Using Sewerage System to Generate Electricity

Jalees Asghar
jasgharofpk@hotmail.com
Zafar Industries Ltd., D/139 SITE, Karachi, Pakistan.

Abstract: *The development of the sanitary engineering has parallel and contributed to the growth of the city. Without an adequate supply of safe water, the great city could not exist and life in it would be both unpleasant and dangerous unless human and other wastes were promptly removed. The concentration of population in relatively small areas has made the task of sanitary engineer more complex. The cities, towns and villages are being polluted ground water. Industries also demand more and better water from all available sources. The rivers receive ever-increasing amount of sewage and industrial wastes and thus resulting more attention to the sewage treatment, stream pollution and complicated phenomena of self-purification. But in many developing countries there is no attention on such treatments and resulting many harmful diseases. In these days, environmental concerns are growing and the idea of generating electricity with less pollution must be favorable. It is the generation of electricity by sewerage water.*

Introduction

The development of the sanitary engineering has paralleled and contributed to the growth of the city. Without an adequate supply of safe water, the great city could not exist and life in it would be both unpleasant and dangerous unless human and other wastes were promptly removed. The concentration of population in relatively small areas has made the task of sanitary engineer more complex. The cities, towns and villages are being polluted ground water and surface water. Industries also demand more and better water from all available sources. The rivers receive ever-increasing amount of sewage and industrial wastes and thus resulting more attention to the sewage treatment, stream pollution and complicated phenomena of self-purification. In many developing countries there is no such treatment plant for the sewerage water. Rivers receive large amount of polluted water and resulting many diseases. Thus self-purification and treatment plants play a vital role in sanitation of water. The other benefit is now introducing in the form of generating electricity.

Water Consumption for Various Purposes

The water furnished to a city can be classified according to its ultimate use or end. The uses are:

1. Domestic use
2. Industrial use
3. Public use
4. Commercial use
5. Loss and waste

The approx. consumption of water in a city is shown in the table below:

Table 1: Projected consumption of water for various purposes in the year 2001 in the American city

Uses	Liters per capita /day	Total %
Domestic	300	44
Industrial use	160	24
Public use	60	9
Commercial use	100	15
Loss and waste	50	8
Total	670	100

Factor affecting consumption

The average daily consumption of different cities is different because of following factors:

1. Size of city
2. Characteristics of population
3. Industrial and commerce
4. Climatic condition
5. Metering

Sewage

Sewage is defined as a composition of:

(a) The liquid waste conducted away from residences, business buildings and institutions
(b) Liquid waste from industrial establishment with
(c) Such ground surface and storm water as may be admitted to or finds its way into the sewers.

Sewage is frequently known as sanitary sewage or domestic sewage. Sewage b is called industrial wastes. Sewer are classified according to the type of sewage that they are designed to carry sanitary sewers carry sanitary sewage and the industrial wastes produced by the community and only such ground, surface and storm water as may enter through poor joints around main hole covers and through other deficiencies.

Physical characteristics of the sewage

Sewage is ever 99.9 percent water but remaining material has a very significant effects. Fresh domestic sewage has a slightly soapy or oily odor is cloudy and contains recognized solids often of considerable size. State sewage has a pronounced odor of hydrogen sulphied is dark gray and contain smaller but occasionally recognizable, suspended solids.

At temperature of about 20 degree centigrade sewage will change from fresh to stable in 2 to 6 hours with the time depending primarily upon the concentration of the organic matter. The latter varies from per capita water consumption, infiltration and quantity of industrial waste discharge to the collection system. The quantity of waste produced per person on a dry solids basis is relatively invariant but quantity of carriage water used is not.

Solids Determination

The solids in the sewage may be suspended or in solution. Total solids include both and are determined by evaporating a known value or weight of sample and weighting the residue. Results are expressed in mg/l.

Suspended solids and dissolved solid determination require filtration of the sample. The filtration is made through a membrane filter similar to those used in bacteriological analysis.

Volatile solids are those solids ignitable at $550^{o}C$. The concentration of these materials is considered to be a rough measure of organic content or in some instances of the concentration of biological solids such as bacteria and protozoa. The volatile fraction is determined by difference between the residue following drying and that following ignition. The residue following ignition is called non-volatile solids or ask and is rough measure of mined content of the wastewater.

Chemical Characteristics

Sewage contains both organic and inorganic chemicals. The organic constituents are present in carriage water but increase due to water use. Ordinary sewage treatment is not directed towards alternating the concentration of the organic contaminants. Tertiary treatment, which may be required in same cases to maintain water quality, employs techniques similar to those used water treatment.

