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HANDLING AND DISPOSAL OF MIXED ORGANIC WASTES: A TECHNOLOGY REVIEW

DRAFT

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JAN 18 1993

Mr. J. Douglas Heyland,
Executive Director & Science Advisor,
Science Institute of the Northwest Territories,
P.O. Box 1617,
Yellowknife, NT.
xlA 2P2

Dear Mr. Heyland:

Thank you for providing the draft report "Handling and Disposal of Mixed Organic Wastes: A Technology Review." The report offers useful information, especially in regard to the emerging agriculture sector in the Northwest Territories.

In the short term, the Department is following up with the Nova Scotia Agriculture College on an option discussed in your proposal.

In the longer term, it will be necessary to draft guidelines covering the disposal of waste matter for agriculture and non-agriculture applications.

I hope we can count on your continued support.

Sincerely,

Original signed by RC Bailey

Roland C. Bailey,
Deputy Minister.

cc: Minister,
Economic Development & Tourism.

COLFORD/ALLEN/lm
all/hey land.ltr

John Colford

SCIENCE INSTITUTE OF THE NORTHWEST TERRITORIES

170-90-59

December 4, 1992

ECONOMIC DEVELOPMENT & TOURISM
REC'D #6802 DEC 8 1992
DEPUTY MINISTER

Mr. Roland Bailey
Deputy Minister
Economic Development & Tourism
Government of the NWT
P.O. Box 1320
Yellowknife, NT XIA 2L9

Dear Mr. Bailey:

Please find enclosed a copy of a draft report entitled: *Handling and Disposal of Mixed Organic Wastes: A Technology Review*

The report contains a review of a number of technological options for a possible disposal system for waste from the chicken and pig farms in Hay River. A simple concept for an integrated system dealing with the waste problem is proposed. (page 20, section 6.4).

We are seeking your assistance in defining the future direction of this important project. In light of this we request your comments on the draft and the proposed integrated system.

Should you have any questions regarding the specific details of the report, please do not hesitate to contact Dr. Joe Ahmad, Manager of the Technology Development Program at 873-7592.

Yours sincerely,

Douglas Heyland

J. Douglas Heyland
Executive Director
and Science Advisor

Enclosure.

c: Honorable John Pollard, M.L.A., Hay River
Mr. Joe Handley, Deputy Minister, Renewable Resources
His Worship Mayor Norm Hill, Town of Hay River
Mr. Charles Scarborough, Town Manager, Town of Hay River
Mr. Bob Doherty, Deputy Minister, Public Works
Hay River Farmer's Association
Mr. John Colford, Director Natural Resources, E D & T

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1 INTRODUCTION

Intensive livestock production has been established within the city limits of Hay River in the Northwest Territories. One hog barn and two chicken barns are currently in operation. Plans are being developed to add a slaughter house. Also a fish hatchery is being proposed. These production and handling units are producing or will produce significant quantities of high strength organic waste. These wastes will be produced year round. However, the climatic conditions in the Hay River area only allow discharge to land.

Only few technologies exist to handle high strength agricultural waste or septage. Most of these technologies are designed for large scale operations in temperate or tropical climates. Some technologies were developed specifically for tropical regions.

The purpose of the project is to identify technologies able to handle mixed organic wastes. These technologies will then be assessed for easy modification for use in Northern climates where ambient temperatures are below zero degrees centigrade for most of the year.

2 OBJECTIVE

The objective of the technology review is to identify technologies suitable for the treatment of pig waste, chicken manure and the grey fraction of slaughterhouse waste, to produce a stable product and effluent of acceptable discharge quality. Technologies should be applicable to the North and should include "appropriate technology."

All data were evaluated for use in a northern climate. As no single technology was identified, suitable for handling all available waste streams, several technologies were combined into an integrated system. This system is most likely to handle the pig, poultry, slaughterhouse waste streams in Hay River.

No engineering design has been made for the proposed system. The report outlines the conceptual design only.

3 APPROACH

A technology survey was undertaken to identify suitable technologies for the treatment of high strength wastes under northern conditions. Specific keywords were used for a literature search. Identified literature on waste treatment in northern climates was ordered for review. Information was gathered from government officials both in Canada and the United States. Researchers and manufacturers were approached for data and background on processes and manufactured systems. Information from Western Europe on state-of-the-art waste treatment of agricultural waste was collected and several facilities were visited by Dr. Timmenga. Special attention was given to anaerobic digestion of the total waste stream because this technology appeals to waste generators for the generation of biogas.

This report includes a short description of each technology reviewed. Detailed information on references, manufacturers and contacts and the description of technologies can be found in Appendix A.

4 TECHNOLOGY REVIEW DRAFT

4.1 Systems To Treat Manure or Wastewater

Manure can be treated, with or without prior handling in systems to form a stabilized product. Systems that accept whole manures include in-situ comporting Solar Aquatic Greenhouses, thermophylic aerobic digestion, pyrolysis, high temperature oxidation and, in certain circumstances, anaerobic digestion.

In the POL [Pig on Litter) or in-situ comporting process, pigs are kept on a deep bed of sawdust. The process produces a stable compost which requires no further treatment and produces no effluents. The system requires a change in farm management and modifications in the barn to accommodate approximately 60 cm of sawdust or wood shavings on the floor. An enzyme preparation is added regularly to facilitate comporting. Comporting also takes place without the addition of an enzyme preparation. The bedding must be aerated regularly. Aeration is performed through mixing of the sawdust with a roto-tiller. Experiments are underway with forced air aeration. Advantages are that no additional wastes are produced and that the pigs are not penned and are allowed to move around, thus reducing stress. Through the rapid use of nitrogen by the comporting process, no elevated ammonia levels are found in the barn. Recent reports state elevated levels of NO_x in the barn air, pointing to a partial denitrification cycle. NO_x is seen as a smog precursor. The moist bedding keeps dust down. The system requires regular turning, removal of all bedding (compost) after each production cycle, and the purchase of fresh bedding. The quality of bedding is of utmost importance (free from anti-sap-stain chemicals, salt, etc.). Several units are in operation in The Netherlands and experiments are being conducted in the Fraser Valley; the results have been favorably received.

The Solar aquatic greenhouse receives high strength wastes and uses an aeration process in a microcosm to stabilize the slurry. Part of the organic matter is assimilated by bacteria, animals and plants in the treatment ecosystem. Effluent is polished in an engineered marsh and is of very good quality. Sludges and harvested plants form the solid products from this process. Sludges are stabilized in reed beds and all vegetative matter can be composted. The operation is enclosed in a greenhouse to keep operating temperatures in optimum ranges for bacterial action. This system has not been tested with pig manure. The greenhouse needed for an average farm would be of modest proportion. Running a solar aquatic greenhouse may require the operators to have an advanced ecological background.

The system was recently approved by the State of Massachusetts for the treatment of septage (EEA personal communication).

Thermophylic aerobic comporting is a process where organic waste is transformed into a stable sludge to reduce its volume. The process takes place under aeration and mixing. Claims that the process is self-sustaining in generation of heat, have not been substantiated. The product, a sludge with a low total solids content, needs further treatment and separation to meet the objectives for on-farm manure handling. A commercial pilot unit runs on vegetable waste. Here, the solids are separated and dried, the liquid fraction is discharged to sewer, The system produces relatively large quantities of carbon dioxide. Experience with digested sewage sludges, for purpose of volume reduction, indicates that sludges produced are difficult to dewater and require relatively large amounts of polymers for conditioning. Systems are USed in Europe and North America to reduce the sewage sludge volumes. Several pilot facilities at sewage treatment plants are operating in B.C.

Thermophylic oxidation of chicken manure was developed in Austria for on-farm use. This process, the MBCD process, requires pelletized, moist chicken manure. The pellets are bio-treated in a reactor where heated air is used in a counter flow configuration. Stabilised pellets are then market as a fertilizer.

In Pyrolysis, materials are heated to high temperatures under low oxygen conditions. Off-gases are collected and can be used for the preparation of chemicals or as fuel. Waste products include tars, charcoal ash and liquids. Under favorable conditions, (low moisture, high cellulose content of substrate, and *large* scale) the system may be cost effective. Capital costs are high and skilled operators are needed. The requirements for low moisture content and high cellulose may make this process unsuitable for the treatment of manures.

Other uses, especially of pig manure, include the utilisation of pig slurry in large boiler operations to reduce NO_x emissions (NO_x is a cause of acid rain). Slurry is atomised and injected in hot flue gases. Only small quantities of manure are needed for each power station or incinerator.

Chemical oxidation takes place in the Vertech Deep Shaft System. Oxygenated organic waste materials are injected in a borehole 1200-1500 meters deep. High pressure generates recoverable heat and the organic waste is oxidized. High installation costs make this system suitable for large scale operations only. Due to the deep borehole, the system is not considered for earthquake prone areas.

The Sequenang Batch Reactor (SBR) is a technology designed for medium strength waste waters. Currently a pilot operation is tested in the Fraser Valley on a pig farm for medium to high strength separated liquid manure. The effluent is not of acceptable discharge quality, but the researchers expect that fine tuning of the process will increase the quality of the effluent, and land spreading will not be needed. Because the whole process takes place in batch mode, the system is controlled by a micro-processor, operating pumps, aerators and mixing equipment, thus making the technology complicated to instau. The aerobic/anaerobic steps in the process remove ammonia from the waste water. Phosphorus is also reduced in the effluent. The SBR produces a significant amount of sludge. Although the sludge seems to settle easily, an extra settling step may be required when a discharge quality effluent is desired. The Fraser Valley pilot does not seem to incorporate this step because the effluent is used for land spreading,

The SBR is an established technology for treatment of domestic wastewater. Several plants are operating to satisfaction in Northern Regions. The commercial units operate with wastewaters containing a BOD5 in the 1500 mg/L range.

Other biological methods to treat small wastewater streams include the Rotating Biological Contactor. This unit has shown several drawbacks including broken shafts and collapsed media.

4.1.1 Anaerobic Digestion

Anaerobic digestion is the degradation of organic material by biological organisms in the absence of oxygen to produce a biomass, carbon dioxide and methane gas. The process occurs in four basic stages:

1. Hydrolysis
   Non-soluble organic compounds are hydrolyses by enzymes excreted from acidifying bacteria;

2. Acid formation
   The hydrolyses compounds are converted into organic acids such as lactic acid, butyric acid, propionic acid, and acetic acid by acid-forming bacteria;

3. Acetogenesis
   Organics of the previous step are converted into acetic acid, hydrogen and carbon dioxide; and,

4. **Methanogenesis**
   Methane forming bacteria convert the products from the previous step into methane.

The process is not considered feasible with first generation systems - lagoon style - because of their low volumetric loading rates, long retention times, and, therefore, correspondingly large reactor sizes. As the systems become more high-tech (and correspondingly more efficient), through the addition of mixing motors, heat exchangers and fixed film media, they are able to handle higher loading rates, in shorter retention times and with smaller volume reactors. However, this more dynamic bacterial population is more susceptible to toxic shock, and the physical design (as in fixed film or Upflow Anaerobic Sludge Blanket, UASB) often has problems with plugging, foaming or impenetrable matts forming which inhibit the transfer of either solid, liquid or gaseous products through the reactors. This makes the more advanced designs less desirable for the treatment of high-strength, high solid content wastes.

Anaerobic systems are biological systems, and the units often require skilled operators to maintain the bacterial population. Operating temperatures must be carefully regulated, the biological flock (or seed material) must be retained and not allowed to wash-out from the reactor, and the population can be sensitive to changes in influent characteristics or to the introduction of antibiotics, disinfectants and sterilants (all common to the swine farming operation).

With regard to the use of the technology for the treatment of swine manure, we spoke to a number of researchers, farmers, engineers and operators. They maintain that the solids content of swine manure is too high and plugs or otherwise interferes with the media in the more advanced designs. Therefore low-tech designs are more appropriate.

They say that anaerobic designs are less complicated than aerobic designs. They say there is a problem with farmers running the amerobic units, in that they often do not have the interest, the time, nor the expertise to properly manage these systems. This is particularly true for units that have biogas recovery and electrical generator sets. Frequent complaints included problems with mechanical mixers and pumps, short life of equipment (and high maintenance costs) due to the corrosive nature of the biogas, troubles with the biogas recovery systems (too complex - scrubbers, dehydrators, generators, heat exchangers), oversized units not tailored to the needs of individual farms. Also problems with Single Cell Protein (SCP) recovery (hogs do not like it, some studies show a decrease in weight gain and reproduction, centrifuges don't operate properly, etc.) were reported. New guidelines from the European Community regulate the use of SCP as a feed substitute. SCP can only be used as feed after a very stringent review of the product. The costs of such a review are prohibitable for the use of SCP as a feed. Many people say anaerobic digestion for the treatment of organic wastes works best on a large scale, either with high strength (mixed) manures or with low strength effluents from the pulp and paper/food industries, and preferably in conjunction with other organic treatment technologies.

Several on-farm pilot operations using pig manure were operating in Canada in the nineteen eighties. Most, if not all of them, have discontinued their operations. In the Netherlands, all but two of the on-farm anaerobic installations are dismantled. Insurance companies are still processing claims worth several millions dollars each year for damage caused by methane explosions and fire related to the anaerobic treatment of manures. One of the operating large scale manure processing plants in the Netherlands includes amerobic digestion as a conditioning step for the separation - drying process of pig manure. The level of sophistication of the bioreactor is not known at this point. The current understanding in Western Europe is that large scale anaerobic digestion of manures is only suitable for odour reduction, some BOD removal and stabilisation of the organic matter. The recovery of biogas for power production is not important due to high costs, low yield and availability of cheap methane gas.

Anaerobic reactors have been used successfully in large scale slaughterhouses to treat the liquid waste. Biogas was recovered for in-plant space heating.

4.1.2 Modular Economic Treatment System

The Modular Economic Treatment System (METS) is a waste water treatment system designed to flocculate all organic matter. Sewage is ground and then flocculated in a mixing tank with a mixture of clay, and several polyelectrolytes. Formed sludges are separated using a hydrocyclone and solids are composted. One prototype is in operation for raw sewage at the University of Saskatchewan. No data is available for high strength wastes. Although the process is very simple, it needs large quantities of chemical flocculent. For domestic sewage, the flocculent cost about $1.10/1,000 Gallons. The effluent seems to approach discharge quality. The solid phase would consist of raw sewage and would need stabilisation before disposal can take place.

4.2 Treatments to Separate or Clarify Water

4.2.1 Recovery of Water

Several technologies exist to remove impurities from a water stream by filtration. Most, if not all, of these technologies operate effectively when the substrate contains only small amounts of impurities. Microstrainers and bed filtration are mentioned for completeness only. These systems need frequent back-wash to remove solids from the filter and thus create a secondary effluent stream. These technologies could be used to polish effluents or for treatment of raw water for process purposes.

4.2.2 Sedimentation and Flotation

To remove solids from a suspension, sedimentation can be used. This process is commonly used in Sewage Treatment Plants (STP's) and water treatment. Sedimentation will increase the concentration of sludges through gravity separation. Sedimentation is usually used after chemical flocculation or biotreatrnent. Particles are settled in large basins with low flow to give the water a high residence time. Several technologies exist to aid the separation. Lamella clarifiers consist of a series of sloped surfaces, catching and coalescing particles. The settling time is reduced because of the short distance beteween the sloping plates. Particles having travelled this distance coalesce with other particles on the plate then roll down the plates and a higher sludge concentration is expected.

With air flotation, fine air bubbles are forced into the liquid stream. Air bubbles contact solids and float solids to the surface where they are skimmed. Sludges with

4-8% solids can be recovered. This technology is excellent for greasy solutions, but may not concentrate pig manure.

Specialized technologies, as described above, or conventional clarifiers can be improved with pre-treatrnent. Sonic aided flocculation has been shown to reduce settling time by orders of magnitude. The technology has been tested with biological materials and with coal slurries with good success. No industrial installations are known.

4.2.3 Dewatering

All mechanical dewatering devices require a pre-treatment, either chemical or biological and chemical, to be effective. Most sludges must be conditioned to improve their dewaterability. The object of conditioners is to promote effective precipitation, coagulation or flocculation. Common conditioners include: synthetic organic polymers called polyelectrolytes; natural polymers such as gelatin, glue, starches, and sodium alginate; and inorganic compounds such as ferric chloride, ferrous and ferric sulfate, aluminum sulfate and aluminum chlorohydrate. The use of these conditioners depends upon the sludge composition, the dewatering process and the desired end result. The pre-treatment process is very important to the effectiveness of the dewatering system especially when dealing with biological sludges. Regardless of the concentrating or dewatenng method, the use of chemical conditioning agents results in improved performance in water removal and the production of drier cakes. The METS system, as described in Appendix A, is an example of separation based on proper conditioning of sludges before separation. Reed beds dewater sludges without chemical input or extensive maintenance.

Devices using filters or fabrics tend to malfunction due to clogging of the filter pores and wear and tear on filter belts. Typical equipment includes screw presses and belt filter presses. The normal life of a filter belt is approximately 60 working days. Substrates (sludges or manures) need to be conditioned for effective dewatering. Conditioned biological sludges can be dewatered to over 20% solids, primary sludges can be dewatered to 20-50% solids. Due to the consistency of pig manure, unconditioned substrate may not be successfully dewatered in a screw press or belt filter press. A trial conducted in the Fraser Valley with a screw press dewatering pig slurry is quite successful. However, the feed given to the pigs, coarsely milled grains, is not standard for the industry. The coarse fragments are easily removed by the screw press. The use of sonic vibrators during the pressing process may increase the solids content of the end product. A mobile belt filter press has been developed in the Netherlands for the separation of pig manures, with an expected production of sludges with a solids content of 30-40%. No further details are available at this time.

Presses are currently used in Europe to thicken slurries and to remove solids. The resulting liquid phase with a solids content of 1.5% is land applied, the thick phase is removed from the farm for centralised processing. Mobile press systems are also available in Canada.

Centrifuges may produce dewatered solids from conditioned substrates with a similar" consistency as from a belt filter press, but capital cost and high maintenance may make them unsuitable for farm use. A trial with a centrifuge is currently conducted in the Fraser Valley. No data is available at this time. Centrifuges are used in Europe to separate digested manures. Some types 'of centrifuges are designed for continuous use.

Hydrocyclones work best where there is a large difference in density between the solids and liquids, e.g., coal dust in water. It would appear that hydrocyclones have a limited use in dewatering biological sludges after conditioning of the - sludges to increase the weight differential. The addition of clay as a pre-treatment may increase the effectiveness.

Angled screens, with or without rollers have successfully been used in the dairy industry. The screens seem unsuitable for the separation of pig manure due to its consistency which is more colloidal than dairy manure. However, they are successfully used in areas where kernel grain is fed to pigs. Undigested kernels are then easily separated.

A newly developed system to partly dewater manures and to reduce ammonia levels in the barn is the HepaQ House. Manure is flushed with water with a low pH (<6) from the barn. Solids are separated (18-20% solids in this fraction) and effluents are either evaporated using the building ventilation system, or used as flushing liquid. The system is a dewatering system to reduce volumes. Solids still have to be treated and stabilised or removed from the farm and liquids are applied to land. The total volume of materials handled and transport is reduced.

Reed beds are engineered marshes to dewater sludges. Volume reductions in sewage sludge of up to 97% have been noted. Some mineralisation was noted. Reed beds may provide an inexpensive alternative for dewatering stabilised sludges. However, no saleable products can be expected in the short term from a reed bed operation and relatively large areas are required.

Freeze thaw beds were designed for the dewatering of sewage sludge using winter cold and summer heat. The freeze-dry cycle changes the structure of the sludge. After thawing, rapid dewatering takes place. The prototype installation contains a concrete basin, lowered walls and a translucent roof. Sludge was supplied in these layers and allowed to freeze before the heat application. After draining in spring, the thickened sludge was removed. Through the freeze-thaw cycle, drainage times improved from over 14 days to less than 20 minutes.

4.4 Polishing Methods

.4.4.1 Bio Phosphorus Removal (Bio-P)

The Bio-P technology is currently used as a tertiary treatment to remove phosphorus from treated effluent without the use of chemicals. In this capacity the technology is used in several Sewage Treatment Plants (STP) in the province. A pilot unit operated by the UBC Chemical Engineering Department, is receiving raw sewage from the local sewer line. The treatment is similar to the SBR process, with aerobic and amerobic steps, but is operated in a flow through mode. With special provisions the Bio-P unit can also remove nitrogen from the effluent. Further research is needed to upgrade this system to use with high strength wastes. A more advanced unit is operated by B.C. Research. This pilot unit consists of trickling filters and an aerobic-anaerobic treatment cycle.

