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"FROM CONVENTIONAL DRYING BEDS TO HIGH RATE, HIGH CAPACITY VACUUM DEWATERING BEDS"

Paul M. R. White, President
U.S. Environmental Products, Inc.
9ll7 Monroe Road, Suite 100
Charlotte, North Carolina 28270
Phone 704-846-2700/ Fax 704-846-6247
E-Mail – PMRW@USEP-INC.COM

ABSTRACT

Minimal draining, decanting, and evaporative drying have been the predominant factors determining performance of the well known lagoon, conventional sand drying bed and evaporation bed process. Previously, the "rule of thumb" design procedure determined the sizing of these beds. Fortunately, more rational design factors were established from experience and published in "MOP 20, l983", resulting in facilities with proper capacity.

Efforts to improve the under drainage in the bed type device have been made over the years, but none have been made as durable as the rigid, porous, epoxy- bonded, aluminum oxide surface which is guaranteed for 20 years.

Attempts at increasing the dewatering rate by applying pressure to the beds have been attempted but only vacuum has proven to be feasible. Early generations of the vacuum bed have applied 8 - l0" Hg, but the current design allows for 24 - 26" Hg vacuum. This has resulted in higher capacities and dryer cakes, in a shorter cycle time.

Case studies will be presented for this low energy, simple technology system that has over 18 years experience on various types of sludges at over 180 locations.

Prior thickening of water plant residuals and biosolids digestion is also addressed as being important for any type of drying bed and mechanical dewatering. Consideration must be given to the final disposition of the resulting cake, be that land filling or beneficial use.

KEYWORDS

Sludge, Biosolids, Residuals, Solids Dewatering, Vacuum-Assisted Drying Beds, Vacuum Beds

INTRODUCTION

Municipal and industrial, water and waste water processes produce a liquid sludge containing a small amount of solids, composed mostly of water. This sludge could be more easily and economically handled if the volume were reduced by removing the water, resulting in a cake which could then undergo further processing or be transported. Beds, by drainage and evaporation have been utilized to achieve this result since the beginning of accepted treatment practices. In more recent decades, mechanical devices have proven to speed this function but these approaches have added complexity to the operation and have resulted in increased initial investment.

I will present the most widely used approach to dewatering, the bed with its advantages, disadvantages and developments in their application that may or may not help their performance. Design procedure recommendations made by authorities in this industry are repeated here. Finally, I will present a proven process that successfully responds to a number of the problems and questions posed by prior dewatering techniques approaches; the Vacuum Dewatering Bed.

The widely utilized sand drying or evaporation bed technology has substantial advantages and disadvantages.

The advantages of this type of bed, they:

- require lower operational skill and attention.
- require lower chemical and energy consumption.
- require lower sensitivity to sludge character quality and variability.
- result in higher cake dry solids concentration.

Disadvantages are:

- limited by well known "rule of thumb" approach resulting in substantially lower area estimates than is actually required, providing erroneous cost estimates and inefficient treatment plants.
- large land area requirement.
- climate dependent.
- highly visible to the public and considering their function of drying of the liquid surface as the lower layers remains liquid, becoming septic, unpleasant odors are generated.
- labor intensive in cake removal due to prohibition of equipment in the bed for cake removal.
- sand compaction, solids plugging, and loss in bed cleaning requiring replacement.

Developments have addressed some of the disadvantages, but in doing so have created additional problems.

Covers reduce the effect of rainfall causing delays in cake removal. While this may increase the capacity, the effects of solar radiation are eliminated, which increases humidity and reduces the drying effect of wind. Cover may increase capacity it will substantially increase the cost of a facility.

Complete or partial paving of the bed to enhance cake removal by loader equipment may reduce labor but also reduces the necessary loss of filtered liquid to the underdrain, thus requiring that dewatering is solely from variable evaporation.

Chemical coagulation and flocculation of the feed sludge to function in a similar manner to mechanical dewatering results in the need for more highly skilled operators and increased costs.

Observations have also shown that distribution of chemically treated solids on the bed dictate piping revisions. Further, overdoses of chemicals is prevalent due to the need for feed sludges to be more stable, thickened, and less variable during filling.

None of these factors should eliminate the "Drying Bed" from a designers' consideration, but all factors must be considered for in the sizing of this approach.

Alternates to paving the bed for mechanical cake removal while maintaining drainage of filtrate have been developed and used by numerous of facilities in long term operation.

One of these alternatives is the 30-year-old English process known as the "Wedgewater" system. A slotted, stainless steel screen, but currently proposed as a plastic block, has proven to be successful in allowing for filtered liquid to the underdrain and facilitate mechanical cake removal.

Observations of excess uncaptured solids into the underdrains and the fragile nature of the plastic block provide the operators the challenge of cleaning underneath and replacement of broken blocks.