The organic constituents include those present in the waste discharged to the sewers and their degradation products. These may be separated analytically into fats, proteins, carbohydrates, and acids etc. but efforts are seldom worthwhile. Nitrogen and phosphorous may be present either as a part of the organic fractions or as inorganic chemicals. Their concentration is important both from a standpoint of possible water pollution and because they necessary in moderate concentration in biological treatment systems.

The alkalinity of wastewater is important since it provides a buffer against acids produced by the bacterial action in anaerobic or nitrifying systems. as sewage ages its PH tends to drop due to production of acids, but rises upon treatment.

Typical Domestic Sewage Characteristics

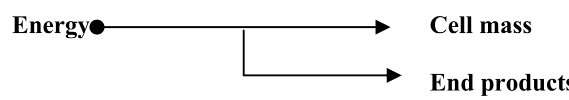
Table 2: present typical variations in the strength of domestic strength of domestic sewage in US Techniques for the chemical analysis of the waste water

Parameters	Week	Medium	Strong
Total suspended solids	100	200	350
Volatile suspended solids	75	135	210
BOD	100	200	400
COD	175	300	600
TOC	100	200	400
Ammonia-N	5	10	20
Organic-N	8	20	40
PO_4-P	7	10	20

Anaerobic Processes

Anaerobic bacteria oxides organic matter utilizing electron acceptors other than oxygen. In carrying out their metabolic process they produce CO_2,H_2O, H_2S, CH_4, NH_3, N_2, reduced organics and more bacteria. A large part of available energy appears in the form of end products; hence the cell production is low and by product such as methane may be utilized as an energy source.

The end products of anaerobic fermentation are likely to be odorous and intermediates such as volatile acids may be toxic to bacteria thus promoting upset of the process. The production of a stable effluent is unlikely since waste do not usually contain sufficient electron acceptors to permit complete oxidation.



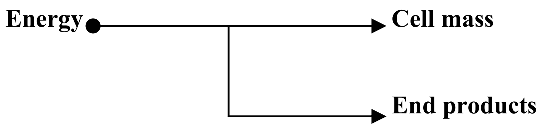
Methane, Ammonia, Hydrogen Sulphide, Reduced organics, CO_2.H_2O, Heat

Aerobic Process

Aerobic bacteria utilize free oxygen as an electron acceptor. The end products of aerobic activity are CO_2, H_2O, SO_4, NO_3, NH_3 and more bacteria. The bulk of the available energy finds its way into cell mass or heat, yielding a stable effluent which will not undergo further decomposition. The oxygen required may be furnished naturally from the atmosphere or mechanically by fine bubble aeration, thin film aeration or droplet aeration.

The oxidation of ammonia to nitrate may or may not occur depending upon the pretension time, oxygen available, temperature bacterial predominance and other factors.

In addition to strict or obligate aerobes there is a third group of bacteria called facultative which can carry on their life process which these microbes utilize their identical to those of the obligate aerobes and anaerobes save that there are certain specific reactions which they can not effect, such as reduction of CO_2 to CH_4 and oxidation of NH_3 to NO_3



Un Meta bolized organics, CO2.H2O, Heat, SO4, NO3, and NH3

Oxidation Pond

Oxidation or stabilization ponds are relatively low cost treatment systems, which has been widely used. Particularly in rural areas the pond may be consider to be completely mixed biological reactor without solid return. The mixing usually provided by natural process (wind, heat, fermentation) but may be augmented by mechanical or diffused aeration.

Aerobic ponds are generally constructed to operate at a depth between 1m and 1.5m (3 to 5 ft) shallower levels will encourage growth of rooted adequate plants, while greater depth may interface with mixing and oxygen transfer from the surface.

Both aerobic and facultative ponds are biologically complex. The general reactions, which occur, are illustrated schematically in fig. Below:

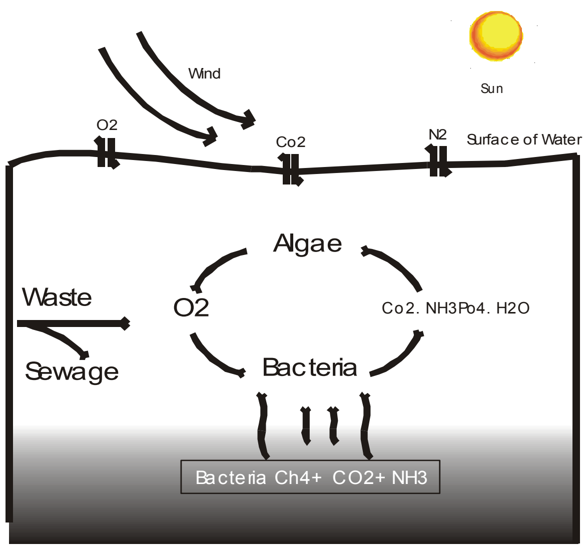


Fig. Oxidation pond schematic diagram.

