition, current status or values of the process points, display trend values or display process points per a defined category.

This WPDS has fulfilled an operational need for a reliable, durable, expandable system of automated process control of sludge dewatering at HTP. The system has served to minimize manhours required to successfully operate the section during a period of high profile and continuous modification and expansion. Work is currently underway to expand this facility for remote monitoring and full automatic control of the conveyance systems, wet cake storage areas and truck loading operations.

**PROCESS OPTIMIZATION**

Prior to November 1987, the sole process goal at HTP was for a successful startup and continuous operation of the centrifuges to enable the City of Los Angeles to discontinue ocean disposal of sludge. After meeting that milestone and a comfort level in operation developed, the goal became optimization of the dewatering process. The sludge dewatering process at HTP follows the usual expected cost-benefit curve between cake solids and centrate capture efficiency.

At HTP, a one percent increase or decrease in cake solids translates to a one million dollar increase or decrease, respectively, in offsite sludge disposal costs. This obvious financial need to maximize cake solids concentration is countered by an operational need to maximize centrate capture efficiency. With the advent of chemical addition in the primaries and the increase in flow to the secondaries, HTP became limited in many aspects of solids handling and processing (digester, primary sludge pumping and dewatering capacity). These two conflicting needs have necessitated the development of a process control program for sludge dewatering.

Daily composite samples are taken for feed, centrate and cake solids for process control purposes. It is logistically difficult for the laboratory to do daily analysis of each (15) individual machine for centrate and cake. However, it is equally difficult to monitor the performance of the separate machines without this individual sampling. Therefore, HTP has developed biweekly individual sampling of the centrifuges for lab analysis as well as daily analysis of the machines by the operators.

The analysis by the operators has been enhanced with the recent purchase of a CEM microwave analyzer. This allows the operator to make machine and process modifications and see the quantified result of the change immediately. The biweekly sampling and analysis of all the machines has allowed the operators to troubleshooting the machines exhibiting relatively poor performance.

In centrifugal dewatering there are numerous process and operational parameters which contribute to the success of the dewatering process. These include the machine variables of bowl speed, pool depth and differential speed and the process variables of the sludge feed rate and percent solids, and the polymer type, concentration, injection point and dosage. At HTP two of these variables, polymer type and differential speed, are the major controls for the dewatering process performance.

The differential speed is the difference in speed between the bowl and the scroll which screws the separated solids out of the machine. The lower the differential speed the longer the retention time of the solids in the machine under applied centrifugal forces which results in a drier cake. The higher the differential speed the lower the solids accumulation level in the bowl and, therefore, a deeper pool for improved clarification of the centrate. At HTP there was a breakpoint in capture efficiency with a decrease in the differential speed below 5.5 - 6.0 rpm.

This differential speed has always been thought to be a machine limitation at HTP. However,
the following CHEMICAL ADDITION section discusses how a change in the type of polymer allows the machines to be run at a lower differential speed (4.0-4.5 rpm) resulting in a significant increase in cake solids concentration while maintaining centrate quality above 95% capture.

CHEMICAL ADDITION

The type of polymer added to the centrifuge feed flow determines the floc formation in the coagulation and flocculation process. This is currently done at HTP, and most other municipal plants, with the addition a cationic polymer. The density and shear strength of these flocs are largely responsible for the performance level of the centrifuge dewatering process (Novak 1989). Recent testing at HTP has found the floc formation to be a limiting factor.

Over the past four years of dewatering experience at HTP the sole type of cationic polymer tested and used has been mannich solutions. The significant reasons for this have been the operational difficulties of feeding dry polymers and the relative high cost of emulsion polymers. Cost equations were developed as part of the competitive bid process for annual polymer contract renewal to allow emulsions (or other expensive polymers) to compete with the lower priced mannichs based on an increased performance level. The increase in solids results in a decrease in volume based on the approximate equation:

\[ \frac{V_1}{V_2} = \frac{P_2}{P_1} \]

where \( V_1, V_2 \) = sludge volumes
\( P_1, P_2 \) = cake percent solids

This reduction in volume results in a cost savings in the offsite disposal costs which currently average $40/wet ton for HTP.

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<th>TABLE 1 - Polymer Cost Analysis Using Performance Bonus</th>
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<td><strong>Product</strong></td>
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Disposal cost is based on $40/wet ton of cake.

