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TREATMENT AND DISPOSAL OF LIQUID WASTE FROM MSW BIOCONVERSION FACILITY

A wastewater characterization and treatment feasibility study were conducted on a unique anaerobic liquid waste generated from a pilot plant facility to produce methane gas from municipal soild waste (MSW) through bioconversion. This paper sets out to analyze these experimental data and discusses various engineering factors which affect the selection of unit processes to achieve the treatment objective and ultimate disposal of the effluent.

1. INTRODUCTION

Several alternatives of meeting the ever growing demand for energy have been investigated in recent years. Production of methane gas from bioconversion of municipal solid waste (MSW) is one of them. This is not a new concept but it gained momentum in seventies due to rapid depletion of fossil fuels and to the increased consciousness on the part of public to have pollution free environment. The process of bioconversion not only provides energy but at the same time results in significant reduction in volume of the solid waste to be disposed. This dual characteristics of this process makes it an attractive alternative for production of energy.

An experimental anaerobic digestion facility has been set up at Pompano Beach, Florida, to test the efficiency and reliability of this process. This facility utilizes 100 t of solid waste every day and produces 68 to 102 m^3 of methane gas. The details of this process are given elsewhere [1]. This system is designed on closed loop concept to minimize the discharge of liquid waste into environment. However, it is expected that during normal operation some liquid waste had to be discharged in order to alleviate the excessive build up of toxic material

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inside the digester. The liquid stream is composed of filtrate generated at vacuum filtration of digested slurry and wash water from various cleaning operations. If this waste is discharged into environment it may enter underground aquifer, surface streams, lakes or impoundments and may seriously impair water quality and endanger the health and welfare of the community.

There are no special guidelines for the discharge of this type of liquid waste into environment, however, detailed analysis of this waste has shown its similarity to landfill leachate in characteristics [2]. Therefore guidelines for disposal of solid waste may be applicable in this case. The guidelines recommend that landfill design should include the possibility of leachate generation as well as a proposed control scheme for protection of ground and surface waters in order to minimize environmental damage and to reduce health hazards [3]. The concern for environmental protection is further elevated due to enactment of the Resource Conservation and Recovery Act by US Congress in 1976 (Public Law 94-580). This law imposes strict control over the management of hazardous waste throughout its entire life cycle. These concerns promulgated this study to investigate the treatability of this liquid waste and to determine means of safe disposal of the effluent to protect environmental quality. This becomes all the more important in case of Pompano Beach, as Biscayne aquifer lying underneath it is the sole source of water supply in South Florida.

2. BIOLOGICAL TREATABILITY

Biological treatability of this liquid waste was investigated using a continuous flow system to obtain the design parameters. Continuous system was employed as it approximates the design and operation of an actual plant. Variable loadings can be evaluated in term of its performance. The details of laboratory scale system along with determination of various kinetic coefficients are reported elsewhere [4], [5]. However this study has indicated that aerobic biological treatment is effective in removing substantial portion of the biodegradable fraction of organic pollutants. Total BOD and COD removals were 98 and 78 %, respectively. Both nitrogen and phosphorous removals were of the order of 85 %. The settling characteristics of bioflocs were generally good. Table 1 gives the characteristics of liquid waste (filtrate) prior and after the biological treatment along with discharge standards of Dade County [6]. Further, the values of the following kinetic coefficients were developed on BOD basis according to the procedure described by Metcalf and Eddy, 1979 [7].

Sludge yield coefficient, $Y = 0.43$.

Microorganism decay coefficient, $k = 0.0917$ (day^{-1}).

Maximum rate of substrate utilization per unit weight of microorganisms, $k = 0.559$ (day^{-1}).