In l977, the US EPA presented the first of several technology transfers on a new process, "the Vacuum-Assisted Drying Bed". This system utilizes a rigid, porous surface in a vacuum tight concrete bed.

Polymer treated sludge is fed onto the bed to a depth much greater than conventional drying beds. Filtrate passes through this porous surface through the bed underdrain, and is collected in a sealed wet well and pumped away by a submersible pump. Vacuum is applied to this wet well, increasing the drainage of the thickening liquid, resulting in a stiff cake similar to a mechanical dewatering system.

With the Vacuum Bed several disadvantages of the "bed" approach were satisfied. The rigid, porous surface allowed for a loader to remove the cake, reducing labor requirements with no damage to the porous plate. The vacuum reduced or eliminated the need for evaporation of the liquid from the cake.

A comparison of these "bed" approaches in more detail follows and suggested designs are presented. There have been substantial improvements to the "Vacuum-Assisted Drying Bed" which minimizes required operator attention, reduces power consumption, increases the loading (solids per square foot), and increases the resulting cake dry solids while reducing the cycle time of liquid feed to cake removal to less than one day. In some cases the cycle time has been reduced to just several hours.

CONVENTIONAL SAND DRYING BEDS

Structural requirements of this type of bed are simple with containment walls for the liquid, a soft, permeable media that allows for drainage of filtrate, and a collection system of underdrain pipes. Feed piping is simple, with a single discharge inlet from digestion, thickening, or a holding tank. The need for this media to remain porous prohibits cake removal by machinery and raises concern over plugging and need for replacement.

As modifications have provided for paved surfaces, these concrete or asphalt areas are non-filtering, reducing drainage requiring greater reliance on evaporation, but increasing accessibility by machinery for cake removal. In some cases runways allowing for a loader to enter the bed enhance cake removal while not eliminating filtering area. Labor is required to place cake in the bucket.

Design Factors:

The biggest single flaw in the design of sand beds has been antiquated governmental regulations. These may have been written based on the widely held "l.0 to 2.0 square foot per capita", or some non-rational "rule of thumb" basis, recently corrected.

Conventional sand drying beds have been well studied by a broad collection of authorities and used by most treatment facilities in the U.S. for reducing the water content of sludge to produce a handleable cake since the 1930’s, or earlier, per MOP 20, l983, by the Water Pollution Control Federation and the EPA Design Manual, "Dewatering..." 1987.

A design factor was presented in the 1960 version of the MOP 20 that had no consideration for climate and defines the bed performance due to evaporation:

a. primary treatment plant sludge
b. anaerobically digested
c. approximately 6% dry solids

For an aerobically digested waste activated sludge at 2% dry solids in various climates; this may not provide for enough area. This publication based recommendation for design on the above amount and character of sludge and resulted in a "square foot per capita" area sizing. This was adopted by many state agencies as well as an accepted authority producing the "TEN STATES STANDARDS" in the early l970’s.

The 1983 printing of the MOP 20 revises this design approach presenting data pioneered with the current treatment practices of the day by Mr. A. T. Rolan from his paper of 1979. This guided designers to utilize a rational design, considering greater sludge quantities, per capita, character of the sludge, and climate. Several nomographs were published providing designers with realistic procedures for sizing sand beds. This results in parameters for required area calculations based on "pounds of dry solids per square foot per year" capacity.

Major factors affecting drying of biological sludges include:

1. The solids content and type of the sludge. Sludge cakes dry at a rate in proportion to their solids content.
2. Depth of sludge cake - the deeper the cake, the longer the drying time.
3. Biochemical make-up of solids - the more healthy and "fatter" the organisms; the slower the drying.
4. Initial drainability of the cake
5. Geometry of cake - cracked cakes dry faster due to larger surface area.
6. Evaporation, as defined by;

a. Temperature - at 5 degrees C the vapor pressure is about l/5 of the vapor pressure at 30 degrees C; consequently little winter drying.
b. Relative humidity
c. Wind
d. Solar radiation
e. Rainfall

Since each of the above may combine to produce the dominant effect; it is understandable that many "old wives tales" exist among operators. For example, a greenhouse could adversely affect drying by raising the relative humidity; or a roofed shed could block the wind with the same results.

The design approximation used in Rolan's 1979 paper is best illustrated numerically:

Theory:

Rolan's calculation is best simplified by considering the depth of bed loading that can be evaporated in a year equal to the annual evaporation plus the draining plus the thickness of the cake.

Covered beds are simply analyzed by substituting the sum of the annual rainfall and the annual evaporation and using this as the "annual evaporation".

Given:

1.0 mgd domestic activated sludge plant with aerobic digestion at a sludge solids of 925 ppd dry solids in central Pennsylvania where evaporation is 30" of water per year.