Fig. 2. Projected increase in cake solids and reduction in volume based on performance testing.
Quality analysis of the polymer is an essential part of the polymer testing process as well as daily control of the delivered product. In addition to active solids analysis, HTP has recently added viscosity analysis to its daily quality assurance program. Viscosity is a function of the percent charge and molecular weight of the polymer as well as the percent of polymer solids in solution. Therefore, testing for viscosity is a double check of the polymer solids content and ensures contract specifications are met on the desired product.

An operational scourge at HTP is the precipitation of magnesium ammonium phosphate commonly known as struvite. This problem has been aggravated with the increase in secondary flow over the last two years. The secondary process at HTP has an inherent uptake of phosphate which increases the probability of struvite formation with any increase in TWAS feed to the digesters. There has been a three-pronged approach developed to monitor and control this potential problem: physical inspection, chemical analysis of the sludge flows, and chemical control of struvite formation.

Physical inspection is accomplished with specially designed probes with pipe wafers which lay flush with the interior pipe surface and can be isolated and removed for inspection.

Inspection of various pipe spools is also performed on a regular basis for verification of the monitors.
Chemical analysis is done comparing the solubility product with the conditional solubility product (Snoeyink 1980) from samples taken from various points in the sludge processing stream (see Fig. 6). If the solubility product at a point in the sludge flow is much greater than the conditional solubility product, struvite will tend to precipitate.

$$K_s = [\text{Mg}^{2+}] [\text{NH}_4^+] [\text{PO}_4^{3-}]$$  \hspace{1cm} (2)

$$P_s = C_T \cdot \text{Mg} \cdot \text{NH}_3 \cdot \text{P}_0$$  \hspace{1cm} (3)

HTP has a long history of diluting the sludge streams with plant effluent, thereby reducing the concentrations of the struvite constituents, and lowering the probability of formation. This method is limited by the current digestion and dewatering process capacities as well as the capacity of the centrate lines. HTP currently uses ferrous chloride addition to the raw and digested sludge to bind up the phosphate and prevent the formation of struvite. This, however, has recently led to the formation of ferrous phosphate, commonly known as vivianite. This bright blue precipitate has formed in the sludge lines from the digesters to the centrifuges. As with struvite, vivianite has a greater tendency to form in solutions of higher pH. However, HTP has not experienced any vivianite buildup in the centrate lines.

Recent investigations into alternative solutions for these precipitation problems led HTP to test if CO$_2$ is released. This lowers the carbonic acid in solution and thus raises the pH. This increase in pH lowers the probability of struvite formation. This led to the hypothesis...
that by adding CO₂ back into the sludge stream, struvite would not precipitate.

After lab testing, a full-scale field test was done which found that CO₂ addition into the sludge prior to centrifugation would be effective in lowering the pH of the centrate. These results have led to a long-term project to evaluate CO₂ addition as an integral part of the struvite protection program at HTP.

**CO₂ ADDITION FOR pH CONTROL**

![Graph of CO₂ addition for pH control](image)

**TWAS DEWATERING**

Integrated in the sludge disposal options at HTP has been discussion of removing thickened waste activated sludge (TWAS) from the digested sludge stream. The rationale for this proposal included: better digestion and dewatering of the remaining primary sludge; removal of the majority of phosphate from the sludge stream (resulting in decreasing or eliminating the struvite/vivianite problems); an anticipated increased efficiency with the sludge drying process (Carver Greenfield) using undigested TWAS; and a greater BTU value of the dried undigested sludge for the incineration process. This led to a field test using an isolated dewatering centrifuge on undigested TWAS.

The preliminary intent of this study was to determine the maximum TWAS cake solids the current dewatering machines were capable of producing; which would determine the
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capabilities and costs associated with the disposal of this sludge. However, soon into this test it was apparent that centrate quality would also be a limiting factor in this process. Key findings of this test are summarized below:

The floc formed with the TWAS was much fluffier and less shear-resistant than with the usual codigested sludge. This less dense floc took a greater volume in the bowl and resulted in a lower throughput of solids by 40-50%.

The polymer demand was 2-3 times the usual digested sludge dosage of 10-12# active polymer/ton of feed solids.

The process operated with the usual cost-benefit between cake solids and centrate quality, however, the window of operation was quite narrow before significant centrate degradation.

Polymer addition upstream of the bowl resulted in the formation of a large fragile floc and consequently complete degradation of the process.

Emulsion polymers formed a more shear-resistant floc resulting in greatly improved floc and increased cake solids.

Performance was optimized with an emulsion polymer with a dose of 45 #/ton; resulting in 14% cake and 90% centrate capture efficiency, at a flow rate of 70 gpm.

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REFERENCES