Table 1

Characteristics of filtrate prior and after biological treatment along with Dade County discharge standards
Charakterystyka filtratu przed i po oczyszczaniu biologicznym według norm Dade County

Parameters	Influent mg/dm^3	Effluent mg/dm^3	Dade county discharge standards mg/dm^3
BOD	500–1300 1033	40–95 70	30
COD	2300–2540 2446	340–500 417	N.S.
Org–N	37.5–71.1 57	17	N.S.
NH_3–N	202–235 220	–	N.S.
NO_2–N	1.6–5.5 3.63	–	N.S.
NO_3–N	0–2.4 1.33	51	N.S.
Phosphorous	24–79 53.6	12.3	N.S.
Chlorides	153–192 172	–	500
Total solids	2500–4200 3473	–	N.S.
Suspended solids	2000–2440 2280	–	N.S.
Volatile	1120–1640 1426	–	N.S.
pH	7.2–7.4	–	N.S.
Alkalinity	1529–1884 1765	–	N.S.
Zinc	4–6	0.65–5.0	1.00
Lead	2.1–2.8	0.43–2.5	0.05
Nickel	0.23–0.32	0.2–0.27	N.S.
Manganese	1.93–3	0.7–2.62	N.S.
Chromium	0.25–0.29	0.1–0.27	1.0
Cobalt	0.08–0.14	0.12–0.07	N.S.
Cadmium	0.02–0.07	0.04–0.05	N.S.
Silver	0.04–0.06	0.01–0.05	N.S.
Copper	0.17–1.3	0.22–0.92	0.5
Iron	33–42	2.70–39	0.3
Calcium	224–447	364	N.S.

N. S. = no standard.

Substrate concentration where rate of waste utilization equals $k/2$, $k = 28.3$ (mg/dm³).

Minimum mean cell residence time, $Q_c^m = 6.88$ (days).

Based on the values of these constants, various aerobic biological treatment systems can be designed and their applicability can be studied for this particular wastewater.

3. BIOLOGICAL TREATMENT METHODS

Biological treatment mechanism involves achieving of coagulation, removal and stabilization of non-settelable organics in the wastewater. Waste stream, i.e. substrate, is placed in contact with a large mixed population of microorganisms in order to decompose soluble and colloidal organic matter (present in the waste stream) to CO_2 and H_2O in the presence of oxygen. The process optimizes the environment for the growth of bacteria so that biodegradation is enhanced. The waste stream must be free of any toxic material and balanced with respect to food requirements of bacteria, i.e. BOD, nitrogen, and phosphorus must be present in the ratios of 100 : 5 : 1. Widely used aerobic biological treatment methods can include the form of conventional activated sludge process and its various modifications, trickling filters, bio-discs, stabilization ponds, and aerated lagoons. In this study only three systems, i.e. conventional activated sludge, extended aeration, and aerated lagoon, are discussed for selection purposes, because these systems can be designed and evaluated based on the laboratory data. A comparative description of these three processes is given in tab. 2. Of several factors which affect the choice of a treatment method the following five ones are considered important in making this decision. These factors are discussed in detail in the following paragraph.

Table 2

Comparative description of activated sludge, extended aeration, and aerated lagoon systems
Opis porównawczy osadu czynnego, przedłużonego napowietrzania i systemów laguny napowietrzającej

Characteristics	Activated sludge	Extended aeration	Aerated lagoon
1	2	3	4
Application	Domestic and biodegradable industrial waste. Good effluent at low cost	If flow less than 50,000 gal/day. Emergency or temporary treatment needs	Good for low and medium strength industrial and domestic waste. Inexpensive land available. Cost and operation control are minimum