Design:

Sludge should be applied twice per year in order to average the effect of winter weather at 18" depth, resulting in a 1.4" deep cake at 25% dry solids (about the minimum dry solids that can be handled on a sand bed).

Annual solids loading = 2 cycles/year x 18"/12" x 62.5 pcf. x 2.0% dry solids = 3.77 psf per year.

Annual sludge = 925 (365) = 337,000 pp year

Design bed area = 337,000/3.77 = 89,395 s.f.

This is a surprisingly large area; amounting to 8.9 s.f./capita at a population of 10,000, as compared with regulatory agency "rule of thumb" at 2.0 s.f./capita. It is not surprising to see the many sand bed failures existing today. Plants designed in accordance with the l983 MOP 20; operates satisfactory.

The availability of land area generally accepted, as the primary factor in the decision to employ this type of bed becomes the least of the factors when all factors of design sizing are considered. The actual material cost of constructing the proper area to serve the facility in question becomes the deciding factor.

For a more in depth review of this brief presentation, the full reprinting of Mr. A. T. Rolan's paper, excerpts of MOP 20's and case studies, the writer can provide a copy of his paper from the New York WPCA Section Meeting, June l6-l9, l985; "Performance Criteria for Conventional Sand Drying Beds, Lagoons, & Stockpiles".

In the writer's opinion, sand bed design has changed into the 1990's and been accepted throughout the profession. The current technology is irrefutable. Regulatory agencies, realizing inadequacy of their standards are changing. Sand beds do indeed work. They simply must be properly sized.

WEDGEWIRE OR WEDGEWATER BEDS

This thirty year old system is built as a plastic, interlocking block with a surface of slots 0.25mm (0.01 inch) wide. This block is laid on flat concrete floor with low walls approximately 20' wide and of various lengths up to an understood maximum of 60' to form a false floor, with flashing or wooden filets at the junction of floor and wall.

Chemically treated sludge is fed to the bed to a conventional depth of less than 12". Free water passes through the surface and a substantially thicker sludge remains. This filtration phase generally lasts for a day, enormously reducing the liquid contained in the sludge, as compared to a sand bed. At this point the cake is not handleable in most cases and the final phase prior to removal is subject to evaporation. Except in the most arid climates, and particularly if the process is expected to perform at all times of the year, these beds are enclosed in heated buildings.

Design loadings allow for 0.5 - 1.0 pounds of dry solids per square foot of 2.0% sludge and up to 1.5 pounds for much thicker sludge. Cycle times, like sand beds are dictated by the climate, actual or artificial. Some states have mandated a one-week cycle, while arid climates may allow for two cycles per week to provide a handleable in 3-4 days.

Operational difficulties originate with the need for significant chemical treatment to release free water but that may also bind with the solids. Further, excessive passage of uncaptured solids will clog the underside of the false floor. Removal of all of the blocks and cleaning has regularly been observed to be required frequently. Deeper loading depths and the operation of mechanical equipment seem to exacerbate this problem.

A small, front-steering tractor with a small bucket is limited to remove the cake due to the fragile block, which requires frequent replacement, is time consuming and made worse by the soft cake.

Finally, a treatment plant with solids per the previous analysis for sand bed, aerobically digested waste activated sludge from a 1.0 MGD wastewater treatment plant produced 925 #d.s/day, operated at 1.0 #/s.f. for two cycles per week, annual average requires 6,400 square feet of wedgewater media, 8 - 20’ x 40’ beds, plus chemical preparation and feed, and washwater systems.

THE VACUUM DEWATERING BED SYSTEM

This technology emerged slowly in the mid 1970’s. The system was acknowledged as successful and proven in referenced publications by USEPA and the WPCF prior to and in 1987, coining the name for the process, "the Vacuum-Assisted Drying Bed".

The 1980’s saw a number of these facilities on a range of sludge types, built primarily with a sealed wet well containing a submersible pump for filtrate removal while under vacuum. Due to the Net Positive Suction Head requirement of this type of pump the maximum possible vacuum was 8-10" Hg. In the mid 1980’s, U. S. Environmental Products, Inc. built a facility eliminating the wet well, as excess cost and inappropriate application of this pump. A shallow, dry pit was designed for a closed impeller pump system with low NPSH requirement allowing the vacuum control valve to be nearly closed increasing the dewatering pressure to 20-22" Hg. This first facility is pictured in the U.S.E.P.A. Design Manual; "Dewatering..." 1987.

In the 1990’s, the standard filtrate/vacuum system was revised to eliminate the filtrate pump, replacing it with simpler underdrain level sensors/controls removing the filtrate from the Vacuum Bed by use of a motor operated valve. This allowed complete closure of the vacuum control valve, providing as much as 26" Hg. vacuum for dewatering the solids to dryer cakes in a 24 hour cycle time.