4.4.2 Ecowat

The Ecowat technology receives anaerobically digested liquid manure. Solids are separated through the use of a centrifuge. The liquid fraction is aerobically treated to nitrify available ammonia and then anaerobically with the supply of methanol as a carbon source to denitrify previously formed nitrates. Phosphate is removed through chemical flocculation and sedimentation. Depending on the type of effluent and the load, the effluent is of discharge quality. Reverse osmosis is suggested as a polishing step to lower the salt content of the discharge.

4.4.3 Engineered Marshes

Engineered marshes have been used for the treatment of several waste effluents including metal containing mine leachates, landfill leachates and sewage effluents, especially in non-supervised remote locations. The marshes are designed to facilitate the absorption of nutrients and contaminants by plants and by the organic matter in the marsh bottom. Engineered marshes are a low tech polishing technology, especially suited to polish partially treated effluents. The technology is not suited for the treatment of high strength wastes. Both horizontal flow marshes, where the effluent is flowing on top of the sediments, and vertical flow marshes, where the effluent is forced through the sediments, are designed for polishing purposes. The vertical flow marsh is the latest development and not much data is available on their performance. The plants in the marshes are site specific and must be customised. With proper design, marshes can be used as a cost effective effluent polishing faality. Disadvantages may include mosquito problems, need for occasional harvest of the plant cover and a reduced effectiveness during the winter. However, a covered marsh with tropical environment may circumvent some of the disadvantages such as the reduced winter operation or mosquitoes.

4.4.4 Reverse Osmosis

Reverse Osmosis, a technology where dissolved matter is separated from water by a membrane, is commonly used in drinking water treatment or in applications where high purity is required. Reverse Osmosis has been assessed for the removal of salts and organic matter from effluents of manure handling facilities. Liquid manure must be pretreated through biological action and/or acidification before membranes successfully remove salts from the effluent. The process requires high pressure and therefore may be expensive to use. Effluents are of high quality.

Conventional polishing methods such as aeration, cascades or trickling filters have not been included in this review. They may well form alternatives to engineered marshes, but require more maintenance and attention. Also, land application may be seen as a suitable alternative.

4.5 Treatment of Solids

Separated solids or solid manures must be stabilised before storage, shipping and marketing. Solids can be dried in ovens or evaporation units, as is done with chicken manure and other (pretreated) manures both on-farm and in centralised facilities. The technology for drying included a rotating trommel oven from Japan - a combination of fermentation and evaporation - and small driers. Small driers are currently not used for pig manure because of limited success in separation of solids from liquids. Drying technologies are energy intensive and one of the industrial facilities in the Netherlands is planned to be located next to a large power station. The economics of drying technology greatly depends on the effectiveness of the separation step and the availability of a cheap source of energy. Anaerobic digestion is sometimes used to pre-condition manures for easy separation of solid and liquid phase. The liquid phase must be treated before disposal.

Comporting can be used to stabilise separated manures. Comporting is a process of bacterial decomposition of solids, thereby stabilizing nitrogen compounds. The process is an endothermic biological process, optimised through aeration, moisture and temperature control. The technology varies from low-tech windrow comporting where materials are piled in long piles and are occasionally turned for aeration, to in-vessel comporting where materials are turned regularly and where aeration and temperature is regulated through computer controlled aeration systems. Composting in out-ofdoors windrow systems with minimal input, may generate odour problems and is a long-term process to produce a stable product. The in-vessel technology could produce a stable product in 28 days. Trough or hybrid systems use intermediate technology such as a windrow turner to agitate the pile, while aeration is optional. These systems are produced for firm-scale operations, while in-vessel systems are used for large scale operations with sewage sludges, yard and garden wastes or municipal solid wastes as substrate. A tunnel system is currently developed for processing of yard waste.

The moisture content and the nitrogen content of the substrate are important parameters. With a bulking agent, wood chips, peat, saw dust, shredded paper, straw, and, in some cases, shredded tires, the moisture content and the nitrogen level of the substrate are corrected and brought into an optimum range. As the comporting process is an endothermic process, it could be used as a substrate drying technique as well as a stabilisation technique.

4.6 Multiple Resource Utilisation Systems

The Unisyn System is based on energy recovery from anaerobic digestion of manure wastes. The system uses a patented fully mixed fixed film reactor. By-products of the digestion are upgraded to value added products. Unisyn operates one pilot operation in Hawaii with dairy manure. The dairy manure was mixed with chicken manure in the past but the mixture was not successful. A small unit was operated in The Netherlands by Ecotechniek with slurry from the veal industry. Although the design calls for pig manure, neither pilot has successfully performed on pig manures (persoml communication: UNISYN; Ecotechniek).

Waste water from the Hawaii operation is used to produce Spirulina algae, a high value product. The sludge from the anaerobic reactor (SCP) is used as a protein source in fish feed (research trial) and effluents are used as irrigation water for salt tolerant crops such as pineapple and bananas. Anaerobic effluent from digesters using manures contains large quantities of salt. The Unisyn system was operated with chicken manure, a substitute with a high salt content. The effluent is not suitable for irrigation of greenhouses. Surplus heat would heat greenhouses and fish farms in a planned operation in The Netherlands. The greenhouses and fish farms, however, will create a secondary waste stream. Currently, Unisyn's approach is being coupled with the Ecowat technology. This new approach would lead to a discharge quality effluent. A proposed project by Unisyn in the Tillimook Valley (Oregon) includes the return of effluent to the farms for land application.

Although in theory multiple resource utilisation is very promising, the pilot facilities in Hawaii and The Netherlands were not yet successful in demonstrating full re-use of resources. More economical modelling and technical developments are needed to optimise this concept, especially where pig and chicken manure is involved. Multiple resource utilisation is successful in the third world where, for instance, on-farm egg production is integrated with aquiculture and crop production. Animal densities are relatively low and space and labour are of less economic value than food.

4.7 European Experience

The objectives for on-farm manure handling in, for example The Netherlands, are different from those formulated for manure treatment in B.C. or the Northwest Territories. In the Netherlands, large scale operations are planned to dry surplus manure for shipping and sales. The objectives for on-farm systems are to decrease the water content for easy transportation, a reduced sludge volume and lower off-farm energy needs. The focus is on large scale operations, while on-farm treatment, except for a brief period where anaerobic installations were in vogue, has largely been neglected. Manure treatment is legislated and subsidised, and manure production is taxed. Several on-farm treatment options, such as the mobile separator and the HepaQ House, reflect the objectives.

In B. C."and in the Northwest Territories, the objective is to totally treat the waste stream, preferably on the farm to produce a stabilised product and discharge quality effluent. Currently, only limited governmental support is available for the treatment and handling of manures and, except for environmental legislation, manure production and treatment is not regulated.

The difference in objectives for on-farm treatment and the differences of scale make it difficult to transplant most European technologies for manure handling to western and northern Canada. Each technology must be evaluated and possibly modified to fit local conditions.

The establishment of large scale facilities in The Netherlands is not without problems. Of the thirteen proposed installations (December, 1989), only one is currently in operation (September, 1992). Problems are in financing, permitting and siting of the plants and in technical problems. All reported systems produce dry manure pellets or cakes. Pretreatment such as amerobic digestion is used for stabilisation only. One system reported the recovery of proteins. No mention was made of other by-products or wastes. It seems that large scale operation is not without its drawbacks. Large government subsidies are required to cover the capital costs and operating costs are substantial.

4.8 Other Considerations

Improved separation of the liquid and solid fractions seems to be needed to improve waste management technology for on-farm use. In agriculture in general, the conventional wisdom seems to be to separate first and treat later. Such a sequence creates several secondary waste streams and the need for conditioning of the raw manure. Separators currently on the market are used for thickening only. In that case, the quality of the liquid fraction is not of concern. Many, if not all, separation technologies need conditioning of the substrate for best results. Research is needed in alternative separation and conditioning technologies.

Not much emphasis has been given to the role feed additives play in the quality of manures. The discussions among pig producers in the Fraser Valley on copper levels in fed and the marketing of Fytase in The Netherlands to increase phosphorus utilisation, thus reducing the need for phosphorus in the feed, point to interest in this area. Research in the field of animal nutition in co-operation with the large feed companies may be needed to focus on this aspect of the manure problem.

DRAFT

5 CURRENT SITUATION IN HAY RIVER

The Town of Hay River, NWT (pop. 2,964) is starting to develop an intensive agricultural industry. Currently one 100 sow farrow to finish operation (with estimated annual production of 2000 pigs), a 100,000 bird layer operation and a 160,000 bird broiler facility are active in the area. The layer barn is situated within the town limits, the broiler barn and pig barn are located several miles out of town. Odour complaints have been received by the Town for the layer barn. The pig farm is in the process of increasing its capacity to a 250 sow operation. The pig farm is operated as a deep pit facility. Liquid manure is collected in a pit underneath the slotted floor. Every two weeks the pit is emptied by gravity into a lagoon. The lagoon is emptied either by soil infiltration or by evapotranspiration.

The establishment of a slaughterhouse, processing 100 hogs per day is being planned, a feedlot and 100 herd dairy operation are projected. The slaughterhouse may discharge wastewater to sewer if the wastewater meets, specified discharge criteria.

Chicken manure is transported to two storage sites about twenty miles from the townsite, or by discharge to the nearby river. The manure is piled high and will eventually compost. One of the storage sites, a gravel pit, is near the river.

Solid ,waste from the proposed slaughterhouse will be transported to Edmonton for rendering. No plans have been made for disposal of liquid waste. The town of Hay River is serviced through a sewer system for disposal of human waste. Sewage is treated in a lagoon system. The present lagoon consists of two amerobic cells, with a total capacity of 12,700 m^3. Polishing of the effluent takes place in a marsh of 49 ha (120 acres) area. According to the Town of Hay River Public Works and Planning Department, average wastewater flow into the lagoon is 1215 m3/day or an average water use of 405 L/day per person. The actual water use is 270 L/person/day, estimated from metered services. The surplus may be from water infiltration into the sewer line or some storm run-off. No "bleeding" of fresh water into the sewer takes place in Hay River. The wastewater is low strength with a BOD5 of 135 mg/L and TDS of 475 mg/L.The lagoons remove 13% of BOD while the marsh removes the remainder from the waste stream. Approximately 26,000 gal/day (117 m^3) of household wastewater is brought in by tanker truck. T'he Director of Public Works suspects that oil problems in the lagoon were caused by these trucked-in loads. The BOD5 of these loads is approximately 1000 mg/L.

The Town of Hay River does not allow discharge into the sewage system of:

- Hoves, toenails or bone scraps.
- Intestinal contents from animals.
- Animal intestines or stomach casing.
- Horse, cattle, sheep or swine manure.
- Fleshings and hair from tanning operations.
- Poultry entrails, heads, feet, feathers or eggshells.
- Hides or parts of hides.
- Animal fat or flesh.
- Hog bristles.
- Bones.
- Blood.

Limits for Wastewater discharges to sewer are:

Suspended Solids	500 mg/L
BOD5	1000 mg/L
Oil and Grease	5 mg/L
Hydrocarbons	100 mg/L
Phosphates	10 mg/L

The data for wastewater strength and lagoon performance were taken just after break-up. Water quality in the -end lagoon and from the marsh discharge may be low due to the melt-off of surface ice, leaving clean water on the surface. However, the wastewater entering the lagoon system may reflect actual values. Due to the residence time and fluctuating flows, samples taken on one day may not reflect the actual performance of the treatment system.

From the limited information, one may deduce that most of the purification takes place in the marsh. Most likely, the marsh by itself could handle all of the domestic wastewater.

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6 WASTEWATER SYSTEM DESIGN FOR HAY RIVER

6.1 Pig Production and Wastewater Treatment

The survey of technologies showed that there is no commercially available economic technology to deal with on-farm treatment of liquid pig manure, resulting in a stabilised product and discharge quality effluent.

The Solar Aquatic Greenhouse may be suitable for the treatment of pig manure, but has not been assessed for this waste. The technology is designed for septage and, based on preliminary treatability studies, it may work for dairy manure. The technology is also suitable for small operations. It would produce discharge quality water and a compost product.

Small scale anaerobic digestion of pig manure has proven not to work on pig farms. The systems are not reliable, need large amounts of maintenance and would be disappointing in biogas production. Anaerobic digestion is currently seen as a method to stabilise organic waste, to make the solid/liquid separation more efficient, as a method for odour control and as a low energy method for removal of some biochemical oxygen demand (KID). Even in large scale, efficient operations, the production of electrical power from biogas is seen as a side benefit, not a purpose of anaerobic digestion. However, high local prices for natural gas or electrical power may change this picture.

The in-situ comporting system or Pig on Litter (POL) system is an alternative farming system where pigs are kept on a thick bed of saw dust or wood chips. Through regular mixing of manure and wood chips, the waste is composted in the barn. To save on wood ships two to three production runs may be kept on the sawdust of wood chips before it needs to be replaced. The Japanese inventor of the system sells proprietary enzyme solutions to enhance comporting. In a trial by Ducan Farms in the Fraser Valley, it was found that comporting is proceeding satisfactorily without the expensive enzyme solution. Mixing or turning of the material is very important as part of the management system. Animals are not as stressed as in regular barns, the ammonia level in the barn is decreased as is the level of dust. Disadvantages of the system include the requirements for a different set-up of the barn and a different management strategy. The main advantage is that all wastes are produced as a stabilised solid product. Virtually no liquid waste is produced on a farm using this system. The in-situ comporting system may be a suitable solution to alleviate the negative environmental effects of the lagoon system used at the pig farm in Hay River.

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6.2 Chicken Production Wastes

Chicken manure is generally hauled and spread on land. In some cases it is composted or dried and pelletized. A successful on-farm comporting operation, treating the waste of about 60,000 chickens, broilers, pullets and layers, is situated in the Okanagan (B.C.). This facility uses the Farmer Automatic windrow turner in an indoor setting. This turner is handling two concrete troughs. Compost substrate consists of straw bedding, chicken manure and a small percentage of mortalities. Comporting takes about 35 days. The product is screened and bagged and is a well sought after organic fertiliser. The producer has applied for approval for use in organic farming. The fertiliser rating of the compost is *2-5-2.*

A low-tech trough composter such as the Farmer Automatic would be a good system to handle all the solid waste from the chicken farm.

The Austrian MBCD process may be suitable for on-farm stabilisation of chicken manure. The equipment is small enough for operation in Hay River. The winterizing of the operation should be considered before installation.

6.3 Slaughterhouse Wastewater

The slaughterhouse will be situated about 5 miles from town near the broiler barn. The solid waste may be stored and then shipped to Edmonton, Alberta for rendering. No plans have been made for the treatment and disposal of the liquid fraction. Two options are available fo disposal of"the liquid fraction, consisting of washings, manures, some blood, fats, grease, hair, etc. The first option is to use the Town of Hay River sewage system, the second option is to perform on-site treatment of the total flow.

The Town of Hay River has established guidelines for the use of their sewer system for industrial discharges. The wastewater from the slaughterhouse would need to be pm-treated to meet the discharge criteria. Primary sludge, oil, grease and hair, and dirt or detritus would be generated in this process.

The remaining flow would then be discharged to sewer, tankered to the town treatment plant, or would be treated on-site. In this discussion, we have focussed on the biological on-site treatment only.

The available information has been considered in the formulation of alternative treatment approaches at Hay River in the Northwest Territories. The information has been considered from a technical feasibility standpoint only. Although some indication of the comparative costs for capital and operating may have been included in the general approach these have been incorporated from a general knowledge aspect and not from a precise evaluation of the various components included in the system. Although there is much in the literature indicating that anaerobic treatment may be economically advantageous for the treatment of high, strength organic wastes, it is considered that the size of the proposed plant is such that recovery of methane gas will be inconsequential in the overall process for this instance. Therefore, anaerobic treatment would only be used to reduce incoming organic load. The current knowledge of the wastewaters for treatment is somewhat scanty and must be further reviewed before final selection of the treatment system is made.

Waste water flows from the hog processing plant would be expected to amount to about 0.2 m^3/hog processed. Although there would be a fixed quantity of scalding tank wastewater representing a somewhat higher fraction of the total wastewater than in the hog operation described in Appendix B, because the scalding tank will have to be a certain minimum size in order to completely immerse several hogs at the same time. Indeed, the tank may be much the same size as the one used in the British Columbia process, which the description in Appendix B is based upon. The total volume of wastewater for treatment were estimated by the Town in the order of 59-89 m^3.

It should be pointed out that the scalding tank water will be hot (approximately 60°C) and its heat should be used advantageously. It could be used to increase the temperature of the balance of the wastewater from the operation which could then be provided for pretreatment by anaerobic digestion. The water quality of the hog wastewater would be expected to have a 5day biochemical oxygen demand of 1,250–2,000 (BOD5) mg/L, and a suspended solids of 500 mg/L.

Pretreatment for these wastewaters consist of at least screening to remove hairs and large pieces of fat, etc. Dissolved air flotation should be considered but due to the small size of the system the same kind of problems that were experienced by the Packerland Company (see Appendix B) may make this pretreatment technique inefficient.

6.3.1 Biological Treatment

The degree of biological treatment provided will be defined by the quality required in the discharge to the environment and the characteristics of the receiving water. We would expect that target discharge quality is:

5-day biochemical oxygen demand	<30 mg/L
suspended solids	<35 mg/L
total phosphorus	<10 mg/L
coliform organisms	<1000 MPN/100 mL

A permit from the Federal Water Board is required for discharge to the environment.

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Of the biological treatment plants that were reviewed in Appendix A, we consider that a sequencing batch reactor (SBR) activated sludge unit would be the most suitable and would likely obtain the desired water quality in a single stage. ,

There are several proprietary designs of the SBR system. Recommended companies are:

- Bioclear Technology Inc., of Winnipeg, Manitoba. Bioclear Technology have significant experience in provision of small SBR systems for Northern communities.

- Jet Tech Inc., Industrial Airport, Kansas. Jet Tech Inc., have installed several very large SBR systems in the United States and in Manitoba, Canada (1 00,000 gpd).

An alternative system would compare to the system designed by Kaldnes/Sintef for treatment of wastewaters in Norway. A description of this system is shown in Appendix A3.

6.4 Integrated System

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By using the POL system for the pig farm, the production of liquid manure is elirninated. Also the need for a lagoon near the farm is eliminated. Depending on the supply of wood chips or sawdust in the area, two or more production runs can be kept on the same bedding. Composted bedding can be stored and re-used as bulking agent in other components of the system, or can be sold separately as a soil conditioner.

When chicken manure is composted, a bulking agent may be needed to provide a carbon source to bind its nitrogen. The C:N ratio of layer manure is about 6, the C:N ratio of broiler manure is about 16. The moisture content of layer manure is approximately 65%, that of broiler manure 35%. The bulking agent can be supplied from the partly finished compost of the POL system. After comporting, the final product will be a nutrient rich stable compost which can be marketed as a soil amendment or organic fertiliser.

Comporting should take place in a comporting building. Depending on the expected volumes, three to four bins should be installed. Up to four bins can be seMced with one turning machine. The bins are enclosed in a building with a odour control system and a ventilation system. The configuration of an odour control system depends on the vicinity of other land users. Chemical scrubbers, bio filters, odour control sprays or dilution fans may be used to control odours. Chemical scrubbers and odour control sprays maybe subject to freezing.

When possible the compost facility should be placed near the slaughterhouse. The compost building heated by the fermenting compost will also house the small SBR unit. This unit will treat the waste from the slaughterhouse. The pre-treated liquid waste from the slaughterhouse is piped to a surge tank in or near the comporting building.

. The primary sludge and detritus from the slaughterhouse is included in the compost substrate for sterilisation and stabilisation. Although the composter may successfully treat animal by-products and materials from the slaughterhouse and the chicken farm, care should be taken not to overload the system with animal by-products. The duration of comporting and curing should be adjusted as well as the turning frequency to allow the animal by-products to stabilise fully. Improperly stabilised materials will give rise to odour complaints and are not "plant friendly."

The aerobic/anaerobic treatment facility is placed in the comporting building to prevent it from freezing. If water from the scalding tank is included, a heat exchanger may be installed to re-use this energy in the slaughterhouse. From the surge tank the waste may be fed through a secondary heat exchanger situated in the bottom of the composter. Here the waste is heated to treatment temperature. From the heat exchanger the heated liquid waste is fed into the SBR.