1	2	3	4
Limitations	Limited BOD loading capacity. Operational complexity	High power, operation and capital costs	Reduced biological activity and treatment efficiency in cold climate
Performance	BOD removal = 85–95 % NH_4–N removal = 10–20 %	BOD removal = 85–95 % NH_4–N removal = 50–90 %	BOD removal = 60–90 % Total suspended solid removal = 70–90 %
Sludge	0.5–0.7 16/1b BOD removed :	Excess solids are the lowest of any of the activated sludge process alternative. 0.15–0.13 1b excess solids/1b of BOD removed	Solids settle at the bottom. May require cleanout every 10–20 years
Design criteria:			
Volumetic loading (1b BOD_5/d/1000 ft^3)	25–50	5–10	–
Aeration time, h	4–8	18–36	3–10 days
MLSS, mg/dm^3	1500–3000	3000–6000	Oxygen requirement = 0.7 to 1.4 lbs/1b of BOD removed
F/M	0.25–0.5	0.05–0.15	Organic loading = 10–300 lbs BOD/acre/day
Sludge retention time, days	5–10	20–40	Energy for aeration = 6–10 hp mill gal.
Air required, Std. ft^3/1b BOD removed	800–1500	3000–4000	Energy for complete mixing = 60–100 hp/mill-gal.
Recycle ratio	0.5–1.0	0.75–1.5	
Process reliability	Good. Also depends upon quality of manufacturer	Good	Service life 30 years or more. Reliability of equipment and process is high. Little operator expertise required
Environmental impact	Sludge disposal, oduor potential and energy consumption	Same as in activated sludge	Possibility of airborne bacteria, potential of seepage into ground water if lagoon is unlined. Less solids
Technology status	Highly developed and widely used since 1950	Package plants have been widely used	Fully demonstrated and used for years

3.1. NATURE OF THE WASTE

Characteristics of waste stream are very important in selecting an optimum treatment scheme. The wastewater is rich in organic matter as indicated by high BOD value. Further, a large portion of the organics is refractory giving the average BOD/COD ratio of 0.5. Nutrients are present in sufficient quality to make this waste amenable to biological treatment. Large fraction of biodegradable organics can be removed through biological treatment, but physical and chemical treatments would be required for the removal of nonbiodegradable fraction of the organic matter, nutrients, and some metals.

3.2. TREATMENT OBJECTIVE

To meet the discharge standards of the local county for safe disposal of treated effluent in surface waters, further, if effluent is impounded in reservoir, it should not contaminate ground water through percolation. Discharge criteria for Dade County adjacent to Broward County are given in tab. 1 for comparison purposes [6].

3.3. TECHNICAL ADEQUACY OF TREATMENT ALTERNATIVES

A survey of tab. 2 will indicate that any one of these three proposed methods is quite adequate for removal of biodegradable organics. The first choice appears to be extended aeration due to its small size and high BOD removal efficiency. Similar efficiency can be achieved by aerated lagoon if solids are recycled after settling in another basin. Since wastewater flow is limited in volume, it would be desirable to provide aerated lagoon with large detention time. Conventional activated sludge is not a good choice for small flow. The secondary treatment alone is not sufficient to bring the effluent quality down to discharge level as can be seen from tab. 1. Therefore, chemical precipitation and filtration would be needed to further polish the effluent with respect to organics, nutrients, and metals. As this facility is located near the sanitary landfill, therefore land treatment will also be a viable alternative for further treatment of the secondary treatment effluent due to the availability of large land area.

3.4. ECONOMIC CONSIDERATIONS

It is generally difficult to come up with accurate cost estimates for various treatment due to widely varying conditions such as nature of the waste, the process, the climatic conditions, the design criteria, the site conditions and local cost of labour, materials, land, and power. Nonetheless, the costs must be estimated in advance to choose the least expensive treatment scheme from various alternatives which are technically adequate to meet the desired objectives. Plant costs covering both the capital and operational costs must be evaluated using the local data. Among the three biological treatment methods discussed earlier, perhaps aerated lagoon can be constructed at the lowest cost. This process also requires the minimum manpower during the normal operation. Treatment efficiency of this process can easily be enhanced by adding a settling basin in order to recycle the solids. Effluent quality can be further improved by adding another low cost treatment method, i.e. land treatment instead of chemical precipitation, which is high in cost.