The effect of the vacuum in dewatering the cake is significant with regard to higher liquid loadings, shorter cycle times, and higher resultant cake dry solids while maintaining low power and chemical consumption rates. This approach to removing the liquid from sludge should no longer be referred to a "Drying Bed", subject to effects of climate; this is the "Vacuum Dewatering Bed System".

The core of the system is the rigid, porous media plate; 2" thick x 24" x 48". The structural component of the plate is an AWWA specification - type pea gravel with a working surface of MOH hardness 9 aluminum oxide. Aluminum oxide is utilized due to its irregular, angular particle nature and the reverse meniscus chemical performance reducing bound water and other plugging liquids. The surface is made up of a selection of gradations, blended, and epoxy-bonded with the pea gravel in one process compressed into a mold.

Epoxy formulas have allowed for plates that will allow the filtrate to be recycled for re-use as a raw water source in water treatment plant residual application due to "FDA/EPA" approval. Other epoxy formulations allow for building plates to treat sludges from wet gas scrubber facilities in petroleum refineries at design temperature of 230 degrees F.

Plates are cured, sometimes heat cured in an oven to increase strength, and load test documented. These are installed under manufacturer supervision for use for an unknown life. Fifteen-year monitoring this material in nearly 200 facilities has failed to show any appreciable damage, primarily from mechanical cake removal equipment.

The plates are installed with two types of resilient joints to allow for traffic of high speed, large loader, along with expansion and contraction. Beneath the plates is a shallow layer of l/2" stone for uniform support. A trough plate with stainless steel screens keeps the stone out of the filtrate underchannel. These materials are installed under supervision into the concrete bed.

The details of the concrete can not be discussed in such short order, except to state that the importance of the waterstops, keyways, construction joints, and other details for a vacuum tight structure cannot be over emphasized.

Selection of polymer guides the preparation of a solution for aging in a with a slow speed mixer. Delivery of this solution to an obstructionless polymer/sludge blender is by a variable speed progressing cavity pump where the rate is generally controlled at the bed where the floc is observed by the operator. A constant flow of sludge high for even distribution and filling of the bed in less than 30 minutes to a depth of 16"-24". A level probe in the bottom of the solution tank stops the filling phase, automatically when the solution is depleted.

The initial gravity drainage phase, approximately one-hour, allows several inches decrease in depth of the sludge prior to the need to apply vacuum. The liquid ring vacuum pump is started and the motorized filtrate drain valve closes automatically. Slowly the filtrate level and vacuum rises in the underchannel. The vacuum is drawn through a wall pipe just above the filtrate drain line at the end of the bed. This upper connection also serves as the "sensor" location.

As the "sensor" is wetted, the vacuum pump shuts down, the bed is vented, the motor operated value (MOV) drains the filtrate. A timer recloses the vent and the MOV, then restarting the vacuum pump. Following a few of these automatic drain cyclings, the cake will have cracked sufficiently to begin loosing vacuum, and that pump is shut down.

The aluminum bed entry gate is removed, and the skid steer loader with a protective HDPE shield on the bucket removes the 2-5" cake. The final smear of solids on the working surface of the plate is removed by the high-pressure wash water booster pump providing 150 psi non-potable water to the special nozzle. A number of facilities have successfully experimented with eliminating the wash down step without loss of performance.

The working surface will accumulate solids, greases, oils, and scums that will plug the bed. Chemicals including sodium hypochlorite, commercial degreasers, and muriatic acid are used for soaking, which will reliably clean the plate usually required to be 4-6 times per year or less.

Performance experience has shown the vacuum bed will provide a cake dry solid that approaches that of a belt filter press, in most applications. Our proprietary and well documented "Pre-Coat" process, using ungraded sand piled in front of each of the sludge inlets, eroded and spread on filling, provides for a substantially dryer cake and reduces wet cake weight for disposal due to enhanced filtration.

The suggestion for covering beds is generally accepted as a wise and inexpensive option due to the bed area required, but not necessary except in very rainy climates, and/or where 5 cycle per week operation is the required. Unless temperatures remain less than 15 degrees F for extended periods and continuing operation is needed, a heated enclosure is not necessary. It has been observed at a substantial number of unenclosed facilities in Ohio, Pennsylvania, and West Virginia that nearly complete dewatering can occur prior to the sludge freezing, at which point it is felt by operators that performance is enhanced.

In keeping with the above example; sizing at a conservative solids loading and frequency as demonstrated at existing facilities, we would recommend a single 16' x 50' bed for the l/2 ton of dry solids per day of aerobically digested, waste activated biosolids. Operator time required may be less than 8 hours per week.

CONCLUSION

Vacuum dewatering beds are a simple process in design and operation as it has removed uncontrollable factors in dewatering, providing a low cost alternative to mechanical methods.

Properly designed on their merits and performance, in comparison of all approaches, the Vacuum Bed may prove to be the most cost-effective method of dewatering available.