Sludge from the SBR is fed into a freeze-thaw separator. It is expected that this sludge contains between 1 and 3% solids. In the separator the liquid-sludge mixture is frozen during the winter. The effluent is fed on top of existing frozen sludge to forma solid layer of ice in the separator. At break-up, thawed effluent is drained from the separator, leaving behind the thickened sludge. Drained effluent may be rerouted into the surge tank for recycling. Results from trials with sewage sludge have shown that sludge with as low as 1.1% solids could be effectively dewatered. Separated and dewatered sludge will be composted for further stabilisation (see Appendix A5).

Alternatively, the composter may be situated on the new land fill site. The water treatment unit may not be included unless the liquid waste is trucked to the land fill site. The composter could then receive the source separated organic waste from the Town of Hay River, as well as the chicken manure and composted pig manure. By including the organic waste in the compost-substrate, the need for additional land fill space is reduced.

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7 STATEMENT OF LIMITATIONS

This report has been prepared by the British Columbia Research Corporation of the Science Institute of the Northwest Territories. The contents of this report are based on personal experience of the authors, scientific literature,. discussions with researchers, government officials and manufacturers. Every effort has been made to ensure the accuracy of the information and to provide an accurate evaluation of the situation in Hay River.

B.C. Research does not guarantee that all potential manure handling and slaughterhouse waste handling technologies are listed in this report. The information in the report is for reference only.

This report is a technology review only and is not intended for use as a design document for a wastewater treatment facility. Design of a wastewater treatment facility will require additional collection of information and evaluation of economic and technical considerations determined by the waste intended for treatment.

Hubert J. Timmenga Ph. D., P.Ag.
Certified Agricultural Consultant

Alex E. Birkbeck
Senior Research Consultant

APPENDIX A
Description of Technology

TABLE OF CONTENTS

1 TECHNOLOGIES ACCEPTING UNTREATED MANURES

1.1 In-Situ Comporting

Pig on Litter (POL); in-situ comporting; ECOPOR.

Facilities Using It

Ducan Farms, Fraser Valley; University of Hong Kong; farms in The Netherlands.

Design Features

Pigs are kept on a thick layer of sawdust or wood chips. Through daily or bi-weekly tilling, the top layer of the sawdust-manure mixture is aerated, prompting the mixture to compost. A compost starter or enzyme additive is needed to activate the comporting purposes.

Pros

The technology results in a stable compost product. No effluents are available for land disposal. Through keeping the bedding moist, no dust problems are encountered, ammonia is readily adsorbed in the mass and converted to other forms of nitrogen. Stable product could be marketed as soil enhancer without further treatment. Pigs are used to being moved around and are used to people being in the *barn*. This "conditioning" reduces the stress level of the pigs at transport time.

cons

Barn need to be modified to handle 60 cm of sawdust. Labour intensive process requiring daily or biweekly tilling of the mass. Need for a commercial compost starter. Reports on increased level of NO_x in barn air.

Manufacturers

Pilot studies at The University of Hong Kong, several farms were brought on stream. Pilot project in Fraser Valley at Ducan Farms, several farms (80) operating for The Netherlands. System marketed by:

Ducan Farms
7512 Lefeuvre Road
Langley, B.C.
V3A 4P9
856-6919

Ecopor B.V.
Poelkensdijk 10
5482 VE Schijndel
The Netherlands

Comments and Recommendations

This technology disengages the land base from intensive livestock production. No effluents to dispose of. Composted bedding could be sold as a soil amendment. It is a stable product. The process was known in Europe in the Middle Ages, when sheep were herded on the heather fields and were driven into a pen or shed for the night. Manure was collecting overnight and was regularly covered with sod. In the spring this composted mass was then moved to the fields for crop production.

Soils in Western Europe with the name of Plaggen **Soils with** organic influences up to **75** cm deep were developed over millennia through this type of agriculture.

-A trial is under way at Ducan Farms to incorporate an aeration system into the comporting mass to lower the need for frequent turning and to aerate the compost. This trial is supervised by the sustainable farming group in Fraser Valley, Ducan Farms does not use the enzyme product, but through careful management keeps the compost process active. Temperatures in the bedding reach 350C.

In The Netherlands, the barn-air has been assessed for Nitrogen compounds. It was found that the total nitrogen content was similar to that in regular barns. The ammonia level was lower but significant levels of NO_x were found. Some concerns were voiced because NO_x is a smog precursor (Bokrna, personal communication).

References

Bokma. Hendrix' Feeds B.V. Veerstuadt 3P. 5831 DN Boxmeer, The Netherlands, 1992.

1.2 MBCD Process

Facilities Using It

Chicken" Farms in Austria/Germany.

Design Features

Thermophylic composter using hot air to nitrify, compost and dry materials. Manure is pelletized before entering the reactors. Air is used in a counter flow approach. All gases are treated with a bio filter. Processing time is *48* hours in a batch mode. Product contains about 70% OM, 4% N, 5% P205, 2 % K20, 6% CaO and 1% MgO. Moisture content is 12%.

Pros

- Ammonia is transferred into stabilized nitrogen.
- Limited moving parts.
- Dry product.
- On farm use.
- Product can be stored for long periods of time.

Cons

- Substrate must beat <55% moisture.
- Specially designed for Chicken farms.

Manufacturer

Dungemittel Productions& Vertriebsges. M.b.H.
D- 8033 Krailling/Miinchen
Talanger StraBe 3a
089/ 8577780

Comments

The system processes waste products such as chicken manure, dewatered manures or sewage sludge. Product is stabilized through comporting and drying. The equipment is suitable for on-firm use. The manure is processed before ammonia volatilization takes place. Dried product contains a higher level of Nitrogen (4%) than chicken manure compost (2%). No need for a bulking agent.

1.3 VerTech Aqueous Phase Oxidation

Facilities Using It

Sewage sludge plant in Apeldoom, The Netherlands. Pilot plant in Dordrecht, The Netherlands.

Design Features

Through high pressure (100 at-m.) and high temperature (280”C), organic waste is oxidized. Due to increasing temperature, the oxidation reaction is exothermic. Oxidation takes place in a 1,200-1,500 m deep bore hole in which the reactor vessel is sunk. Heat is exchanged using counter flow principles. Ash is separated from liquid fraction. The liquid fraction may need polishing before discharge.

Pros

- Small Unit.
- Sterile ash and effluent.
- Reduction of organic matter.

cons

- High-tech equipment.
- Not suitable for earthquake prone areas.
- Need for a drillhole.
- High capital cost.
- Only suitable for centralised or large scale use.
- No track record with manures.

Manufacturers

Vertech Treatment Systems bv.
Baarnsche dijk 14
3741 LS Baam
The Netherlands
Phone: 31-2154-82888
FAX: 31-2154-17541

Comments

1.4 Solar Aquatic Green Houses

Facilities Using It

Town of Harwich, Ma. for Septage, pilot plant for sewage, food waste effluent (ice cream factory). Plans for superfund sites for toxic leachate control.

Design Features

Septage is pumped into tanks inside a greenhouse. The tanks are aerated and support a plant, bacteria and animal community. Effluent is treated in engineered marshes and other polishing steps (indoors). An out of doors reed bed takes excess sludge for stabilisation. Harvested reeds and indoor vegetation is collected for composting. The septage pilot plant has a capacity of 100,000 Gal/month or 15 m^3/day. The greenhouse containing the aerated vessels and the marsh measured 42*125'. An additional reed bed for sludge disposal (out side) measured 125*1 O'. T'he average BOD input is 3,000 mg/1, the range is 500–30,000. TSS input is 6,000 mg/L. Output effluent is 20/20 or better with TKN of 14 and TP of 4-5. Additional work may lower the TP. When septage is used as substrate, the effluent is sterilised through UV treatment. This treatment will bring the MPN down to >5/100 mL, the local drinking water standard. The latest figures show an effluent with BOD 5 mg/L, TSS 57 mg/L, total N 5.4 mg/L, Nitrate 1.9 mg/L, TP 2 mg/L. The technology has been approved for use with septage by the State of Massachusetts.

Pros

System produces a clean effluent for disposal. The green house protects the system from the weather. This system is also suitable for cold climates when inside temperatures and light levels are controlled. Effluents from partial treatment could be used as water/nutrient supply in commercial green houses. Discharge quality effluent is produced. Low tech approach, resilient, flexible system.

cons

Land required for greenhouses and ponds without production of a marketable product. Greenhouses are used as a holding and processing faality and not for production of crops.

Manufacturers

Ecological Engineering Associates
13 Marconi Lane
Marion, Ma. 02738
(508) 748-3224

Comments and Recommendations

Interesting concept for use in the "user-pay" field of treatment of high strength wastes such as septage. Relatively low cost operation compared to a STP of regular design. Not proven for manures other than septage. No saleable by-products from the system as operated in Harwich. The amount of plant biomass produced is small and would not warrent the establishment of an on-site cornposting facility. Treatability studies showed promise for treatment of dairy manure.

1.5 Thermophilic Aerobic Digestion

Facility Or Use

Sewage sludge stabilization in STP'S, several units are in operation in B.C.

Vegetable Waste, operational unit in North Vancouver, B.C. (International Biowaste, North Vancouver).

Design Features

Thermophilic digestion has been used in B.C. on a pilot scale, to reduce the volume of sewage sludges in sewage treatment facilities. Normally sludge reduction is in the order of 30-50% while 80% of solid reduction has also been claimed. The technology is being used in Germany and several research publications were generated in Europe.

In Canada, pilot units were established in McDonald College and in Vancouver, for use with high strength organic wastes. International Biowaste operates a commercial unit in North Vancouver. Vegetable wastes are received and processed. Sludge is then separated and dried. Effluent is discharged to sewer. The process includes a fully mixed aerobic digestor, where aeration takes place with forced air and the material is mechanically mixed. Some external heating is applied to the reaction vessel. The product is an organic fibre for use as fertilizer. The nutrient value is 3-3-3.

Pros

. Operation of equipment possible by inexperienced person.

- Temperature only detail needed to be monitored.
- Possible feed generated by operation - crude protein of **31%** on dry bases, high mineral content, but low energy value.
- Pelletized sludge maybe sold as fertilizer.

cons

- Additional heating required.
- Costs for dewatering and pelletizing may be high. The process will not produce a clean effluent.

Manufacturers

Thermo Tech Waste System Inc.
#203, 1120 Austin Avenue
Coquitlam, B.C.
V3K 3P5

Dayton & Knight
West Vancouver, B.C.
(for sewage sludge)

International BioWaste Corp.
52 Riverside Drive
North Vancouver, B.C.
929-8106

Comments and Recommendations

Swell Barrington, Dept. Of Agricultural Engineering, McGill University, did the research for Thermo Tech. She commented that the process needs to have more work on it - re-design the stirring mechanism so that the heat is not transferred to the digester. The system is not really thermophilic - or mesophilic. The system might be suitable to reduce the volume of waste dealt with as part of a larger system.

Other research dealt with dairy manures. The system was not able to maintain thennophilic temperatures and greater biological activity would be achieved by aeration with oxygen. The window of opportunity between failure and success is rather small. Dilute solutions require additional energy while thick solutions impale aeration and mixing. Dilution or thickening of influent to obtain the required solids content may be necessary.

The operation in North Vancouver (International Biowaste) takes vegetable waste from supermarkets. Product is shredded, digested, dewatered and dried. Some external heating is used in the reactors.

References

Grant, F. and F. Brommenschenhel: ***EPA-660/2-74-034. (1974).***

Hoffman, B. and LS. Craner: “Liquid comporting of dairy cow waste.” (No place). (1973).

Kelly, H.G: “Aerobic Thermophilic Digestion or Liquid Comporting of Municipal Wastes.” ***Environmental Engineering*** *Proceedings of Specialty Conference/EE Div./ASCE p. 650-662. (1989).*

1.6 Slurry Injection - Flue-Gas

Injection of pig slurry in flue-gases for reduction of NO_x from boiler emissions,

Facilities Using It

Pilot in steam generating plant in Germany; experimental work by TNO, The Netherlands.

Design Features

NH3 that occurs naturally in pig manure is used for secondary nitrogen oxide reduction in flue stacks. Currently synthetic ammonia is used. Slurry is atomized and injected into the flue gases where the two react into nitrogen and water. Slurry works in a wide temperature range (700–1,000°C).

Pros

- Use of pig slurry to fight acid rain. No effluents or wastes to treat except fly ash from flue.

Cons

- Pig manure to be transported to large boilers, limited volumes required. One pig farm can supply ample manure for a large power plant.

Manufacturers

Véba Kraft Werke Rugr AG (VKR; Gelsenkirchen-Buer)
Germany

TNO Environmental and Energy Research
Laan van Westenenk 501
P.O. box 342
7300 AH Apeldoom, The Netherlands
(31)-5%93493

CommentsfRecommendations

1.7 Pyrolysis

. Facilities Using It

Pilot scale installations in lumber industry, pilot scale installations in organic waste disposal.

Design Features

Organic matter is super heated under reduced oxygen conditions. Off gases are captured and either separated, burned for energy recovery, or hydrogenated for production of diesel like fuels. Liquids can be separated into chemical components for further use in chemical industry. By-product is charcoal.

Pros

Pyrolysis is an energy delivering technology and can easily convert wood wastes in engine fuels or space heating. Through careful monitoring of the process and through the choice of substrate, more valuable products can be recovered. Process may be used for the destruction of hazardous waste.

Cons

To create high quality products to be used in the chemical industry, the substrate should be dry, < 25% moisture and should contain large quantities of cellulose. Produang diesel fuel may not be economical due to the large quantities of (expensive) hydrogen gas needed in the process. Probably not suitable for pig manure due to large moisture content and variable quality. Process is only valuable in large scale operations. The process will generate waste liquids, waste gases and waste solids, some of which maybe Special Wastes.

Manufacturers

American Power and Waste Management Ltd. (for woodwaste gasification)
Vancouver, British Columbia
(604) 682-7220

Comments and Recommendations

Probably not suitable for pig manure due to large moisture content and variable quality. Process is only valuable in large scale operations. Several pilot plants were established in North America to gasify biomass for fuel extraction and the preparation of chemicals.

1.8 Fermentation; Production of Lysin

Facility or Use

Royal Gist-Brocades; The Netherlands; bench scale experiments to be upgraded to pilot by 1993.

Design Features

Separated liquid manure is sterilized and then inoculated with lysin producing bacteria. Lysin is then recovered for use in feed.

Pros

- Reuse of part of Manure as feed.

Cons

- Large scale facility needed.
- Waste products; pilot scale.

Comments

No further information available. Pilot scale operation to be funded by Dutch Government at a rate of Hfl 22 m. Will be connected to Promest facility in Helrnond. The production of chemicals from manure is the second generation in manure treatment. No industrial plants are available.

1.9 Modular Economic Treatment System

Facilities Using It

Untreated Sewage, Pilot scale only.

Design Features

Untreated sewage is ground and then flocculated in mixing tanks with clay and polyelectrolytes. Sludges are dewatered in a hydrocyclone and then composted. Standard effluents are approaching discharge quality Prototype capacity is 4,000 gal/day.

Pros

- Simple low tech approach, limited moving parts.

Cons

- Technology not proven for high strength wastes.
- Need for polyelectrolytes: $1.10/1,000 gal.
- Mixture of chemical flocculants and clay.
- Dewatering needed.

Manufacturers

R.H. Cook and Assoaates
Pilot Butte, Saskatchewan
SoQ 3Z0
(306) 781-4435

Comments/Recommendations

2 SEPARATION/THICKENING OF LIQUID WASTE

2.1 Microstrainers

Facilities Using It

- ***None*** found using it with swine waste.
- Pulp and Paper Mills.
- Municipal water supplies.

Design Features

Microstrainers contain a horizontal, cylindrical unit with influent delivered to the inside. The wastestream flows radially outwards through a fabric mesh, leaving the suspended solids trapped on the inside of the drum. Solids which blind to the fabric mesh as the drum rotates are washed into a collection trough inside the drum by backwash jets. Ultraviolet light, in addition to the backwash jets, is often used to prevent slime growth on the micro-fabric.

Vargo Super Filter removes dilute concentrations of suspended solids of light weight material such as pulp and paper fibres. Similar in operation to the microstrainers, noted above. An unique feature of this filter is the **100** mm deep arcumferential folds of fabric which provide increased surface area as well as a rigid support which eliminates the need for a separate support grid. The folds are also believed to provide for lower shear, than for smooth drum surfaces, between the deposited fibre and the feed liquid which in turn reduces turbulent disruption of the filtration process.

Pros

cons

- High backwash flows may cause excessive dilution of the collected solids and result in a dilute sludge which is difficult to handle.
- No data on parent solids of sludge is available at this time.

Manufacturers

- Crane Canada Ltd.
- Vargo: Pokon Corporation

Cornments/Recornrnendations

References

Environcon Ltd: , *Assessment of* ***Filtration and Stmining for the Reduction of Effluent Suspended Solids. CPAR*** Project Report #236-1, Environment Camda, Forestry Service, Pulp and Paper Pollution Abatement. (1973).

2.2 Bed Filtration

Facilities Using It

- ***None*** found using it with animal waste.
- Pulp & Paper mills have experimented with it in the past.
- Municipal waste water is sometimes filtered this way.
- Method is used in fish hatcheries.

Design Features

High Pressure Filtration

Influent flows under pressure through a bed of sand or other filter medium. The particulate are caught in the sand. Occasionally, the bed of filter media must be backwashes to clean out the trapped particulate. There are many variations on this theme. Besides single and dual systems other configurations are multi-layer, upflow and bi-flow.

Multi-layer is a system where the effluent flows through several stacked beds of medium. Each bed usually has a different grade of medium.

Upflow includes a graded bed unit where the effluent flowing upwards through media comprised of pebbles and sand. During the backwash operation, the filter media becomes graded with the smaller particles at the top and the larger ones at the bottom. A patented steel grid prevents bed expansion during upflow filtration.

Gravity Bed Filtration

The intluent flows by gravity through a sand or coal media. Vancouver Aquarium uses gravity bed sand-filtration to filter the water in their fish tanks. The system works very weil for most species of fish however, frequent backwashing is required for the mammal tanks, possibly due to the hair and oils produced.

Moving Bed Filtration

Pilot-scale data only.

Waste water enters the head tank then flows through a bed moving countercurm ntly and is discharged through exit screens located at the side of the bed. The sand and the filtered solids are pushed by a hydraulic diaphragm toward the head tank where the face of the bed is removal by a mechanical cutter. The pulsating diaphragm during relaxation allows clean sand to fall into the space vacated by the diaphragm. The sludge-bed media mixture at the bottom of the head tank is transferred to a washing column where it is cleaned with filtered effluent. The solids in the wash water are removed by sedimentation or filtration and the excess effluent can be recycled back to the moving bed filtration process. Filter media: sand, pebbles, gravel, coal.

Pros

- Gravity bed filtration: passive process, does not require a great deal of mechanisation except for pumps to backwash the filters.

- Potentially using wood chips or other bulking agent that would be thrown into a comporting pile for a filter media maybe efficient.

cons

- Blinding of filter media.

- BackWashing of media required to purge the captured solids could represent a new effluent problem.

- Isolation of solids from media may not be easy.

Manufacturers

Johns-ManviUe Prod. Corp. (Moving bed filtration).

Degremont Canada Ltd.

Comments/Recommendations

In general, sand or gravel media would not be easy to work with (blinding, cleaning, separating solids from the media.) The backwash will create a secondary effluent flow. Systems can only be used where influent quality is good and effluent quality needs to be excellent, such as in aquacukure or drinking water purification plants.

References

Environcon Ltd: Assessment *of Filtration and Straining for the Reduction of Effluent Suspended Solids. CPAR Project* Report #23&l, Environment Cam&, Forestry Service, Pulp and Paper Pollution Abatement. (1973).

2.3 Air Flotation

Facilities Using It

- *None* found using it with animal waste.

- Muniapal sludge, grease containing wastewater from slaughterhouses, etc.

Design Features

Fine bubbles are used to buoy up particles. The bubbles may be generated by air dispersed through a porous medium, or by air drawn from the liquid under vacuum, or by dissolved-air flotation whereby air is forced into solution under elevated pressure followed by pressure release.