3.5. ENVIRONMENTAL CONSIDERATIONS

All treatment processes, like any manufacturing process, always result in some residue for disposal. This is true in case of aerated lagoon as well. The production of solids is minimum as can be seen from tab. 2 and cleaning of lagoon will be required every 10 to 20 years. The residue can be disposed at nearby sanitary landfill, and the effluent will be subject to land treatment for further polishing. This treatment requires long term commitment of large land area. Concerns with vectors and crop contamination have been identified but can be controlled by proper design and operation of the facility.

4. DISPOSAL METHODS

There is no standard system which is suited to the disposal of all types of wastewaters. Investigations must be made to determine the cheapest and practicable technique, being at the same time environmentally and socially acceptable. Stream disposal is the commonest technique in the United States and is generally the cheapest one, provided that no advanced treatment is needed. Land disposal is often socially and politically desirable, and may be economical where suitable land is available and stream standards are restrictive, although it is quite expensive compared to discharge to surface waters. In this particular case land treatment is considered a viable alternative for further treatment and/or ultimate disposal due to availability of land at sanitary landfill site and its distant location from population areas.

According to USDA Soil Survey [8], soils in Pompano Beach area are classified mainly as Hallandale fine sand and Plantation muck. Hallandale fine sand consists of a single type soil between the ground surface and bed rock with organic content of 14.5 g/kg, pH 8.2 and cation exchange capacity of 1.13 eq/g [9]. The soil profile of Plantation muck showed three distinct layers, the top, the middle and the bottom ones with organic contents of 27.9, 670.7, and 705.2 g/kg, respectively. Their pH varied from 7.3 to 7.1 and cation exchange capacity from 4.53 to 1.58. These types of soils have limited drainage capacity, which is confirmed by neighbouring soils in North–West area of Miami, composed mainly of poorly drained fine sand, marl, and peat [10]. The best land treatment for this type of soil will be slow rate gravity flow with a provision of underdrainage system for collection of effluent prior to its discharge to surface waters or ultimate disposal by diverting to groundwater.

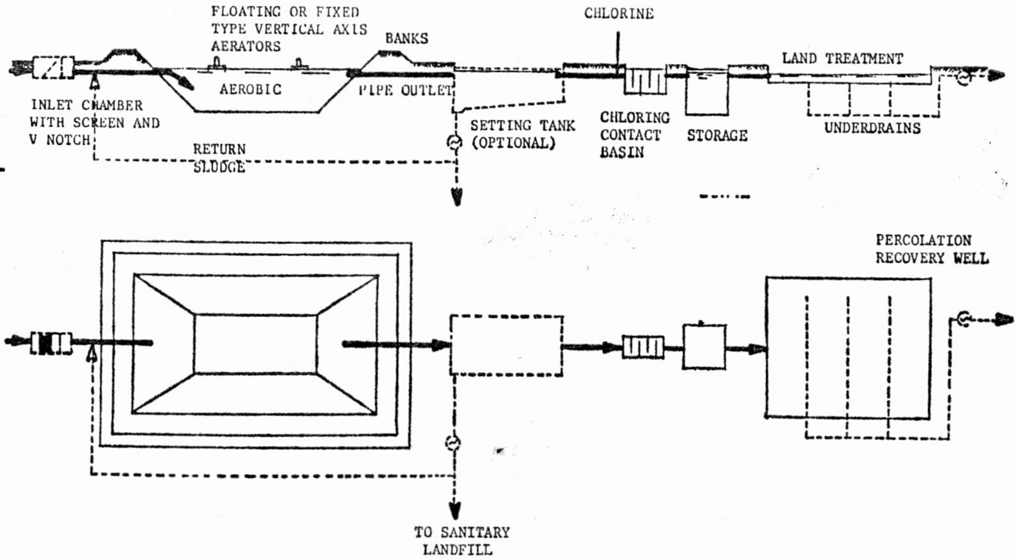
In slow rate gravity flow method wastewater is allowed to flow under gravity to vegetated soils with slow to moderate permeability. Water is treated as it seeps through soil matrix by filtration, adsorption, ion exchange, precipitation, biological activity and also by plant uptake [11]. An underdrainage system comprising pipe network is buried under the surface to recover the effluent for reuse or discharge, and to further control the groundwater. Vegetation is an important part of the process as it extracts nutrients, reduces erosion and maintains soil permeability. In this method wastewater must be pretreated prior to its application to land. The common methods include primary treatment for isolated location, secondary treatment and coliform to 1000 MPN/100 cm^3 for agriculture irrigation, secondary treatment with disinfection to 200 MPN/100 cm^3 fecal coliform for public access.