Effluent is recycled at a rate of 30% to 150% of the influent flow where influent enters near the tank bottom and exits from the base at the opposite end. Float (particles that have been buoyed up) is continuously swept from the liquid surface and discharged over the end wall of the tank. Optimum recycle ratio must be determined by on-site studies.

Solids loadings of 2-4 lb./ft^2/hr with hydraulic flow of about 1 gpm/ft^2, can produce floats of 4-8% solids (muniapal sludge).

Pros

cons

- Chemical preconditioning is normally required.

Manufacturers

Pollution Control Engineering
Suite F-11912 River Road
Santa Fe Springs, CA 90670

Comrnents/Recornrnendations

Solids concentration of the float is too low for animal waste, the system is exceptionally efficient for greasy solutions.

Removal efficiency of these systems depends on the concentration of oil and grease in the wastewater. Typically wastewater from a food operation will contain 1,000 to 10,000 mg/L oil and grease. A dissolved air flotation system will lower these concentrations into the 10&200 mg/L range. The removal can be enhanced by additive of chemical flocculating agents. However, Macaulay, 1987 indicated that poor performance of flotation units at the Packerland Packing Company was one of the reasons for redesign of the system.

Production wastewater streams were previously pretreated with dissolved air flotation (DAF) followed by chemical conditioning and additional secondary dissolved air flotation. Flotation tank skimmings were dewatered by vacuum filtration and land applied. The DAF effluent was discharged to the City of Green Bay municipal sanitary sewer.

References

Krofta, M., D. Guss and L.K. **Wang:** "Development of **Low-Cost Flotation** Technology and Systems for Wastewater Treatment." In ***Proceedings 42nd Purdue Industrial Waste Conference, 1990, 185-205.*** Chelsea, Michigan: Lewis Publishers, 1988.

Macaulay, M.N, T.W. Stebor and ***C. I-.*** Bemdt. "Aerobic Contact Pretreatment of Slaughter House Wastewater." In ***Proceedings 42nd Annual Purdue Industrial*** *Waste* ***Conference, 1987,647-655.*** Chelsea, Michigan: Lewis Publishers, 1987.

Stebor, T.W., C.L. **Berndt,** S. **Marmau** and R. Gabriel. "Operating Experience: Anaerobic Treatment at Packerland Packing.'* In ***Proceedings 44th Purdue Industrial*** Waste ***Conference,*** 1990,825-834. Chelsea, **Michigan:** Lewis Publishers, 1990.

Viessman, Warren Jr., and Mark Hammer. Water Supply ***and Pollution Control, 4th Edition. New York*** Harper & Row, 1985.

2.4 Lamella Clarifier

Facilities Using It

None found using it with swine waste,

Design Features

Gravity clarifiers with greatly increased settling area. It has multiple sloping plates close together such that solids do not travel far before settling on a sloping plate. During their travel downwards on the plate, settled particles will snowball into large sludge particles, increasing the solid content of the bottom sludge. The solids accumulate at the bottom of the sloping plates. The settling time is reduced because of the short distance between the sloping plates. Particles having travelled this distance coalesce with other particles on the plate, then roll down. The supematant is discharged at the top of the clarifier.

Pros

- Greatly increase settling area for a given space.
- No moving parts and little maintenance.
- The residence time in the clarifier is lower than in a conventional unit.

Cons

- Pretreatment of wastewater may be needed.

Manufacturers

EIMCO Process Equipment Company
P.O. Box 358
Delta B.C.,
V4K 3Y3
9460421

Ecodyne - Graver Water Division
2201 Speers Road
Oakville, Ont.
L6L 2X9
(416) 827-9821

GEC ALsthom International Inc.
45 Rockefeller Plaza
New York, NY 10111
(212) 632-3680

Parkson Corp. (Axel Johnson Co.)
P.O. Box 408399
Fort Lauderdale, Florida 33340-8399
(305) 974-6610

Linatex

Axel Johnson (Canada) Inc.

Comments/Recommendations

2.5 Sonics Aided Flocculation

Facilities Using It

New technology of Austrian origin. No North American users. Process still in pilot stage. Pilot work performed at the Wastewater Technology Centre in Burlington on the treatment of sediments from the Great Lakes.

Design Features

Sonic waves are generated in a flow through system with suspensions of solids. The waves cause the particles to flocculate, faalitating precipitation in a clarifyer. Process has been tested for coal dust slurries and bacterial sludge. Settling times decreased from 50 minutes to 6 minutes for bacterial sludge and from 6 hours to minutes for coal dust slurries.

Pros

- Small unit to handle large flows. Pilot units for pulp mills will operate on a minimum rate of 5 m3/h.

- No moving parts to wear out or replace.

Cons

- Unproven technology. Organic waste may need pre-treatrnent or conditioning.

Manufacturers

Triton Environmental Consultants, /Sonoflock Environmental Technology Ltd.
120-13511 Commerce Parkway
Richmond, B.C.
V6V 2L1
(604)279-2093

Comments and Recommendations

Unit may be incorporated in a settling system following (biological) treatment. May reduce the size of a settling tank or clarifyer.

2.6 Screw Press

Facilities Using It

- A German design is used with swine manure.
- Used at pulp mills, sewage operations, etc.

Design Features

An auger surrounded by a dewatering screen or filter. The slurry enters the auger at one end, water is squeezed out through the filter and the solids leave the auger at the other end. Back pressure is established with a cone or plate at the discharge of the press.

Pulp and Paper Primary sludges dewatered to: 45% to 55% solids. Pig waste solids dewatered to 25-35% solids with a 0.5 mm screen.

Combined primary sludges and biological solids could be dewatered 20-40% solids; biological solids dewatered to 4950%. The screw press requires 1 to 5 kg of polyelectrolyte per ton of sludge.

Pros

- Fairly simple piece of equipment to maintain and operate.

Cons

- Filter has a tendency to plug, need of conditioning chemicals.

Manufacturers

Andritz - Ruthner Inc.
1010 Commercial Boulevard
South Arlington, Texas 76017
(817) 5611

HIM/ America Inc.
P.O. Box 1445
Pine Bluff, AR 71613
(501) 536-7101

FAN Engineering
Oeldek Strabe 10
4740 Oelde
FRG Germany
(02520-8008)

FKC Co. Ltd. (Doug Fogg)
P.O. Box 1677
Port Angeles, Washington 98362
(206) 452-9472

Ramtech Systems Inc.
Three Riverway, Suite 770
Houston, Texas 77056
(713) 623-8133

Comments/Recommendations

The pig manure used in trials in the Fraser Valley originated from a farm with its own feed mill. Particles in the feed are much coarser than in feed from a commercial mill. The screw press has not been assessed for use on farms with commercial feed. The solids content in the liquid fraction decreased from 3% to about 1%. The recovered fraction contained 35% solids and could be composted without the use of a bulking agent. This technology may be used for partial separation of pig manure to reduce the organic loading.

2.7 Gravity Belt Filter

Facilities Using It

' None found using it with animal waste.

Design Features

A perforated conveyor belt 'operates' along the bottom of a rectangular tank. Gravity removes most of the water through the belt and the thickened sludge is discharged at one end.

Usually requires some additional means of removing the water or thickening such as a "picket fence" designed as miniature ploughs called chicanes or a sonic vibrator.

Pros

- Can handle relatively high volumes of influent and reduce the total volume significantly.

Cons

- Biological sludges may not dewater very quickly.
- Potential for filter clogging.
- May need conditioning chemicals.

Manufacturers

Ashbrook Simon-Hartley
P.O. Box 16327
Houston, Texas 77222
(713) 449-0322

Parkson Corp. (Axel Johnson Co.)
P.O. Box 408399
Fort Lauderdale, Florida 33340-8399
(305) 974-6610

Comments/Recommendations

Little technical dab available at this time.

2.8 Rotary Screen Gravity

Facilities Using It

None found with swine manure.

Design Features

A cylindrical screen is rotated around a sloped axis and the influent enters the higher end. The water flows out through the screen, the solids slough out the lower end of the cylinder, with or without the application of a vacuum on the outside of the screen to increase efficiency.

Pros

- Will dewater at a high flow rate.
- Continuous process.
- Low maintenance and operating costs.

Cons

- ***Need*** to condition the sludge prior to dewatering.
- Will have some solids loss into effluents.
- Uneven solids discharge.

Manufacturers

Hycor Corp.
29850 N. Highway 41
Lake Bluff, IL 60044
(708) 473-3700

Pollution Control Engineering
8520-A Sorensen Avenue
Santa Fe Springs, California 90670
(213) 945-7521

EIMCO Process Equipment Co.
P.O. Box 358
Delta, B.C.
V4K 3Y3
946-0421

HIW America Inc.
P.O. Box 1455
Pine Bluff, AR 71613
(501) 5367101

Parkson Corp. (Axel Johnson Co.)
P.O. Box 408399
Fort Lauderdale, Florida 33340-8399
(305) 974-6610

ComrnentslRecommendations

2.9 Belt Filter Press

Facilities Using It

- Prototype designed for swine manure.
- Pulp and paper mills.
- Municipal sewage treatment facilities.

Design Features

Two conveyer belts running parallel to each other are wound around the same roller. The common roller squeezes the slurry between the two belts. Water flows through the fabric filters and the solids remain on the belts. Chemicals are used to condition the waste stream.

Belt life varies from 30 days to 4 months (with proper maintenance and debris removal devices), typically 30 to 90 days. Primary Sludge can be dewatered to 20% to 50% solids with a rate of 10 to 30 gpm of sludge per foot of belt width. Biological Sludge can be dewatered to 10% to 20% solids with a rate of 5 to 10 gpm of sludge per foot of belt width.

The largest belt presses manufactured typically handle about 200 gpm. This technology requires a homogeneous inflow to get maximum dryness.

Pros

- The press will create a homogeneous largely dry sludge cake.

Cons

- Short belt life.
- Need of chemicals.
- Intricate machine needs continuous attention.
- Technology is used to remove part of solids from (pre-treated) manure. Recovered solids are dry (35% TS). Effluent typically has 1-1.5% TS.

Manufacturers

Andritz - Ruthner Inc.
1010 Commercial Boulevard
?50uth"Arlington, Texas 76017
(817) 5611

Ashbrook Simon - Hartley
P.O. Box 16327
Houston, Texas 77222
(713) 449-0322

H.D. Fowler Co.
P.O. Box 160
Bellevue, Washington 98009
(206) 746-8400

Hydrocal Inc.
Suite E8, 23011 Moulton Parkway
Laguna Hills, California 92653
(714) 455-0765

Roediger Pittsburgh Inc.
3812 Rt. 8
Allison Park, PA 15101
(412) 487-6010

Comments/Recommendations

Operating parameters and results are dependent on the characteristics of the sludge and conditioning chemicals used. Pilot scale testing is essential. The press used for pig manure produces sludge cake of about 35% solids. It will lower the solids content of pig manure to 1-1.5% from >5%. Technology is being refined to increase efficiency and belt life.

2.10 Inclined Screens

. ***Facilities Using It***

- Dairy operations.
- Only found in swine operations where kernel com is included in feed.

Design Features

Slurry flows down an inclined screen from a header; the solids stay on the screen, liquids pass through. In the Clay system, the slurry flows down at the left side of a sloped screen and then is dragged up the right side of the screen by scrapers. At the top of the screen the scraped solids fall into a channel where they slide into a roller and are squeezed out into a pile. The liquid fraction collects beneath the screen and is recovered. TS content of solids fraction = 11.9-19.0 % (Dairy manure) for Clay, 3.3% for Key Dollar and 9.0-11.2% for Agpro.

Pros

- Roller press may greatly contribute to the performance of the separator (dairy manure).
- Relatively cheap equipment to remove coarse solids from manure.

Cons

- Grit (i.e. sand) passes through the screen, effluent contains large amount of organics.

Manufacturers

Agro Inc.
Route 7
P.O. Box 100
Paris, Texas 75460
(214) 78%5531

Clay Equipment Corp.
101 Lincoln
Cedar Falls, Iowa 50613

Comments and Recommendations

Inclined screens are commonly used in dairy operations using the "flush system." Solids are removed from liquid manure flushed from the barn before treatment, land application or recycling. Solids are composted or applied to the land.

In swine operations where kernel com is used as feed, the screen will remove the undigested kernels from the waste stream. Kernels could then be re-used as feed.

References

McKenzie, Frazer B: ***Evaluation*** of *Three* ***Solid/Liquid Manure Separators*** Using Dairy ***Cattle Manure.*** B.Sc. Thesis. Department of Bio-Resource Engineering, The University of British Columbia, Vancouver, B.C. 0986).

2.11 Sonic Vibrators

Facilities Using It

Not found in agricultural use.

Design Features

Sonic vibrators are used to extract maximum water from a partially dewatered sludge. Acoustical vibrations in conjunction with mechanical pressure and electric current remove the free water trapped in the sludge. The device is similar to a belt press but has an additional belt that acts as a cathode while a large roller acts as the anode.

Pros

- Produces a very dry cake due to combined action of vibrator and presses.
- Relatively new technology, therefore probably hasn't been tied with agricultural waste.

cons

- Relatively new technology, therefore there is not much information on case studies available.
- May require thickening or conditioning of the slurry before separation.

Manufacturers

Ashbrook - Simon- Hartley
P.O. Box 16327
Houston, Texas 77222 "
(713) 449-0322

Comments and Recommendations

2.12 Vacuum Filtration

Facilities Using It

- *None* found using agricultural waste
- Some Pulp and Paper Mills have used the technology.
- Also found in the Food Industry.

Design Features

Vacuum filtration can be applied to many processes. A low pressure behind the screen or belt or filter will encourage the water to travel through the filter. The vacuum filters described, all consist of **a** large drum half submerged in the slurry. A vacuum is applied on the inside of the drum, pulling the liquid into the center of the drum while the solids stick to the media on the surface of the drum. The difference between the types depends on the media used and the means of removing the solids.

Belt-unit: A belt is wrapped around the large vacuum drum and around several smaller rollers. The solids are removal from the belt when they pass over the small diameter rollers. The system may also be quipped with spray washers. The belt is made of fabric, either natural (cotton etc.) or more likely synthetic (nylon, dacron etc.).

Coil filter: Identical to the belt-unit except that the media wrapped around the drum and rollers is not fabric. Stainless steel, helically coiled springs (i.e., like small diameter “slinkys”) are wound around the drum. Usually in two layers.

String-discharge: Identical to the coil filter, except that instead of coils, string is wound around the drum and smaller rollers.

Drum filter (also called a scraper-discharge): Similar to the belt-unit except that the belt is wound around the drum only. There are no smaller rollers. The solids are scraped off the surface of the drum as it rotates, by a stationary knife.

Pros

cons

- Usually requires chemical pretreatment of biological sludges to achieve satisfactory yields and a clear supematant.
- Potential for blinding of belt media.

Manufacturers

Pollution Control Engineering
8520-A Sorensen Avenue
Santa Fe Springs, CA 90670
(213) 945-7521

Komline - Sanderson
12 Holland Avenue
Peapack, NJ 07977
(201) 766-2774

EIMCO Process Equipment Co.
P.O. Box 300
Salt Lake City, Utah 84110
(801) 526-2000

Comments/Recommendations

"Old technology" for sludge dewatering.

2.13 Plate and Frame Presses

Facilities Using It

None found using it with swine waste, used with sewage sludge.

Design Features

Both types of filters consist of depressed plates held vertically in a frame for proper alignment and pressed together by a hydraulic cylinder. Filter cloth is stretched onto the plates. Slurry is pumped under pressure into the empty space between the plates, and bounded on either side by the filter clothes. The liquid is squeezed through the filter cloth and the solids remain in the space between the plates. The liquid leaves through an outlet in the bottom of the plates. The solids (also called filter cake at this point) are further compressed and dried by high pressure air (225 psi) forced into the slurry inlet.

Removal of dewatered cake is done by manually separating the plates and loosening the layers of cake from the recessed plates with a wooden paddle if they do not drop by force of gravity.

Variable volume diaphragm press is designed for automatic operation. After opening, the cakes are forcefully discharged and the filter cloth is automatically washed before the press closes for another cycle.

Dewatering of wastewater sludge requires lime and ferric chloride conditioning polymer flocculation is not suitable. Chemical conditioning improves sludge filterability by flocculating fine particles so that the cake remains reasonably porous, allowing passage of water under high pressure. Precoating the media with diatomaceous earth or fly ash helps to protect against blinding.

Cake solids content greater than 35% (40 to 50% solids is possible).

Batch process takes about 2 to 3 hours.

Pros

- Variable volume diaphragm press: reduced manual labour.

cons

- Variable volume diaphragm press: increased mechanical complexity.
- More expensive, higher operating costs and very large compared to vacuum filters and belt presses.
- Slurry must be pretreated.

Manufacturers

Baler Equipment
P.O. Box 1837
Portland, Oregon 97207
(503) 224-9059

Bepex Corp.
P.O. Box 880
Santa Rosa, CA 95402
(707) 586-6000

CPC Engineering Corp.
441 Main Street
Sturbridge, MA 01581
(508) 347-7344

CommentslRecommendations

The filter clothes are susceptible to blinding or clogging. Without performing a pilot test with agricultural waste, it's difficult to tell if this technology would work. In general, it is much too labour intensive and awkwardfor use in an on-farm situation.

2.14 Centrifuges

Facilities Using It

- ***some*** products are used with (pre-digested) swine waste (see Ecowat).
- Used in the food processing industries and some municipal sewerages.

Design Features

Basket centrifuge; batch process, a cylindrical screen (also called the basket) standing vertically, is rotated about its long axis. The basket is enclosed by a sealed cylindrical bowl. Slurry is applied at the bottom of the basket behind an accelerator wheel that brings the (slurry's) speed up to maximum bowl speed. Solids accumulate on the inside of the basket wall while clarified effluent overflows a lip ring at the top of the basket. The cake that forms on the inside of the basket is scraped off with a knife or skimmer.

Solids capture in excess of 90% is possible without chemical addition while producing a concentrated slurry up to 10% solids.

Disc centrifuge: Limited use in wastewater sludges similar to the basket centrifuge except that the sealed cylindrical bowl is split into two halves. Periodically the upper and lower halves are separated mechanically (accompanied by a loud bang) to empty the supematant.

Solid Bowl scroll centrifuge: A tapered auger (also called a rotating-screw conveyor) is mounted inside a rotating closed cylinder (also called a bowl) with a cone section at one end. The bowl and auger spin around their long axis. The slurry enters into cone of the bowl at the narrow end of the auger. Alternatively, the slurry may enter through the side of the cylinder. The slurry is spun against the inside bowl wall. Settled solids are moved by the auger to the narrow end of the bowl. The supematant (or liquid) discharges at the other end over an adjustable dam plate.

Solid bowl scroll centrifuge is best suited for separating solids that compact to a firm cake and can be conveyed easily out of the water pool. Flocculent solids can generally be made scrollable by chemical conditioning of the sludge.

Cake of 2&37% solids with 40-90% solids capture are possible, polymer dosed basal on operating conditions and sludge characteristics.

Pros

- The solid bowl scroll has operational flexibility. Machine variables include pool volume, bowl speed, and conveyor speed.
- Anaerobically digested solid separate effectively because of their particulate nature. Raw primary sludge is more difficult to dewater efficiently, since it contains organics that are difficult to clarify and scroll.

- Totally enclosed, thereby minimizing odours.
- No sprays or exposed sludge.
- Solid bowl scroll: continuous process.

cons

- Solid bowl scroll: If solids compact poorly, moving a soft cake causes redispersion, resulting in poor clarification and a wet concentrate and difficulties obtaining a clear centrate.
- High moisture cake, while biological sludges require substantial chemical conditioning.
- Rapid wear and repair is not a simple task.
- Expensive to purchase and operate.

Manufacturers

Alpha - L.aval - Sharples, (Steve Fenton)
101 Miller Avenue
Scarborough, Ont.
MIS 4S6
(416) 299-6101

Baker International
WEMCO Division
P.O. Box 15619
Sacramento, CA 9582
(916) 929-9363

Bird Machine Co. Inc.
Naponset Street
South Walpole, MA 02071
(508) 6684400

Dorr - Oliver Inc.
12 Wheelers Farm Road
Milford, CT 06460-8719
(203) 876-5500

Jenkins Industrial Machine Works
1137 Swift
North Kansas City, MO 64116
(816) 471-3785

Comments/Recommendations

A centrifuge is being tested on a hog farm in the Fraser Valley. This farm has a feed-mill and may not be representative for hog farms in general. Feed and manure contain large quantities of roughage. A centrifuge has been used in the ECOWAT system (see page A3-62) to successfully separate aerobically pre-digested sludge from the liquid fraction.

2.15 Hydro Cyclones

Facilities *Using It*

- None found with swine manure.
- More commonly used in chemical, mining and food industries

Design Features

Slurry is injected tangentially into the cyclone at a very high speed. The slurry swirls about the center of the cone and moves toward the narrow bottom of the cone as new fluid is injected. Cent*gal force causes heavier material to travel to the wall of the cyclone and out the lower opening. If the hydrocyclone is designed and adjusted correctly, the fluid, which is less dense, will create a vortex, reverse direction and leave the cone through the "vortex finder".

Some fluid leaves the apex with the solids.

Coagulant such as polyelectrolytes are effective in improving hydrocyclone efficiency for removal of biological solids. Clays may be used to weight the particles.

Pros

- ***Have* a** high capacity for the space required.
- Good separation based on particle size and particle weight.

cons

- Cannot remove fine suspended solids.
- Must use chemical conditioners prior to thickening biological sludges.

Manufacturers

Technequip
297 Garyray Drive
Weston, Ontario
M9L 1P2

Pekor Iron Works Inc.
P.O. Box 909
Columbia, Georgia 31902
(404) 324-1354

Alpha - Laval, (Steve Fenton)
101 Miller Avenue
Scarborough, Ont.
MIS 4S6
(416) 299-6101

Comments /Recommendations

From the available literature, it doesn't appear to be worthwhile to pursue cyclones any further for use in agricultural waste at this time. Results with biological sludges. were not good. The weight differential between the solids and the liquid phase may not be high enough. Clay added as a pre-treatment may weight the solids and **increase** operation efficiency. The METS system uses clay to condition the solid fraction of raw municipal wastewater to enable separation in a hydrocyclone.

2.16 HepaQ House

Facilities Using It

Hendnx"Feeds and Paques have joined to invest in a pilot scale pig house called HepaQ House; pilot facility in The Netherlands, two or three farms are using the technology commercially.

Design Features

The objective of the HepaQ House is to reduce ammonia in the barn and to reduce the water content in separated sludge for easy transportation and further dewatering. The shallow "deep pit" of HepaQ House is flushed two times per day with a flushing liquid with pH 6 to reduce ammonia emissions in the barn. A flow pattern is established in the deep pit using plastic baffles to reduce the quantities of flush and to prevent short-circuiting. The slurry is then separated into **a** liquid fraction and a viscous fraction by means of settlement. The viscous fiction has a TS content of 18-20%. The liquid fraction is recycled as flush after aeration and pH adjustment. Excess water is evaporated with band evaporator, using the ventilation fans of the building. Results obtained in the test stage showed a reduction of **50%** in manure volume and **70%** less ammonia emissions.

Hendnx Feeds and Paques both expect this new system to be available on the market in the course of 1991.

Pros

- Virtually no labour required; lowers the ammonia levels in the barn.
- High solids manure for off-farm disposal.

Cons

- The system produces water vapour and thickened slurry.
- Evaporator may cause odour problems, chemicals **needed**.
- Need for land **base** or off-farm disposal.

Manufactures

Paques/Hendrix Feed (Sperd **Bokma)**
P.O. Box 1
5830 MA Boxrneer
Phone: 08855-89911

Comments/Recommendations

Liquid fraction is "treated" with acid and is aerated. The objective for designing the system was to thicken pig slurry on-farm, before it is shipped to centralised drying plants and to improve the barn environment.

2.17 Freeze Dry Sludge Dewatering

Facilities Using It

Pilot scale operation in New Hampshire for dewatering of sewage sludge, ' operational in Oswego, New York and Duluth, Minnesota.

Design Features

Sludge from waste water treatment facilities is collected in a "sludge drying bed" and frozen during the winter. At spring breakup, meltwater is allowed to-drain. Sludge cake is rapidly dewatered till 30-35%. The sludge cake is then removed by ' front end loader and discarded.

The advanced design includes a drying pit with one ramp to allow entry of a loader, slotted walls and snow protection. Sludge is added in layers on top of frozen material. The dewatering bed serves as a storage facility for all sludge produced during the winter.

The shucture of the sludge is changed through dehydration of the material and compression by ice. Sludge particles coagulate and water can drain out quickly.

A related technology is freeze cristalisation, where a refrigerant is bubbled through a solution. Water is crystalised on the surface of the refrigerant and then removed from the surface as pure ice. Freeze cristalisation is a method to concentrate solutes by removing pure water. This technology has been used to concentrate a plating solution and to clean mine drainage.

Pros

Low-tech method for dewatering sludge. Uses winter cold to separate solids from a liquid fraction. Works with sludge concentration ranging from **1.1%** to 6.4%. Draining times are very short.

Cons

Experimental procedure. Has only be tried for dewatenng of sludge from an anaerobic digester. Depends on winter cold. Effluent is still of relatively high strength BOD (330), COD (740) and TSS (96 mg/L) and may need further polishing. No data available on nitrogen and phosphorus content. Dewatering only take place at spring break-up.

comments

The freeze thaw drying bed has been used in a pilot operation only. However, freeze thaw drying beds have been used in commercial applications. The technology works best with anaerobically digested sludge. Low levels of solids (1.1%). were tested in this treatment with excellent results. Drainage water needs further polishing. It is a low-tech method to dewater sewage sludge and other concentrated waste streams.

References

Martel, C. James: *Development and Design of Sludge Freezing Beds.* CRREL Report 88-20 for US Army Corps of Engineers (1988).

Martel, C. James: Dewaterability of Freeze Thaw Conditioned Sludges. *Journal of Water Pollution Control Federation 61:237 (1989).*

Martel, C. James: Development and Design of Sludge Freezing Beds. *Journal of Environmental Engineering 115:799 (1989).*

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2.18 Reverse Osmosis

Facilities Using It

Drinking water suppliers; householders; used in desalination plants. In the Netherlands, reverse osmosis has been used for final treatment of effluent from manure handling facilities.

Design Features

Membranes are used to separate water from dissolved solids using a pressure differential over the membrane. Effluents from manure handling facilities in Western Europe cannot be discharged due to the high salt content of the effluent. Reverse osmosis is used to reduce the salt content (Van Tongeren and ten Have, 1991.)

Manure needs to be pretreated through removal of solids and acid treatment with 1-10L of concentrated acid/m^3 manure. Without biological treatment, discharge to surface water may not be permitted due to high COD and NH4 levels in the permeate. Biologically treated effluents can be concentrated up to six times, non-treated effluents can be concentrated 2.5-3.5 times. Pressure of 4040 bar is needed to treat manures.

Pros

Process to separate water with a low salt content from manures. Suitable for thickening of manure in the on-farm situation.

cons

- Expensive process for use with manures and "thick" waste.
- Needs pretreatment through biological treatment or acidification.

Manufacturers

Zenon Environmental Inc.
8577 Commeraal Court
Bumaby, B.C.
(604) 444-4808

Cornrnents

The life of the membrane is expected to be about two years. The process is well suited for the polishing of effluent of a biological treatment facility. The membrane will remove a portion of the solutes from the liquid stream, depending on the pressure applied and the concentration of the solutes. When the technology is used to treat wastewaters with a high concentration of contaminants, the resulting effluent may not be of discharge quality.

References

Van Tongeren, W.Q.J.M. and P.J.W. ten Have: *Toepassings mogelijkheden van omgekeerde osmosis by mest verwerking*. Report CB/349, TNO - Environment and -Energy, Apeldoom, The Netherlands (1991).

2.19 Engineered Marsh Treatment For Sewage Sludge De-watering and Mineralisation (Reed Bed)

Facilities Using It

Three references from the recent publication were found describing work with engineered marshes (Constructed Wetlands in Water Pollution Control, 1990), pilot scales studies in Denmark, France, and Germany. All look at sludge from conventional sewage treatment plants, aerobically stabilised and anaerobically stable sludge.

The Solar Aquatic Greenhouse pilot plant is using a reed bed for sludge dewatering.

Design Features

Most units were constructed from old sludge drying beds. Otherwise, special containment were built along the lines of sludge drying beds. The units had sloped bottom surfaces with draimge to collect seepage liquid. The drainage varied form porous gravels separated from the sludge and reed growth media by geotextile or drainage pipes. The drainage pipes were of the perforated PVC type or a specialised German pipe called BIOTERRA. These drainage pipes acted as aeration mechanisms as they are connected to the surface by additional piping. The sides of the marshes were high enough to contain overlaid sludge layers. Liquid passing to the drainage pipes was transported back to the wastewater treatment unit.

Sludge was applied to the surface at various rates, slowly at the beginning of plant growth to ensure sufficient plant propagation and no damage to young plants. *Phragmites* was the common plant used, but it is recommended that the plant used be chosen as to the sludge to be applied. Up to 2-3 years may be needed to obtain a mature reed bed to maintain maximum treatment.

Once the reed beds have established themselves, various applications were tried, usually with a rest period between applications, but not necessarily. Literature was cited claiming up to 20 years of continuous application, with the systems described in the three articles operating at around two to three years continuous application. Application during winter months, when freezing occurs, is not recommended. De-watered sludge does not need to be removed, the sludge will develop into a soil/compost-like material and in some cases mineralisation was recorded.

Examples

For a aerobically stabilised sewage sludge of 0. S1.0% dry matter and 3-4% party digested anaerobic sludge, up to 96.7% reduction in volume was recorded. 1176 m^3 of sludge was added, a height of 10.23 m (theoretical height) left a residue of 39 m^3 and 0.34 m deep sludge layer. (4 X 100 m^2 beds at a 800rn^3 per year at 370 dry matter).

For a partly anaerobically digested sludge at 4.5% dry matter at a 300m3 per annum application rate (2X 100 m^2 beds) 91% reduction was observed. The sludge added was 171 m3, an equivalent height of 1.71 m, and was reduced to 15m^3 and a -0.15 m sludge layer.

Pros

- Reed beds appear to have greater ability to remove water from sludges than drying beds, less Iabour intensive and don't need to have any transportation of sludge away before or after de-watering. They do not need to be turned as sludge drying beds, and do not have the disadvantages of land disposal of sludges.

- A low-tech, low maintemnce method for dewatenng sludge.

Cons

- *Need* to design appropriate system. It was suggested that this type of system may need more land than a drying bed, therefore land cost might be a factor. Reeds need time to establish; only stabilised sludge can be used in reed beds due to odour problems. Minimal operation during winter. No saleable products, may need to be emptied in the long run, creating difficulties with reed debris and root systems.

- As compared to traditional method of de-watering, sludge drying beds and land applications require holding tanks for storage prior to hauling away for application (if suitable land is available within reasonable distance), this is expensive to build, but less labour intensive.

Manufacturers

There are no manufacture of these systems, they are self constructed according to design criteria.

Comments and Recommendations

Relatively new technology, some gamble associated unless pilot scale studies (long term) used to determine potential problems.

Appears to be quite successful at de-watering of sludge without removal of the finished product.

One author suggested that the de-watered sludge could be removed in the long run (did not say how it should be done to avoid damaging plants) and used as a fertiliser.

The quality of the seepage maybe a factor as it will need to be dealt with as well.

Plant choice may be quite critical in this case as it will need to be exposed to the sludge at high concentrations. Plants should be native to the area where the reedbed will be located.

Currently used with **sewage** sludges from clarifiers with a TS of up to 4%. Sludges from manure stabilisation or treatment facilities may have TS contents of approximately 15%. The technology is not proven for dewatering of sludges with a high solids content.

References

Neilsen, S.M: Sludge Dewatering and Mineralisation in Reed Bed Systems. Constructed Wetlands in Water Pollution Control, IAWPRC. Proceedings of the *International Conference on the Use of Constructed Wetland in Water Pollution Control, September 24-28,2990.* P.F. Cooper and B.C. Findlater eds. Pargamon Press, Oxford (1990).

Lienard, A., et. al: Sludge Dewatering and Drying in Reed Beds: An Interesting Solution? General Investigation and First Trials in France. Constructed Wetlands in Water Pollution Control, IAWPRC. *Proceedings of the International Conference on the Use of Constructed Wetland in* Water *Pollution Control, September 24–28, 1990.* P.F. Cooper and B.C. Findlater eds. Pargamon Press, Oxford (1990).

Hofmann, K: Use of Phragrnities in Sewage Sludge Treatment. Constructed Wetlands in Water Pollution Control, IAWPRC. *Proceedings of the International* Conference *on the* Use of *Constructed Wetland in Water Pollution Control, September 24-28,1990.* P.F. Cooper and B.C. Findlater eds. Pargamon Press, Oxford (1990).

3 WASTEWATER TREATMENT

3.1 Sequencing Batch Reactors (SBR)

Facilities Using It

- Peter Hill's farm in Langley, B. C.: Swine waste.
- Sewage treatment.

The following systems have been installed in the Winnipeg area (all were made by Bioclear):

- Spruce Point Mine: *5,000* Igpd.
- The Pas Indian Band: 150,000 Igpd.
- Rivercrest: 50,000 Igpd.
- Glenlea; 1.000 Igpd.
- Industrial Wastewater: High strength food-processing wastewater.
- Other installations in Northern Manitoba.

Design Features

In this system, the wastewater remains within the same vessel. The reactor is alternately mixed and then allowed to settle. Some reactors are operated with periods of aeration alternating with periods of settling and amerobic conditions.

Mixed liquor and / or sludge is removed periodically.

The hydraulic retention time is anywhere between 15 days and 0.5 days.

Ammonia is nitrified to nitrite and then to nitrate during the aerobic stage. In the anaerobic stage the nitrate is converted to nitrogen gas. This is a result of microbial activity. Both amerobic and aerobic microbes are present in the vessel at all times, but the organisms only become active when the oxygen levels are favorable. Therefore we can conclude that strict-anaerobes are not very active in this system.

It's possible (and recommended) to run more than one SBR in parallel to prevent complete shut down of the treatment system in the event of a failure.

The capability for the SBR system to withstand shock loads of toxic substances and high organic loads is further confirmed in studies by Pisano, et. al., 1990 and Reinhard, et. al., 1990.

Pros

- The advantage to the SBR is that ammonia is removed from the system. This is a result of anaerobic and aerobic microbes working within the same system. Traditionally, amerobic digestion has been used to reduce the volume of a sludge.

- Requires relatively small space because there is only one vessel.
- Liquid-solid separation within the reactor occurred readily without the aid of flocculation agents, leading to the development of a sludge blanket.
- The reactor required very little operator attention since it was effectively controlled by a microprocessor controller.
- SBR'S are not subject to "short-circuiting" whereas the Continuous Flow systems may have problems.
- Filamentous bacteria, which do not allow a sludge *to* settle, are less likely to develop in an SBR The batch mode of operation also discourages the growth of microorganisms that cause sludge bulking.

Cons

- Because the SBR uses only one vessel, pumps, and timers are required. The more complicated the equipment, the more often it can break down.
- Filamentous bacteria, sulphur-fixing bacteria and other undesirable organisms can over-run the system forcing a complete shut-down, washin& and start-up, to correct the problem. Unpredictable how often this might happen (every other month or never).

Manufacturers

Bioclear Technology Inc.
Box 13, GRD 524, RR #5
Winnipeg, Manitoba
R2c 2Z2
(204) 222-6388

Northern Purification Services
261-B East First Street
North Vancouver, B.C.
V7L 1B4
(604) 984-4168

Jet Tech Inc.
Industrial Airport
Kansas

Comments/Recommendations

Six Bioclear systems are operating within the jurisdiction of Manitoba Department of Northern Affairs. These systems are designed for the treatment of wastewater from populations of 300-500 persons in areas where winter temperatures are frequently -40°C. Wastewater is hauled to the treatment facility.

Mr. C. Boyd (Manitoba Department of Northern Affairs) indicates that he has six Bioclear Technology systems in his jurisdiction at:

- Manigatnan
- Mallard
- Baincs River
- Indian Lake

- Pine Dock
- Matagsen Island

The system at Indian Lake is a retrofitted RBC unit designed for treatment of 39,000 gpd wastewater. The other systems are designed for treatment of wastewater from populations of 200-300 persons in areas where winter temperatures are frequently at -40°C.

The systems operate without problem, no operator problems, they are resistant to shock loads, show no odour problems and are economical to operate. Operational costs compare to those of a lagoon at about 5¢ per gallon for treatment. Cost of hauling is about 5¢ per gallon.

Influent BOD5 concentrations are about 1,200 mg/L and effluents range from 100 to 25 mg/L. Disposal sites vary from into a natural marsh to directly into a fresh water body. The systems are fitted with UV disinfection and chlorine.

At start up, the systems usually are operative and stable within three weeks and sludge production is apparently lower than that produced by RBC units. Support services from Bioclear are reported to be excellent.

Mr. Boyd also reported that there are a further three plants which have been installed near the northern Manitoba border by Public Works Canada. Mr. Boyd reported that a company called Jet Tech from the United States supplied an effective large system (100,000 gpd) but attempts to scale this down result in units having odour problems.

Performance of Bioclear Technology Inc. Units

	Flow Igpd	Total No. of Data Points	Effluent BOD5 (m#L) No. of Data Points With Value <10	<20	Suspended Solids (mg/L) No. of Data Points With Value < 10	< 20
Glenlea	1,000	57	54	55	49	56
River Crest†	50,000	18	6	13	5	13
Spruce Point Mine	5,000	11	11	—	11	—
River Crest‡		2 3	—	(9)	14	21
La Pas Indian Reservation	150,000	11	11	—	10	11

† 1983 data at start up
‡ 1988 data from Cityof Winnipeg
() TOC

The 1988 data for River Crest show two occasions where high solids losses from effluent occurred. Neglecting these values, the average effluent suspended solids was 8.8 mg/L and organic carbon was 22 mg/L.

In a pilot system, waste from a soy bean process, the Bioclear system reduced the incoming BOD5 from 12,630 mg/L to 800 mg/L, chemical oxygen demand was reduced from 31,430 mg/L to 243 mg/L when decanted effluent contained an average 330 mg/L suspended solids.

References

Droste, R.L: *Comparison* of *Continuous Flow and Sequencing Batch Reactors* for *Biological Wastewater Treatment for The Biotechnology* of *Wasta.eater Management, Science and Regulation.* Workshop (1990).

Pisano, S.L, J.C. O'Shaughnessy, D. LaMurre, C. Gray, S. Peterson and M. Sykes: "Toxic Organic Shock Loading of Rotating Biological Contractors and Sequencing Batch Reactors." In 44th *Purdue industrial Waste Conference Proceedings, 1990, 125-147.* Chelsea, Michigan: Lewis Publishers (1990).

Reinhard, J. D., J.A. Gordon and KS. Young: "Performance Analysis of a Continuously Fed, Intermittently Decanted Activated Sludge Plant Receiving a High Ammonia Packing House Waste." In *44th Purdue Industrial Waste Conference Proceedings, 1990807-824.* Chelsea, Michigan: Lewis publishers (1990).

Wun-Jem, N: A Sequencing Anaerobic Reactor for Treating Piggery Wastewater. *Biological Wastes.* Elsevier Science Publishers Ltd., England (1988).

3.2 Ecowat Process

Facilities Using It

Pilot plant in the Netherlands by Ecotechniek for aerobically stabilised piggery waste. Also usable for sewage and wastewater from airplane deicing fluids.

Design Features

Biological breakdown of organic matter, vitrification of ammonia and phosphorous through "biochemical co-precipitation." Physical/chemical dephosphorisation can be integrated. The process works in several steps.

In the aerobic step, wastewater is aerated, BOD is removed and ammonia is ' nitrified. Next, through flocculation with additives, and the use of a centrifuge, phosphorus is removed from the effluent through precipitation with chemicals. Sludge cake contains approximately 15% dry matter.

The liquid fraction is then denitrified under amerobic conditions under addition of methanol. Nitrogen escapes as N2 gas. In this state, 'biochemical co-precipitation" takes place. The effluent from this phase may be discharged. When a high salt content prevents discharge to open water, reverse osmosis may be used to remove the salt content

Effluent characteristics are: BOD <20, COD <500, TKN <15, NH3-N <3, TP <1 mg/1.

Pros

- Discharge quality water.
- High processing rate for removal of ammonia.
- Removal of phosphorus.

Cons

- ***Need*** of methanol and flocculating agents.
- Centralised or cluster use only; no on-farm size system available.