This slow rate treatment is capable of producing the best results of all the land treatments [12]. The percent treatment efficiency after flowing through 5 ft or more of unsaturated soil are: BOD and total suspended solids 90 to 99; total nitrogen 50 to 95; total phosphorus 80 to 99; and fecal coliform up to 99.99% when applied counts are more than 10,000 MPN per 100 cm^3. Land requirement for this process varies from 56 to 560 acres/mgd and soil depth should be 3 ft or more. BOD loading rate is 0.2 to 5 lb/acre/day. Underdrains are placed 3 to 10 ft deep with center to center spacings of 30 to 500 ft and diameters ranging from 4 to 8 inches.

Overall evaluation of the treatment process depends upon all the above factors. From this discussion it can be concluded that for this particular liquid waste (filtrate) stream, the best treatment would be aerated lagoon with recycling arrangement and followed by land treatment due to availability of large area near the facility. A flow sheet for this suggested scheme is given in figure. All items indicated in the figure are self-explanatory.

5. SUMMARY

A brief project description of producing methane gas from MSW is given along with the characteristics of the liquid waste generated from the above process. Lab studies have shown that waste can be treated biologically. Five factors affecting the choice of treatment processes are discussed in detail with respect to this unique liquid waste. These factors are nature of waste, treatment objective, treatment alternatives, economics, and environmental considera-



Process schematic for treatment of liquid waste
Schemat procesu oczyszczania płynnych odpadów

tions. Based on these factors the choice of treatment process is confined to activated sludge, extended aeration, and aerated lagoon with recycling. The final proposed scheme consists of aerated lagoon with recycling and land treatment based on the specificity of the waste and the site of the facility.

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OCZYSZCZANIE I USUWANIE ŚCIEKÓW POCHODZĄCYCH Z BIOKONWERSJI STAŁYCH ODPADÓW KOMUNALNYCH

Badano właściwości, a także możliwości, oczyszczania ścieków pochodzących z pilotowej instalacji przeznaczonej do produkcji metanu w procesie biokonwersji stałych odpadów komunalnych (MSW). Przedstawiono analizę danych doświadczalnych oraz omówienie czynników decydujących o wyborze jednostkowych procesów oczyszczania i prowadzących do osiągnięcia wymaganego stopnia unieszkodliwienia i usunięcia ścieków.

BEHANDLUNG UND ABLEITUNG DER ABWÄSSER VON BIOLOGISHER UMWAND LUNG STÄDTISCHER ABFÄLLE

Die Beschaffenheit und Ableitung der Abwässer vom Pilotsystem für Methanherstellung im Laufe der biologischen Umwandlung städtischer Abfälle wird untersucht und die Untersuchungsergebnisse werden ausführlich besprochen. Es wird in diesem Fall darauf hingewiesen, daß eine günstige Wahl von Einzelreinigungsverfahren anzustreben sei, um den gewünschten Reinigungs- und Umweltfreundlichkeitsgrad zu erzielen.

ОЧИСТКА И УДАЛЕНИЕ СТОЧНЫХ ВОД ОТ БИОКОНВЕРСИИ КОММУНАЛЬНЫХ ТВЁРДЫХ ВЫБРОСОВ

Исследовались свойства, а также возможности очистки сточных вод от полузаводской установки, предназначенной для производства метана, в процессе биоконверсии коммунальных твёрдых выбросов. Представлен анализ опытных данных, а также дано обсуждение факторов, обусловливающих выбор единичных процессов очистки и приводящих к достижению требуемой степени обезвреживания и удаления сточных вод.