Manufacturers

Ecotechniek B.V.
Beneluxlaan 9
3527 HS Utrecht
P.O. Box 8447,3503 RK Utrecht
Phone: 31-30-957922
Fax: 31-30-940929

Comments

The technology is Computer operated and has a high capital expense. It is therefore not suitable for on-farm use. A small scale version has not been developed. A prototype installation was operated successfully for more than two years. No commercial applications have been installed. The process seems suitable to treat effluent from a large scale manure processing plant using anaerobic fermentation for the stabilisation of manures.

3.3 Rotating Biological Contractors

Facilities Using It

Subdivisions, recreational properties for sewage treatment.

Design Features

The rotating biological contactor was introduced in Europe in the mid *1960's. The* system consists of a series of discs mounted on a shaft. A small motor rotates the shaft. The disc assembly, half-submerged in the wastewater, slowly rotates when the disc is submerged. It accumulates substrates from the wastewater onto slime and biological firm growing on the disc. As the disc rotates, these biological films are exposed to the air and absorb oxygen needed for respiration and growth. As the organisms on the film age, some film sloughs off and passes out in the effluent. This is settled in a settling chamber.

An earlier evaluation (Smith, et. al., 1982) of RBCS for recreational areas compared several options for wastewater treatment: RBC-sand filtration, extended aeration, oxidation ditch, facultative / aerated lagoon, and septic tank / leach field. They found RBC-sand filtration to have the highest first cost of all alternatives presented. However, O&M cost is lower than extended aeration / sand filters and oxidation ditch / sand filters. Over a twenty year useful ife, [sic] the RBC system was less expensive in terms of total cost.

Pros

- Small scale unit for domestic sewage systems.
- System can be designed for specific vitrification rates.

Cons

- *The* RBC / sandfilter system may not be cost effective.
- High maintemnce costs have been encountered due to mechanical problems.

Comments

> Smith, et. al., 1982 conclude that considering the total cost of treatment and impacts to the environment, the RBC / sand filters system is preferable to both the extended aeration / sand Falters and the oxidation ditch / sand filters. In addition, the RBC / sand filter system should be chosen where: septic tank / leaching fields are inappropriate, land availability or cost prohibit lagoons, and vitrification is to be designed for (Smith and Scholze, 1989).

However, telephone discussions with Mr. C. Boyd, Engineering Manager of the Manitoba Department of Northern Affairs in Thompson revealed the numerous problems experienced with RBC'S:

- Media breakdown.
- Complete collapse of the media.
- Can cost $60,000/year to maintain.
- Does not resist shock loads of organic substrates.
- Broken shafts.
- A lack of warranty.
- Motor breakdowns.

References

Smith, E.D. C.P.C. Peon, J. Cullinane and G. Hawkins: *Evaluation of Rotating Contactor Technology/or Civil Works Recreational Areas.* USA CERL Technical Report N-126. Champaign, Illinois (1982).

Smith, E.D. and R.J. Scholze: "USA CERL'S Experiences With Small Wastewater Treatment Plants in the USA." In ***Small Wastewater Treatment Plants,*** Odegaard, ed. p69-76. TAPIR, Trondheim (1989).

3.4 Biological/Chemical Treatment

Facilities Using It

Small communities in Norway; Sewage treatment.

Design Features

Biological treatment of low flow waste streams from small communities is combined with chemical treatment to reduce phosphorous. Several combinations are used:

- Sirnultanious precipitation.
- Pre-precipitation.
- Combined precipitation.
- Post-precipitation,

Simultaneous precipitation combines chemical addition to active sludge operation; the combined plants are based on the biofilrn process (noxmally RBC) and addition of chemicals directly to the biofilm effluent before flocculation and sedimentation. Pre-precipitation is used in a lagoon situation and post-precipitation is almost entirely based on activated sludge process.

Aluminum sulfate and ferric chloride are commonly used flocculants in the chemical precipitation process (for phosphorus removal). Effluent data showed that from 174 Norwegian biological chemical treatment plants, post precipitation activated sludge performed the best, but these plants tended to have the lowest actual utilization of design capacity.

The most important factors that cause the treatment plants not to meet the effluent standards (for Norwegian requirements) are poor quality of the sewer system, improper design of the plant and organizational problems. Satisfactory separation of particles, flow equalisation and proper operational management are the basic demands to achieve low effluent concentrations for total phosphorous and biochemical oxygen demand. Average and medium effluent characteristics were:

	Average			Median		
Process	TP	BOD5	SS	TP	BOD5	Ss
Simultaneous Precipitation A/S	1.75	45	441	1.2	18	36
'Combined Precipitation Biological Contactor	1.47	25	30	0.8	10	27
Post Precipitation Activated Sludge	1.0	15	17	0.54	11	14

odegaard and Storhaug, 1989 provide a further review of small treatment plants in Norway and the working group recommended two systems as being acceptable in relation to performance.

— One system based on a low loaded activated sludge process with queming of particulate matter as pretreatment and with a separate waste sludge holding tank.

— One system based on a low loaded biofilm system (biofilter, RBC etc) with a large septic tank serving both as pretreatment and waste sludge holding tank.

In both designs the hydraulic control is achieved through a constant head tank. In this way a close to constant flow is applied in the process while the surplus water will be returned upstream. A stable hydraulic load on the settling unit is a matter of crucial importance for securing a stable operation of a small plant.

For the system based on the low loaded activated sludge plant, pretreatment through comrninution of particulate matter that normally would be screened away, is recommended.

For the system based on a biofihn process, pretreatment based on a large 2-3 compartment septic tank (or Imhoff tank) is recommended. The septic tank serves a triple purpose: pretreatment unit, sludge storage tank and equalization tank. It has therefore to be designed for all these purposes and consequently it will require a large volume.

The bioreactor of this system may be based on any of the traditioml biofilm reactor types (trickling filter, RBC, submerged, aerated filter etc.). Among the biofilm reactor systems, RBC'S have been dominating in Norway. The RBC'S have, however, to a certain extent lost their popularity because of many mechanical failures, and considerable interest has been shown to an alternative biofihn process, the submerged, aerated biofilter. This system consists principally of an aerated reactor filled with a media for the biofilm to grow on. The biofilter media is normally based on corrugated plastic sheets welded together to cubes, well known from plastic trickling filters, but new developments with respect to biofilm growth media are being done.

If chemical treatment is to be used, the chemical should be added downstream of the biofihn reactor and the suspension of biofilrn particles and precipitates should be thoroughly flocculated before settling, preferable in a multicompartment flocculator (combined precipitation). Three-valenced salts of aluminum or iron are most suitable as precipitation chemicals.

Pros

- Proven technology for small treatment plant for domestic sewage.

- Proven for cold climates.

cons

- Technical difficulties with RBC units, where RBC are included.

- Post-precipitation needs considerable attention by operators.

Comments

Submerged aerobic biological filter is used to replace the RBC or activated sludge system. A preciesigned plant is brought on the market including pre-treatment septic tank, anaerobic submerged biofilter, aerobic submerged biofilter, flocculation and settling. Effluent is treated with *Wand* ozone (Kalnes / Sintef System).

References

ociegaard, H. and R. Storhaug: "Small Wastewater Treatment Plants in Norway." In *Proceedings, International **Specialized*** Conference *on Design and Operators of Small Wastewater Plants, p45-52.* H. Odegaard, ed. (1989).

Storhaug, R: "Performance Stbility of Small Biological Chemical Treatment Plants." In *Proceedings, International Specialized **Conference** on Design and Operators of Small Wasteunzter Plants, p284-290.* H. Odegaard, ed. (1989).

3.5 Oxidation Tower

Facilities Using It

Swiss design, pilot plant in Raalte, The Netherlands for swine waste.

Design Features

Separated effluent of an anaerobic pre-treatment is cleaned in a bio-oxidation tower. Heated air is used for temperature control and to encourage evaporation. Cleaned effluent is reused in barn as flushing fluid.

Pros

Cons

Comments

System still in pilot stage. Performance not as well as expected. No further information available at this time. Major modifications have been made.

3.6 Anaerobic Lagoon

Facilities Using It

- Gasser Farms (Eastern Canada - swine/dairy mixed) not operational.

- Mason Dixon Farms (Pennsylvania, south of Harrowsburg - dairy) fully operational.

- Small communities in the North for sewage treatment.

- Anaerobic lagoons are commonly used for storage, settling, treatment of dairy manure and odour control. After storage, the liquid phase is land applied by tanker truck or spray irrigation. An inclined screen may be used to remove solids from the manure prior to storage in the lagoon.

Design Features

- Most simple design, consisting of a large, rectangular storage tank with an influent pipe at one end and a effluent pipe at the other end. The tank is uncovered, thus there is no biogas retrieval. There is no mixing, although sometimes the surface is agitated with a flotation device. The influent is not heated, nor are there internal heating devices.

- Retention times **are 25-50** days (and is a function of the influent characteristics and the vigour of the bacterial population).

Pros

- Low capital costs, low operations costs and low expansion costs. Doesn't require much technical expertise nor complicated mechanics.

Cons

- Poor effluent quality (i.e., doesn't reduce the % T'S, BOD, COD as much as a more sophisticated unit would). Solids removal is required to clean up the effluent for ease of irrigation-type of application. Also, need to periodically remove the residual, stabilised sludge from inside the lagoon.

- Requires a relatively large land base, because retention times are relatively long and therefore storage requirements are high.

- Open storage like this means gases are vented to the atmosphere and therefore the system "contributes to atmospheric pollution (CO_2, CH_4, NH_3) and global warming".

Manufacturers

No one designs or builds these units. They are built for open-air storage or as a low-cost, but inefficient alternative to a more sophisticated design.

Comments and Recommendations

As a very low cost technology, and if there is an existing storage facility that can handle the capacity, this may be a viable pre-treatment step in a complete manure . treatment train.

3.7 Bulk Volume Fermenter

Facilities Using It

Unknown for swine manure, but many for industrial effluents.

Design Features

- *The* same as the anaerobic lagoon, but covered with a floating membrane under vacuum. The membrane is used for biogas coUection, temperature control and positive odour control. The membrane cover can be insulated.
- As with the open lagoon, there is no mixing or heating.
- This is a "low-rate" system, i.e., loading rates are 0.5-3 kg COD/m3/d.

Pros

- Same as amerobic lagoon with the additional option of biogas retrieval and use. The gas bag also minimises odour and heat loss.
- No need for primary sludge treatment or de-watering.
- Due to the large physical size of the BVF, can tolerate shock loadings (organic, pH, temperature, solids, toxicity).
- Minimal explosion hazard because of the flexible membrane.
- Biogas is produced evenly and can therefore be used continuously at its rate of production.
- Can be operated at lower temperatures (20-40°C).
- Produces less waste sludge than a high rate (high-tech) reactor.
- It is possible to recycle "waste biological sludge from an aerobic system to the reactor, which rem-its in savings in sludge de-watering, handling and disposal costs and has a further benefit of produang additional biogas while recycling nutrients and alkalinity to further reduce operation costs."

Cons

- *Same as* anaerobic lagoon. The biogas retrieval requires more sophisticated mechanics and instrumentation and there are problems with the corrosive nature of the gas. High H2S and CO_2 contents, react with the 40% moisture of the gas to produce sulphuric and carbonic adds, both of which are corrosive and damage the metal parts associated with the gas handling and energy production systems. In-line scrubbers can be installed to remove H2S (to <2 ppm) and water, however this is an added technical demand on the operator.

- The gas bags are made from '*Hypolon", a space age polymer, and are subject to damage from high cross-winds and from UV light. A properly constructed facility would require the addition of a frame building to protect the gas bag from these potential environmental impacts. Temperature extremes and adverse snow/rain fall events do not effect the bags.

Manufacturers

ADI International Inc. (Dr. Bob Landine) ADI "offers seven anaerobic technologies", this being the least costly. They have many natioml and international installations, although none specifically for swine manure.

Comments and Recommendations

There are other low-cost technologies that have some simple design modifications that improve the efficiency enough to not warrant use of this system as a stand-alone unit. It has been used in conjunction with other systems as a pre-treat-ment step.

Many researchers / design engineers / fanners say that anaerobic treatment is not justified on the basis of biogas recovery alone. This is largely due to poor energy economics, but also due to problems associated with engine generator sets, heat exchangers, pumps, boilers, etc. This is particularly true for the farm operator running a medium-sized operation (1*200 hogs) who doesn't have the time, the desire, nor the technical expertise to run a complex and potentially dangerous gas collection / recycling system.

3.8 Plug Flow Reactor

Facilities Using It

- ***Cornell*** University (Dr. William Jewell and his assistant, Bob Cummings from the Ag. Eng. Dept. Much of the design specifications and comments here are as **a result** of **a** conversation with Bob Cummings).

- Arizona Dairy Corporation (a unit designed by Dr. Jewell's private company and installed in a 5000 milking head dairy operation).

Design Features

- Similar to a Bulk Volume Fermenter except that the floor is tilted to allow the sludge to flow under gravity. Influent is pumped into the raised end and effluent is pumped out at the lower end. There is a collapsible bag for biogas retrieval.

- Reactors have internal heat exchangers, although some preheat the influent. Mixing is achieved through thermal overturn, the gradual movement of the sludge down the grade, and by the biogas bubbling up through the reactor.

- Reactor operates best between 35-50"C.

- Retention times are 2S30 days.

Pros

- Relatively low capital costs and low maintemnce requirements.

- Maintenance energy required to keep the temperature in the reactor stable is about 10% of the gas production. The main energy requirement is in heating the influent. This is usually done by recovering the waste heat from an engine generator set.

. Dairy manure works better than hogmanure, because of the higher % TSand also the rumen bacteria are compatible with those in the reactor.

cons

- Floating biogas cover minimises wind damage to the biogas bag, however W may still be a problem.

- % TS must be >10% to maintain gravity flow and homogeneity of digestor contenk. Typically the influent concentration is about 30'% TS and the reactor content about 15-16%. This high initial % TS is achieved by dehydration (either through **screening** and/or **evaporation)** Or by **mixing** different manures or bedding materials together.

- When TS c10%, the reactor develops a scum layer and traps the biogas. Biological instability (due to improper influent loading or to biological "spiking") can cause foaming and this will plug up gas lines.

Manufacturers

Dr. Jewell from Cornell University.

Comments and Recommendations

This particular technology is not suited to treating only swine waste, because of its incompatible % TS.

3.9 Completely Mixed

Facilities Using It

- Fallis Farm (Millbrook, Ontario - 95 sow, farrow to finish operation) No longer operational. Mainly a question of economics and lack of technical support.

- Linden Lee Farms (PEI -200 sow, farrow to finish operation) Was fully operational but due to economics and trouble with maintaining the gas recovery/engine generator system, the system is now only partially functional. The energy production was less than theoretically designed, and the global energy costs did not increase according to predictions. Furthermore, the gas recovery system was prone to breaking down and parts were expensive. He stressed the poor economics. Aike Wilting now diverts 10% of his manure stream (about ***20,000*** L/d) through his reactor (275 m3) in order to grow a seed anaerobe population with which he inoculates his open storage lagoon. He does this solely for odour control in the interest of good public relations. The system requires his input every two to three weeks (or when time permits) in order to recycle the waste. The reactor runs at ambient temperature, retention time is in the order of +25 days and he no longer mixes the material. His maintenance is minimal and he has been operating like this for two years.

- Selves Farms (Fullarton, Ontario -400 sow, farrow to finish operation) The unit is fully shutdown after intermittent operation for about 5 years. The farmer pssed away and his wife and son tried to operate. The system was a 230 m^3 below ground tank which had eventually cracked and leaked. These people had limited success with feeding trials of SCP recovery. As with so many of these *systems,* the problems were probably a combination of design, technical and political.

- Olds College (Olds, Alberta - 60% swine and 40% dairy operation -140 sows, farrow to finish and 60 cows) Educational institution that also has beef, sheep, poultry, equine and crop schools. The hog barn is a slatted floor with flush out gutters and below ground storage. The cows are bedded on recycled newspaper because they had problems with matt formation in the reactor when they used other beddings. Straw floats and shavings sink in the reactor, creating matts that are difficult to mix and digest, and they inhibit the transfer of the gas through the sludge. The newspaper has improved the digestion capability and therefore, lowered the retention time. Their digestor is 385 m^3 and processes about 17000 L/d, at about 8% TS and about 2 kg COD/m^3/d. The retention time is about 20 days. They mainly operate for odour control, but also for educational purposes and because this is the cheapest way for them to process their waste. The digested effluent (2% TS) is irrigated onto field crops (barley, silage, alfalfa) during the growing season (approximately 10^6 gal in the spring and 0.8X 106 in the fall). It naturally requires a land base to store and apply this. The effluent is a cheap source of immediately available nutrients (N and P) and application rates must be carefully monitored to avoid over- or under-fertilisation. They are not particularly interested in reducing the BOD/COD because they feel that this contributes to "soil microbial health. Some of the stabilised digestor sludge/effluent is rtionstituted with chopped straw and then fed to a silo. Some is also used to feed a compost (as a source of readily available N) for the treatment of other manures. The biogas is flared off because the economics were not enough to justify maintaining an energy recovery system. Furthermore, gas purity was a problem due to corrosion.

- New York -300 cow dairy operation.
- North Carolina - poultry, all systems fully operatioml.
- Minnesota -50 cow dairy.
- Iowa -480 sow, farrow to finish and poultry.

Design Features

- The reactor design consists of an upright, fixed-volume tank, with a mixing device in the top centre, an influent pipe at the top and an effluent pipe at the bottom.
- Heating is done with steam or by heat exchangers, externally to the influent or inside the digestor.
- Mixing is intermittent using a mechanical, propeller style mixer, and through biogas transfer.
- Retention times are 10-20 days, but are frequently longer.
- These are medium rate facilities with loading rates of 4-10% 'I'S and 1-3 kg COD/m3/d.

Pros

- Can handle a variety of different wastes and influent composition and therefore little pre-treatment or preconditioning is required.
- They are easy to heat (due to their shape) and easy to control.
- If you take land-base into consideration, and do not include the gas recovery/engine generator system they are probably the cheapest facility to make.

Cons

- There is a problem with "wash-out" of the anaerobic floe, when the effluent is removed from the bottom of the reactor.

- Intolerant to toxic shock substances. This is probably due to the relative size of the reactor. This is a critical factor in hog production, because antibiotics, disinfectants and sterilants are used frequently and can be inadvertently transferred to the reactor during barn maintenance if the operator is not careful.

- The economics of gas recovery is not there.

- Because of the mechanical mixer, a relatively high maintenance system.

- Some say capital costs are prohibitive, without the help of granting agencies. Mixers can be a problem if they do not use the industrial style, which can be expensive. They break down and are subject to corrosion. The industrial mixers cost $40,000 (cf. $6,000 for an agricultural one) but they use less power and are designed to be used continuously. They are, therefore, less prone to maintenance costs.

- Maximum size of the reactor is limited by the size of the roof (c10 m in diameter). Some feel a variable volume with a floating roof would be more appropriate

Manufacturers

- ***CH2M Hill*** (Waterloo, Ontario) - Ray Stickney (these people were heavily involved with the Ag. Canada/Energy Mines and Petroleum Resources research of the early to mid '80s and designed the first three farms above.)

- Harvestore Products - Dr. Richard Vetter (these people designed the last five farms listed above.)

- ADI has customised similar systems for the treatment of food processing wastes.

Comments and Recommendations

Ray Stickney said there was no economic incentive to maintain their research projects. Anaerobic digestion does not eliminate the polluting effects of nitrogen/phosphorus, although it does reduce the TS, BOD and COD which are criteria for effluent disposal to bodies of water. He feels that the relative costs of these low-tech alternatives are probably very similar, depending on how automated the systems are. He feels that anaerobic digestion is just the first stage of a complete manure treatment stream. He also feels that further clarification, centrifuging and de-watering can allow ultimate disposal of the waste to rivers.

Richard Vetter was an Ag. Engineering researcher in Iowa and is now devoting his time to manure management systems. He echoes most of the other peoples' comments and has some creative thoughts on using AD in a larger waste management scheme, much like the UNISYN concept. Their company designs a lot of industrial facilities for the treatment of organic wastes.

3.10 Fixed Film

Facilities Using It

- Buteau and Tremblay Farms (CRIQ) (St. Henri-de-Levis, Québec - at the begiming of the research project, 6,000 sow finishing operation and at the end of the project, 1,200 sows) Downflow, stationary (PVC) fixed *film 50* m3 reactor. Loading about 8000 L/d and 34°C and with a retention time of 7 days. 2.5% TS and 6 kg COD/m^3/d loading rates. The material was pre-separated and pre-heated. The unit was sold back to the farmer and is not operational. Spoke to the researcher at Ag. Canada in Québec who dealt with the project and understand it was a combination of economics and politics that led to the eventual closing down of the unit.

- Folkema Farms (Ingersol, Ontario - 150 sow, farrowing operation) Downflow, stationary (PVC) fixed film 38 m^3 reactor. A loading rate of 7.8 kg COD/m^3/d at a temperature of 37"C. This unit was constructed by A.O Harvestore and is now for sale as part of the complete farm because the owner/farmer has since become a salesperson for AO.

Design Features

- Fixed film reactors have a high surface area/volume ratio, thus theoretically, anaerobic digestion is more efficient and retention times are reduced.

- Their design is basically very similar to that of the completely mixed digestor, with the material introduced either from the top or the bottom of the reactor, and the effluent removed at the opposite end, and biogas removal as usual.

- The fixed film can consist of PVC, rubber, clay, or any other material that does not react with the bacterial population.

- The influent is either pm-heated or heated in the reactor with heat exchangers or with steam.

- Mixing and transfer is due to thermal overturn and through biogas production. Mixing is enhanced in the downflow system, because the fluid movement is in the opposite direction to biogas percolating up through the material. For this reason, the downflow is a better system than the upflow.

- Retention times are in the order of 5-10 days.

- Operating temperatures are 35–45°C.

?%0s

- It is a simple design (however, the fixed media is just another design parameter that will need maintaining).

- No "wash-out" problem. This is because the material is continuously being fed in at the bottom and removed from the top of the reactor.
- Adjusts relatively easily to changes in influent characteristics and to hydraulic loading, thus has more flexible operation conditions.
- Has a larger, more stable population that can handle larger volumes of material in a smaller volume reactor.
- Short retention times.
- No internal, mechanical mixers and no effluent recycling problems

Cons

- There is a six month start-up time, waiting for the biofilm to reproduce.
- Solids with a relatively high particle size will clog up the media.
- The media has problems with scaling, which must be cleaned/replaced, and therefore this maintenance step can severely hamper waste throughput.
- This system does not effectively treat low-strength wastes.

Manufacturers

- PAQ Lavelin (Toronto, Ontario).
- Porter Dillon, Ltd. (New Brunswick).

Comments and Recommendations

We spoke at length with Roger Chagnon at the Agriculture Canada Research Station in Québec about the Buteau & Tremblay farm facility. The retention time of the system was 2 days and therefore the amerobic population was very unstable and prone to toxic shock. The size of the operation allowed for a full-time technician, without which the project could not have succeeded. Manure was not always available, and heating it was a problem. Gas corrosion caused maintemnce problems with the heater and controls. He said that undigested hair floating to the surface of the liquid formed a matt which impeded biogas percolation although design modifications could alleviate this problem. Their media was 1 inch^2 PVC tubing which had little plugging problems.

An average sized farm cannot afford the capital costs of $200,000–300,000, an amount equivalent to the cost for land, buildings, and stock. A co-operative could absorb this expenditure. Furthermore, cooperatives are more likely to get government funding and can absorb often expensive insurance premiums.

He recommended using the effluent in conjunction with some other technology like comporting. He also suggested running the liquid through growing plants as a final polishing step. The advantages of this, other than the polishing, is that saleable product (compost, greenhouse produce, fish, spirulina, etc.) results in a stable market environment. They tried SCP recovety, but had little success.

The Folkema Farms facility was an operating unit, until the farmer quit the business. The influent was pre-screened by a two-stage Parkwood screen (1/8" stainless steel screen over a 1/16" stainless screen). The solids (8070 moisture) were recycled 50:50 with dry feed and fed back to the hogs. The manure increases the fibre content of the ration from 2% to 20% and they found it **actually** reduced problems with specific diseases, scours, increased birthing survival and weight gain. They estimated, with a 150 sow operation (flush gutter system), they saved $35,000 in feed.

The effluent from the screened material was run to a holding tank, from thereto a plate coil heat exchanger (which recovered heat from the engine generator set, and then into the digestor. The digestor contents were automatically recycled back to the heat exchanger if the temperature dropped too much. There were automatic effluent and influent pumps to regulate the flows in and out of the reactor.

The fixed film concept is **also used in** the Unisyn design and in the aerobic/anerobic treatment process for municipal wastewater. The Unisyn design includes amerobic digestion, biogas recovery, re-use of effluent for fish production, plant-crop production and production of algae.

3.11 Upflow Anaerobic Sludge Blanket

Facilities Using It

- Unknown for hog waste. There are two pilot scale facilities, both in the Netherlands, for the treatment of dairy cow and calf manure.
- There are numerous full-scale facilities for the treatment of pulp and paper wastes and processing waters from the food industry.

Design Features

- The unit is normally a fixed volume, upright cylindrical tank with a suspended solids blanket over a much denser, granular sludge bed in the bottom.
- Influent is introduced through evenly distributed nozzles into the bottom of the tank and then percolates up through the sludge layer. During the anaerobic digestion, a small portion of the organic matter is used for new cell growth that takes place in the form of granules with extremely good settling ability. This settled material is the granulated anaerobic sludge which is the stable component of the sludge blanket.
- An integral component is the gas/solid separators at the top of the reactor which allows the biogas formed to escape from the liquid/solid component. The gas-free zone above the separators allows for the settling of any entrained sludge particles to the reactor bottom, while the clarified effluent flows over weirs at the top.
- The influent is heated prior to introduction to the reactor, either through heat exchangers or through steam.
- The waste is pre-acidified.
- Mixing is achieved by the upflow velocity of the waste and through biogas production.
- Surplus granular sludge can be removed to start up another reactor, or be further treated for SCP recovery, as compost or by other forms of stabilisation.

Pros

- The units are small but highly efficient and therefore, cost-competitive, because it takes a relatively small unit to be able to deal with large organic loading rates.
- Very short retention times.
- Minimum solid waste disposal.

Cons

- They reactors are sensitive to changes in waste characteristics.
- Work best with low to medium strength (soluble or low SS) wastes.
- Requires a high level of operator skill.
- Hard to establish the granulated sludge blanket.

Manufacturers

Biopaq Lavalin

Comments and Recommendations

3.12 Hybrid Fixed Film/Sludge Blanket

Facilities Using It

Unknown.

Design Features

- Self explanatory because it is a hybrid of two designs.
- The fixed film media sits above the sludge blanket and then the gas separators above that. Otherwise the unit works very much as the UASB.

Pros

- Same **as** the UASB.

cons

- The same as the UASB with the additional problems of the media plugging up with solids, and problems with scaling.

Manufacturers

Unknown.

Comments and Recommendations

This particular design may not be suitable for treatment of animal waste because there are no indications of it being used in the field.

3.13 Fluidised Bed

Facilities Using It

Unknown

Design Features

- ***This is*** a fixed-volume, upright, cylindrical tank. Influent is introduced through evenly distributed nozzles on the bottom of the tank, and effluent is withdrawn from the top of the tank.
- The biofilm is supported on small particles such as sand or carbon, which are suspended in the reactor liquid through the introduction of the influent, and further suspended by the rising biogas.
- These are effiaent, high loading rate, low retention time (12-24 hours) reactors, due to the high surface / volume ratio of the biological components.
- The influent is heated prior to introduction to the reactor, through heat exchangers or through steam injection.
- Mixing is achieved by influent introduction.
- **Particles** are separated from the effluent and returned to the reactor.

Pros

- Very short retention times, therefore very cost-effective.

Cons

- Best with dilute wastes with low solids contents.
- Problems with seed material.

Manufacturers

Unknown.

Comments/Recommendations

3.14 Anaerobic Contact

Facilities Using It

Unknown

Design Features

- Similar to the completely mixed, except that solids are retrieved from the effluent stream and recycled.

- **The influent is pre-heated using heat exchangers or steam injections. Mixing is mechanical.**

- Retention times are significantly shorter (0.5-4 days) than completely mixed design, probably due to the recycling of the effluent.

Pros

- Similar to completely mixed. [4]

- The effluent is of a higher quality because of the separation of the solids nom the liquids. Therefore, this quality is a function of the separation process.

- Less expensive reactor volume requirements because of the higher retention times. This is probably marginal, when you look at the relative expenses of other components of the system.

cons

- Success of the system depends on the ability of the solids to settle, which is a function of the influent characteristics.

- Works best with medium to high strength wastes because dilute wastes have problems with settling.

Manufacturers

ADI.

Comments and Recommendations

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4 POLISHING METHODS

4.1 Engineered Marsh Treatment

Facilities Using It

- **Local** experience with **treatment** of hog fuel leachate, Ieachate from land fills and storm water run-off.
- Technology is assessed for removal of metals from mine drainage.
- Engineered or natural marshes are commonly used for **treatment of sewage** treatment effluent or raw sewage.

Design Features

Wastewater is treated in a planted marsh with impermeable bottom. Plants will remove contaminants from the waste stream including organic matter, plant nutrients such as nitrogen phosphorous and potassium and metals. Metals and phosphorous may accumulate in plants and detritus. Plant material needs to be harvested on a regular basis to prevent a build-up and to ensure efficient operation. Accumulations of detritus may have to be removed occasionally.

Pros

- Relatively low cost treatment of wastewater.
- Low energy consumption.
- Low life-cycle cost.
- Compatible with low lying land with naturally occurring aquatic vegetation,

Cons

- Planting and establishment of wetland vegetation may not be easy.
- Long start-up period, after two years system running at about 50% design parameters, and not all beds achieved complete plant coverage and maturity.
- Need for relatively large land base.
- Marshes will only operate effectively during the growing season.

Manufacturers

There are no manufacturers of these systems. They are self constructed according to design criteria. There are guidelines available for the construction of engineered marshes based on the treatment of domestic sewage.

Comments and Recommendations

This is a relatively new technology with some risk associated unless pilot scale studies (long term) are used to determine potential problems. It is most suitable for . polishing partially treated effluents, in this case where the hog manure has been treated by some process and needs to be polished to discharge to surface waters or for spray irrigation. The systems have shown that ammonia reduction is possible, but optimisation of ammonia reduction has not been defined There has been extensive work using various versions of constructed wetlands; therefore, design are numerous and treatment capabilities differs depending on plant type, size of system, retention time, location, etc.

A **pilot system receiving medium strength agricultural wastewaters failed in reduang the organic loading of the waste water. These results show that marshes may only work for** waste water <3,000 mg/L BOD. Also, plant populations should be customised to local conditions.

The Solar Aquatic greenhouse uses this technology indoors for polishing effluent. Here, the growing season is extended through supply of heat and artificial lighting.

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4.2 Vertical Flow Marsh System

Facilities Using It

Usually used in conjunction with Horizontal flow systems. Most of the research has been done by the Max Planck Institute, and tests have been performed at CEMAGREF in Lyon, France (A. Lienard), Oaklands Park (part of Camphill Village Trust in the U.K (U. Burka in Newham, Gloucestershire).

Design Features

A vertical flow system has been established at the Oaklands park, in the UK based on Max Planck Institute technology.

The demonstration of the vertical flow system consists of five stages: stage 1 and 2 are both vertical flow marshes, stage 3 is a marsh with vertical or horizontal flow, stage 4 is a marsh with horizontal flow, and stage 5 is a pond prior to discharge.

In the first two stages the sewage to be treated passes vertically through the beds. There are several beds in parallel in the vertical-flow stages with each bed receiving flow in rotation. The flow then passes to 2 or 3 horizontal flow stages.

The vertical flow stages were usually planted with *Phragmites australis. The* horizontal- flow stages contain a number of other macrophytes. These may include Iris, *Schoenoplectus, Sparaganium* or Typha.

The media used in all the beds is gravel topped with sharp sand.

Pretreatment of the sewage was settlement and / or fine screening (c6 mm).

Stage 1 sized at 0.6 m^2/pe (65g BOD/m^2d) and stage 2 at 0.3m^2/pe (population equivalent).

Dosing of beds for 1 to 2 days with 4 to 8 days of rest is practiced to provide time to thoroughly dry out the beds. This assisted in oxygen transfer, biodegradation of organic matter and vitrification of ammonia.

Distribution of flow onto the beds is by gutter channels suspended over the beds having holes in the bottom. Cascading of wastewater over the edges of the channels is also used.

Collection of flow is through a perforated pipe which runs along the base of the bed. This pipe is connected to the surface to allow air to pass into the base of the bed. Other aeration pipes are used to provide air to the gravel layer at the bottom of the beds.

Pros

- Initial test show that the vertical flow bed method may perform better **than horizontal flow methods.**

- Uses the entire bed for treatment.

cons

- Design is slightly more complicated than typical horizontal flow systems.

- Not been studied as much as horizontal flow systems and potential problems may be unidentified.

- The system only operates during the growing season.

Comments and Recommendations

- *The* vertical flow marsh has great potential to polish an effluent effectively. It is a low maintenance system and utilises concepts familiar to farming people. It is not a system requiring technically trained people to operate.

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4.3 Duckweed Pond

Facilities Using It

City of Picayune, Mississippi, under construction, 4,500 m3/day sewage treatment plant.

Town of Union, Mississippi, operational plant 2,500 m3/day (October, 19}90), sewage treatment plant.

Design Features

Shallow ponds are used to remove nuhients through plant-uptake and microbial action. The ponds are covered with one or more duckweed species. The plants take up nutrients and produce biomass up to 40 t/ha in subtropical areas, and up to 25 t/ha in temperate climates. No plant production takes place during colder periods of the year. Duckweed is high in protein and may be used as animal feed. Harvesting takes place by hand from duckweed collection chambers placed near the outfall.

Pros

- Nutrient and BOD removal claimed.
- May produce a value added product.

cons

- Need for relatively large areas for building ponds.
- *Lemna* Spp not recognized as animal feed, comporting may be only disposal option.
- Technology does not have track record.
- Duckweed only active at relatively high temperatures.

Manufacturers

Nu-Tech Industries
1093 Corona Crescent
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Comments and Recommendations

4.4 Biological Phosphorous Removal - Bio-P

Facilities Using It

- Only been used for the tertiary treatment of domestic sewage effluent. Full scale operations in Kelowna, Penticton, Westbank and Salmon Arm.

Research facility operated at B.C. Research by UBC Department of Civil Engineering and by B.C. Research

Design Features

- Biological phosphorous removal by bacteria due to excess P uptake (more than required for growth), through the incorporation of a series of aerobic and anaerobic treatment steps.
- Typically designed to reduce 7 mg/LP to 1 mg/L or less.
- Ammonia can be removed if provisions are made for vitrification by special aeration design features.
- Denitrification can also occur with special design features.
- TKN 30 mg/L (of which 20 mg/L is NH3) can be reduced to approximately O mg/L.

Pros

- Same disadvantages and advantages apply to this system as to a conventional activated sludge system and suspended growth system.
- Greatest advantage is that it can reduce nutrients without the addition of chemicals which reduces the volume of sludge to be dealt with.

Cons

- System is technically complicated to design and operate with a variable waste flow such as muniapal effluent.

Manufacturers

Can not buy packaged unit. Consultants familiar with the design of these systems are:

Novatec Consultants
Stanley and Ass.
Night and Peasald
Dayton and Knight

Comments and Recommendations

- Only used for domestic sewage to date as a tertiary treatment system.
- Performance on agricultural waste unknown
- Would need to do a pilot study to determine suitability for high strength wastes.

5 TREATMENT OF SOLIDS

5.1 Comporting (Windrow)

Facilities Using It

Municipalities, composters of leaves or yard and garden waste.

Design Features

Substrate is placed in a long row on a hardened pad and is turned regularly **by** windrow turner or front end loader. A turner will add comminution to the turning action. Due to low technology input, comporting may take a long time, up to 12 to 18 month for leaves. This time could be decreased by frequent turning or addition of nutrients. In some operations the wi.ndrow is combined with forced aeration. This combined technology is used for comporting municipal solid wastes.

Size reduction, removal of contaminants and mixing of materials to acquire proper C:N ratio maybe required.

Pros

- Depending on the hardware, windrowing is a cheap method of comporting.

Cons

- ***This low* tech system may create** adverse olfactory conditions in the pile **when not enough** aeration takes place. Long processing times are needed to stabilise the substrate. Processing is followed by a curing stage.
- Preprocessing of waste maybe needed.

Manufacturers

Windrow turners:

Scat Engineering
P.O. Box 265
Dalhi, Iowa 52223
(800) 843-7228

Brown Bear Corporation
P.O. Box 148
Lennox, Iowa 50851
(515) 333-4551

Scarab Manufacturing Inc.
Route 2
P.O. Box 40
White Bear, Texas 79097
(806) 883-7821

Wildcat Manufacturing Co. Inc.
P.O Box 523
Freeman, SD 57029
1-800-627-3954

Coy, Eagle Crusher Comp. Inc.
4250 S.R. 309
Galion, OH 44833
(419) 468-2288

Sittler Compost Turner Valoraction Inc.
Box 892
Sherbrooke, P.Q.
JIH 5L1
(219) 864-7942

Comments and Recommendations

Windrowing is a suitable technology **where the substrate does not contain materials that** putrefy easily. The technology is less suitable for wet climates, - unless rain protection is installed. The windrows will create a diffuse source of leachate and run-off. Approximately 5% v/v Ieachates may be produced. Windrowing is best done on remote sites due to odour generating potential.

Some of the windrow comporting facilities in the US have been modified from the actively agitated type to the passive windrow. Cedar Grove in Seattle is an example. The conversion took place to reduce odour emissions during turning. The processing time increased from three to four months to two years.

5.2 Comporting (Trough, Hybrid)

Facilities Using It

Yard waste composers, manure composers.

Design Features

In a concrete trough, substrate is mixed and aerated by a traveling mixing unit. The unit works on a flow through principle. Through the mixing unit the substrate is transported from one end of the trough to the other. With a replacement of seven feet and a production time of 28 days, the average trough is 220 feet long. Four to six bays can be serviced by one turner unit. Some units are fitted with aeration systems and are computer controlled.

Pros

- Reduces comporting to an 28 day active cycle.
- Small scale production unit.
- Each bay or trough can handle up to 10 tonnes per day.
- To increase scale, more bays or troughs could be added.

Cons

- ***Need*** for **a** large building.
- Curing needed after the active cycle.
- Large operation my contain large numbers of bays.
- Odour control technology is needed when putricibles are incorporated in the compost substrate.

Manufacturers

Royer Industries
P.O. Box 1232
Kingston, PA 18704
(717) 287-9624

Farmer Automatic
P.O. Box 39
Register, GA 30452
(912) 681-2763

IFS
Salmon Brook Corporate Park
655 Winding Brook Drive
Glastonbury, CT 06033
(203) 657-3447

Comments and Recommendations

A **small unit for use on farms and small commercial comporting facilities.** All **operations are contained in a building. The building could have odour control - units. Units applying turning only, are reasomble inexpensive.** An IPS unit is operated by Envirowaste in Aldergrove, B.C. This installation processes manures, yard and garden waste and various animal by-products. An Farmer Automatic is installed in Winfield, B.C. to process strictly chicken manure. Both installations received odour complaints and are now installing odour control systems.

5.3 Comporting (Aerated Pile)

Facilities Using It

Yard and garden waste facilities, sewage sludge facilities, municipal solid **waste** facilities. Developed by USDA Beltsville Laboratory.

Design Features

Substrate is piled on a ductwork and air is either pressed into the material or sucked through it. The technology may incorporate infrequent turning. Pre-processing may be needed such as mixing, shredding and moistening in a rotating drum or addition of bulking agent.

Pros

- ***Low*** maintenance operation.
- Production of compost in 6-10 weeks.
- Size not limited, additional units can be added (blower, controller and duct work).

Cons

- **May** need **pre-processing** such as a trommel or mixing units.
- To operate effectively, the technology may need additional mixing steps, thus requiring front-end loaders or backhoes.

Comments and Recommendations

Large yard and garden waste facility in The Netherlands (VAM in Wijster) operates with this technology. Source separated materials are piled in long windrows four metres high and five metres wide. Each windrow is aerated with a large blower. After six weeks, compost is screened and cured.

The technology is used, both indoors and out of doors to compost sewage sludge bulked with woodchips. The aerated pile process combined with mixing is used in the Bii.hler Miag design. The aerated pile combined with pretreatment in a Dano Drum was operating during a short period in Portland, Oregon. The Agripost facility in Florida, using aerated pile design stopped production in 1991. Various reasons including odour complaints and low quality of produced compost (made from MSW) were ated for closure of the plants.

5.4 Comporting (Tunnel)

Facilities Using It

Sewage sludge facilities; yard and garden waste; mushroom compost.

Design Features

Sludge and bulking agents are mixed and then fed into a tunnel with a hydraulic ram- Optimal conditions are created in the tunnel through aeration. Material is discharged into a pit for further processing at the discharge end of the tunnel. The tunnel composter concept has also been developed for the preparation of mushroom compost. This specific technology is currently being adapted for yard and garden waste by Double T Equipment.

Pros

con's

Manufacturers

Double T Equipment Manufacturing Ltd.
2 East Lake Way
P.O. Box 3637
Airdrie, Alberta
T4B 2B8
(403) 948-5618

Ashbrook-Simon-Hartley
11600 East Hardy
Houston, Texas 77093
(713) 4494322

Comments and Recommendations

The Ashbrook tunnel comporting unit is only being built for large scale operations. a farm size unit is not available. Double T builds small units.

5.5 Comporting (In Vessel)

Facilities Using It

Yard and garden waste facilities, sewage sludge facilities, municipal solid waste facilities.

Design Features

Substrate is aerated with forced air and turned with augers. All operations are contained in a hall or dome. Substrate is fed into the comporting vessel by auger.

Pros

- Well controlled process through computer guided aeration and mixing.
- Operating temperatures are controlled through theairflow through the mass.

Cons

- Process limited to large scale facilities. Minimum size is 10,000 T/y input.
- Expensive to build and operate.

Manufacturers

sorain Cecchini
American Recovery Corp.
Suite 600,900- 19th Street NW
Washington, DC 20006
(202) 775-5150

Fairfield Service Co.
240 Boone Drive
Marion, OH 43302
(614) 387-3335

Comments and Recommendations

Comporting facility for the processing of large quantities of yard and garden waste, sewage sludges or Municipal Solid Waste. Several units have a good t-rack record both in the US and in Canada.

Fairfield units are operational in Camda and U.S. One Sorain pilot unit is establish in the US. Not suitable for on-farm use.

APPENDIX B

Wastewater Generation at an Abbatoir

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WASTEWATER GENERATION AT AN ABBATOIR

Description of a Typical Operation

Killing Area

In the killing area, a hog is shocked, stuck, hung and bid. The majority of the blood, which has a very high biochemical oxygen demand (BOD) is collected and may be recovered for food use or reclaimed as animal feed. Blood that spills onto the floor enters the wastewater stream and may be retained in holding (surge) tanks prior to treatment.

Scalding Tank

Following bleeding the hogs are passed through a scalding tank used to clean the outside of the animal and prepare it for dehairing. The contents of the scalding tank, which contains some blood, hair and oil are-discharged at the end of each shift. The temperature of the scalding tank is approximately 60°C.

Hog Dehairing and Polishing

After scalding, the hogs pass through a dehairing machine which physically scrapes the hair off the skin. Removed hair and is augured to a holding tank where any associated blood separates and flows into the blood holding tank. The collected hair may be transported to a landfill. The dehairing process generates a liquid waste which is very frothy in nature and contains hair. The dehairer and the associated froth is cleaned up at the completion of the kill.

Most of any remaining hair left on the animals after dehairing is removed as the hog passes through a flame rack. Finally, a hand-held torch is used to ensure complete removal of hair. The hogs then pass through an automated polishing system. The water used in the polisher is discharged to the existing wastewater collection system.

Butchering

Following polishing, the hog enters an area where butchering begins, known as the killing floor. The butchering process generates many waste by-products. Liquid (blood and spray water) and some solids (body parts not suitable for sale, animals rejected by health inspectors, fat, etc.). The majority of the solid waste is collected beneath the killing floor and is removed daily to a rendering operation. Several body parts including the lungs, kidneys, hearts, livers, spleen and sometimes ears are packaged and shipped out as saleable products. Misters (spray nozzles used to maintain a high humidity to minimize shrinkage) and hand-held sprayers used to wash the butchered animals generate a liquid waste containing various amounts of fat which is not collected and enters the collection system. Floor washdowns at the completion of the kill also generates a liquid waste-containing various amounts of fat.

Cold Rooms

Prior to shipment, the butchered hogs are stored in cold rooms. The misters used in the cold rooms generate a liquid waste which also enters the collection system.

Truck Washdown

Prior to leaving the facility, weather permitting, each truck is swept out and washed down. The liquid waste collected is routed to existing holding tanks separate from the tanks holding the butchering and handling process waste liquid, During periods of freezing temperatures, the trucks are only swept out. For a slaughterhouse operating in subarctic conditions, this will apply for most of the year.

Receiving Area

The receiving area and holding pens are washed down daily and the associated liquid collected in the same tanks storing the truck washdown. As in the case of truck washdown, washdown of the receiving area may not be feasible for most of the year at a slaughterhouse operating in sub-arctic conditions. Some form of dry cleanup would be more appropriate. The materials from this cleanup would then be sent to the comporting process.

Cleanup

A wet cleanup of the abattoir begins after completion of the killing process. Chemicals used in the cleanup may include Klenzade Dy-Gest I and Klenzade Dy-Gest Il. The ingredients of these cleaners are listed at the end of this appendix and are comprised of surface active agents. The cleanup procedure involves cleaning up all waste scraps, hosing down the floors, cleaning the scalding tank, the dehairer, and the polisher. The maprity of the solid parts are squeegeed into a bin for transfer to a rendering operation. The washdown water and cleaning solution end up in floor drains and eventually aU the washdown liquids reach the main holding tank

Wastewater Collection

All wastewater, except for the scalding tank maybe routed through floor drains to associated holding tanks. The washdown from the trucks, receiving area **and holding pens are collected in tanks.** For an operation in a temperate zone, these tanks are usually underground. For an operation in subarctic conditions, the tanks would need to be protected from freezing and permafrost. Liquid wastes (including nightly washdown), except for blood collected from the processes immediately after shocking, may be collected by floor drains and routed through a series of manholes to a main holding tank, The scalding tank discharge is most likely plumbed into the series of manholes. Washdown from the hook and trolley cleaning and sterilization room and the holding pens may also be routed through these manholes. The washdown from the hook and trolley cleaning room will contain surface active agents (detergents) and phosphates from the cleaning agents.

Characteristics and Treatment of Slaughterhouse Wastewaters

Relevant articles on treatment of wastewaters from slaughterhouses have been gathered. The maprity of these articles dealt with advanced forms of wastewater treatment. The degree of treatment required is dependent on the sensitivity of the point of discharge where discharge of the wastewater was into a surface water.

Morris and Bzdyl, 1977 and Marson and Pos, 1978 stated that the waste characterization from slaughterhouses varies from plant to plant depending on a number of factors including types of processes, quality of **process water, efficiency of operation and plant housekeeping.** Monis and Bzdyl, 1977 and Marson and Pos, 1978 found blood and fat to be the major pollutants. Hair, flesh, manure, cleaning agents and dirt are present in varying degrees.

Typical waste strengths found in similar operations are presented in Table 1. The listed pH, BOD, SS and Oil and Grease vary from 6.7 to 7.6,752 to 2,150 mg/L, 319 to 1.012 mg/L and 60 to 3,900 mg/L respectively.

Data obtained for a slaughterhouse in the Vancouver **area show similar characteristics for wastewater quality. Typically the discharge to sewer contained:**

- **1081 mg/L BOD5 and ranged from 300 to 2,400 mg/L.**
- **1099 mg/L suspended solids ranging from 88 to 4,950** mg/L.

Scalding tank water had slightly higher BOD5 at 1,630 mg/L.

For a typical slaughterhouse processing 4,000-5,000 hogs per week, the typical weekly flow rate of sewage pumped from the main tank was 35,000 gallons (160 m^3) per working day (3s gallons per hog; 0.157 m^3). After expansion of this operation, the flow rate increased to 47,000 gallons (214 m3) per day. For slaughter of 9,000 hogs per week, the typical wastewater flow is 26 gallons per hog (0.115 m). However, for operation in a sub-arctic climate, wastewater flows may be significantly higher unless the plant can be operated without fear of freeze up. Design of water systems for use in sub-arctic conditions usually incorporates continuous bleed systems which lead to significant dilution of wastewaters.

Table 1
Wastewater Characteristics at Similar Operations Prior to Treatment

Plant Type	pH	BOD	SS	Oil & Grease	Treatment
Dutch Pig Abattoir	—	950	—		SCR, CHE, FLO, ACT, CLA, SFI, ACF, CHL
Abattoir[1]	—	1,490	726	—	CHE, CLA
US. Abattoir[1]	—	1/571	824	—	CHE, CLA
Packing House Wastes[2]	6.7	1/800	—	850	FAT, EQV, CHE, FLO, SLD
	6.7	980†	—	250†	FAT, EQV, CHE, FLD, SLD
Swedish Slaughter House[3]	7.1	1,791	1,012	—	Alwatech
Kenosha Beef Slaughter House[4]	7.2	752†	319	—	ANL, ALA, CHE, CLA, FLT, CFIL
A.F. Moyer and Sons Beef Packing Plant (Pennsylvania)[5]	7.6	2,000	1,000	60	COT
J.H. Routh Packing Company Hog Packing House (Ohio)[6]	—	2,150	—	3,900	SCR, FLO, ALA, NIT, CLA, CHL

† Following well designed fat trap

ACF: Activated Carbon Filter
ALA Aerobic Lagoons
c m : Chemical Addition (mixing and flocculation chambers)
CLA: Clarification
EQU: Equalization
FLO: Flotation
NIT: Vitrification
SFI: Sand Filter
ACT: Activated Sludge
ANL: Anaerobic Lagoons
CHL: Chlorination
COT: Co-Treatment with Other Waste Streams
FAT: Fat Trap
FLT: Filtration
SCR: Screening
SLO: Sludge Dewatering
Alwatech: Precipitation in sodium ligno supphonate under acidic conditions

1 Hopwood, 1977.
2 Morris and Bzdyl, 1977.
3 Bough, 1976.
4 Rooney and Wu, 1981.
5 Green, et. al., 1980.
6 Weber and Hull, 1979.

Literature Findings

As shown in Table 1, there is a wide variety in slaughterhouse wastewater strength and diversity in treatment schemes. Although the wastewater strength is a function of the individual operations as well as the cost of process water, the treatment schemes employed are dependent on the regulatory requirements and charges (for discharge to sewer), available land, location to a sanitary sewer, equipment and maintenance costs, etc. Generally the more stringent the discharge guidelines the more complex the treatment system. As well, discharges to receiving environment receive more advanced treatment as compared to sanitary sewer discharges.

Slaughterhouse wastes can be treated by means of processes which rely on simple physical properties of the wastes, by systems which modify the physical properties by chemical addition and by processes which rely on biological conversion of the organic substrates in the wastewater. A more detailed description of these processes follows.

Treatment Options

The most suitable treatment approach selected from the various treatment options available depends on the wastewater characteristics. Some other factors to be considered include:

- Location of plant (closeness to urban dwellers).
- Permit requirements (degree of treatment required).
- Discharge rates.
- Cost of raw water (expensive water may make recycling of treated wastewater economically feasible).
- Case histories of treatment systems at similar industries.
- Availability and cost of trained technical staff.

Physical Treatment Methods

Physical treatment schemes rely on the physical characteristics of the wastewater, which include the density and the size of the individual waste components (fat globules, grit, suspended solids, etc.) and the propensity for separation of the waste components due to these factors. The most common methods include:

- Screening **or combination.**
- Dissolved air flotation.
- **Ultra filtration and reverse osmosis.**
- **Centrifuges.**
- Mechanical filtration.
- **Gravity separation.**

Screening or Combination

Screening or combination of raw wastewater is a universally applied technique intended to either recover recyclable solids from the system and protect downstream equipment, or both.

Gravity Separation

Gravity Separation is used in wastewater treatment to remove gross solid matter in two different stages. In the first stage, inorganic grit is removed by short retention settlement or by centrifugal action. The material removed in this first stage is called "detritus" and is normally disposed of to landfilL

In the second stage, conventionally called "primary settlement," the gross fraction of settleable organic solids are removed in settling chambers (clarifiers) providing several hours retention of the wastewater flows. For small wastewater treatment plants this stage is frequently omitted and 'the total load of organic substances is passed on for either reduction (anaerobic) or oxidation (aerobic) treatment.

Dissolved Air Flotation (DAF)

Wastes which contain a large fraction of oils and greases are frequently provided primary treatment by means of flotation. This flotation can be enhanced by means of dissolved air or hydrogen. The most commonly used method is the dissolved air flotation system. In this system, air is introduced into the wastewater under pressure. Owing to the pressure, the air dissolves to a greater degree than it would under atmospheric pressure. When the liquid is released into a tank open to the atmosphere, the dissolved air comes out of solution in the form of fine air bubbles which attach to the oil and grease particles and increase their upward velocity. The concentmted oils and greases are then mechanically removed form the surface. There are several commercial companies providing flotation equipment. These include Krofta Corporation and Pollution Control Engineering.

Fat, oil and grease (FOG) may adversely affect both aerobic and amerobic biological processes primarily because this material's degradation is restricted by its insolubility. **Also,** because of their low specific gravity, FOG materials tend to .- **coat** surfaces and to float, creating scum conditions.

"Mechanical Filtration

Mechanical filtration processes used in water and wastewater treatment are an extension of the screening process (for more details see Appendix A - Section 2.2 ' Bed Filtration).

- Simple gravity filtration in open beds constructed from layers of sand, fly ash or other relatively fine solid media.
- **Rapid gravity or pressure** filtration systems constructed from fine grained sand, gravel, anthracite or even activate carbon materials.
- **Pre-coated pressure filtration or vacuum filtration systems. The precoat being of diatornaceous earth material.**

Ultrafiltration and Reverse Osmosis

Although ultra filtration (UF) systems have been used for the **recovery of protein in milk wastewaters, it is unlikely that these systems would have any application for slaughterhouse wastewater treatment. Similarly, reverse osmosis 0?0) systems, although capable of producing high quality water and reclairning either organic substances or inorganic metals, are relatively expensive both in capital and** operating costs. Neither UF nor RO systems would be of any use for the proposed installations in the North West Territories unless:

- **Some of the materials** reclaimed had value to off-set the cost of the process.
- **There was a** highly sensitive environment to protect necessitating production of a high quality effluent devoid of nutrients or salts.

Centrifuges

Centrifuge systems were extremely popular for the dewatering of sewage sludges during the sixties. However, the systems fell into disfavour due to high operating costs, power and maintemnce. The problem was primarily due to the abrasive character of sewage sludge. In addition, the centrifuges **failed** to produce very dry solids in the cake. Modem day centrifuges have resolved this problem and many new installations for sewage sludge dewatering include centrifuges in the process. The design of modem day centrifuges is such that extremely dry sludge is produced. Centrifuges could be considered for dewatering sludges but because of the relatively small size of operation, **a** simple plate and frame filter system incorporating precoat **assistance or a precoat disc filter system are likely to be the best options. However, sludge dewatering based on the freeze-thaw process is another alternative which would utilize material conditions.**

Chemical Treatment Methods

Chemical treatment methods use the addition of various chemicals to change the '" **chemical** mture of the waste stream, thereby improving physical treatment or subsequent biological treatment, or causing direct chemical oxidation. This **may** include the addition of primary inorganic flocculating chemicals such as ferrous sulfate or aluminum sulfate and **organic** polymers to aid settling or DAF processes or addition of a powerful oxidant such as hydrogen peroxide. pH adjustment may also improve the settling and flotation characteristics. Addition of Iignosulfomtes, which react with proteins will form insoluble precipitates allowing separation.

Biological Treatment Methods

Biological treatment is used to remove colloidal and soluble organic substances - **which can't** be settled or floated. In the biological process, micro-organisms (bacteria, protozoa, fungi, algae, etc.) consume the soluble impurities as food. These impurities therefore, have an oxygen demand due to respiration of the aerobics involved in the biological process. Aerobic biological treatment methods which have been **used** for slaughterhouse wastes include lagoons, oxidation ditches, package aerobic systems, rotating biological **contactors and trickling filters.**

However, during recent years a drive to make wastewater treatment systems energy efficient has led to the development of wastewater systems based on the amerobic process. In the anaerobic process, the soluble substrates are reduced and converted to methane, hydrogen, carbon dioxide and water rather than into carbon dioxide and water as occurs in the aerobic process.

Anaerobic Treatment

Anaerobic treatment enjoys several generally acknowledged advantages over aerobic treatment including:

- Lower power costs. particularly by avoidance of aeration systems in large organic load applications.
- Lower waste sludge production (25–50 % lower than aerobic activated sludge).
- **The potential fuel value of the biogas by-product in boilers and/or gas driven engines.**

Several **potential disadvantages also need to be recognised:**

- Slower reaction rates and lower organic removal efficienaes. Anaerobic systems typically achieve 70-85% BOD5 removal as compared to 90-95% or higher for aerobic processes.
- Thermal demand to maintain optimum process temperature.
- Potentially increased sensitivity to toxic materials such as oxidizing compounds or caustic cleaners.
- An anaerobic process must be maintained within. a narrow pH range requiring close monitoring.
- The biogas by-product may require cleaning and compression for recovery.
- The potential for noxious odours especially if hydrogen sulfide is present (Stebor, et. al., 1990).

Packerland Packaging Corporation, a slaughterhouse processing 2,600 head of cattle **a** day installed an anaerobic treatment system after extensive pilot testing

(Stebor, et. al., 1990). The system was designed for a COD loading of 3.0 kg/m3/d with a surge tank to smooth out flow and load fluctuations. Gas generation was expected to be 0.24 m3 per kg COD added. Methane concentration was **82%**. the design **allowed** for 1.32 m3 (350 gallons) per head of cattle slaughtered. The average expected removal efficiencies were based on the pilot experience: COD - 84%; BOD5 - 93%; **TSS** - 75%. Sludge was removed and **dewatered** with a belt filter press after conditioning. Biogas was recovered for heating purposes.

Dague, et. al. (1990), **examined** the feasibility of treatment of pork processing wastewater in a covered anaerobic Lagoon, fitted with a floating cover for gas recovery for FCD Foods Inc. of Dubuque, Iowa. this **facility** has been **very** successful **from** both financial and an environmental standpoint. the total investment of $1.5 million was returned within two years through **savings in** operating costs for wastewater treatment and in energy values recovered.

No operational problems have been experienced with the facility. However, the plant uses chlorine to suppress sulfate reduction in the amerobic effluent. Although this controls odours effectively, the process does involve use of toxic chlorine gas which is an additional cost. Note that the cleanup agents used "for hog processing contains sulfur compounds. In review of anaerobic treatment plants in Europe, both Mueller, 1988 and Birkbeck reported that compost filter systems were extremely effective in controlling odours from systems treating pulp and paper mill effluents

In other studies, Monteith, et. al., 1982 showed that mesophilic operation was more stable and more energy efficient than thermophilic operation for anaerobic **treatment of beef and swine manure. At mesophilic temperatures, hydraulic retention time (HRT) greater than ten days was required to inactivate salmonella bacteria. Swine manure was readily fermentable at** mesophilic temperatures, producing biogas of excellent quality at a high rate. Manure characteristics are very **individual, and various portions (e.g.,** fed ration, manure handing system, Use of antibiotics, etc.) may influence the success of anaerobic fermentation. Laboratory work on individual manures is thus recommended before a digester is constructed.

It should be noted that heavy metals such as copper maybe inhibitory to methane gas production. Copper is **a common additive to hog feedstuffs and will likely accumulate in the** animal feces.

Chemicals Used at a Hog Processing Plant

- Cleaners

1. Klenzade Dy-Gest I

- **Sodium Xylene sulfonate**
- **Sodium Metabisulphite**
- **Propylene glycol**
- **Triethanolamine**
- **Enzymes**
- **Wetting agents and surfactants**

2. **Klenzade DyGest 2**

- **Sodium Carbonate**
- **Sodium** tripolyphosphage
- Sodium polyphosphate
- Tetra sodium EDTA

Sterilizer

1. Klenzade Hook and Trolley Cleaner

- Sodium hydroxide
- Sodium carbonate
- Sodium glucomte
- Tri ethanolamine
- Linear alcohol benzylated ethoxylate

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