Sludge treatment and disposal

(a) Amount and characteristics of sludge
(b) Sludge conditioning

Anaerobic Digestion

Solids retention time in anaerobic digestion is strongly affected by the temperature ranges from about two days about 35 degree centigrade two 10 days at 20 degree centigrade $\theta^{d}c$ is usually lager by a factor 2 to 4^{2} modern digester are both heated and mix. The temperature is maintained at 35-degree centigrade and mixing is sufficient to completely intermix the contents ones daily. Most digesters are mix more thoroughly but complete mixing in the since in which it exist in activity sludge is not necessary. Mixing is provided by recalculated gas from the headspace above the mix liquor or by mechanically driven propellers with drafts tubes. A modest amount of mixing is provided by withdrawal and return of sludge for heating but this insufficient by itself.

The addition of waste sludge should be relatively uniform in order to avoid upsetting the process. Addition should be made at least twice daily, and more frequent loading is desirable.

Design of anaerobic digester is still largely empirical. Criteria for low rate (unmixed) and high rate (mixed) systems presented in the table below.

Table 3: Anaerobic digestion design process

Design criterion	High Rate	Low rate
Solids retention time, days (θ c)	10 ----- 20	30 ----- 60
Volatile solids loading kg/m^3 per day vol. m^3 per capita	2.4 ----- 6.4	0.6 ----- 1.6
Primary only	0.04-----0.06	0.06-----0.09
Primary and tickling filter	0.08-----0.09	0.12-----0.14
Primary and activated sludge	0.08-----0.12	0.12----0.17
Digested Solids	4-----6	4-----6
Concentration volatile solids reduction%	50	60
Gas production (m3/kg vss added)	0.53	0.65
Methane content%	65	65

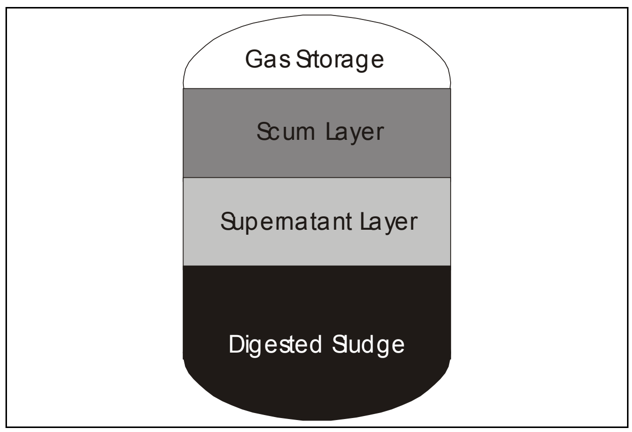


Fig. High rate anaerobic digester

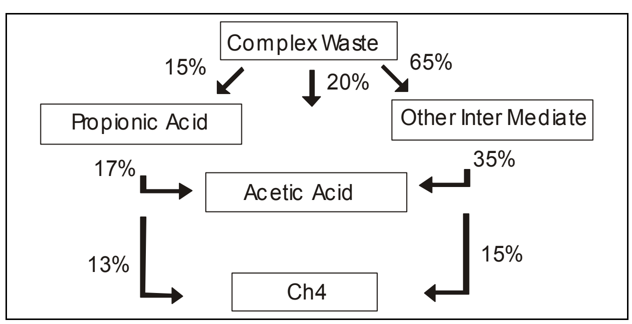


Fig. Metabolic pathways in anaerobic digestion

Aerobic Digestion

Aerobic Digestion produces volatile solids reductions compare able to those in anaerobic digestion, has BOD in supernatant, fewer operational problems, and lower capital cost. Operating cost for energy is higher and no useful by-product such as methane is produced. The digested sludge may be more difficult to dewater than anaerobically digested solid. Design criteria are similar to those for high-rate anaerobic system and are presented in the table vi.

Table 4: Aerobic digestion design criteria

Parameters	Value
Retention time (θ c) activated sludge	15-----20 days
Activated sludge plus primary air req.	20-----25 days
Air required activated sludge	20----35 l/min per m^3
Activated sludge plus primary	55-65 l/min per m^3
Solid loading	1.6---3.2 kg vss /m^3 per days

Water Pollution And Sewerage

Water has remark ability to renew and clean it self. When waste material are deposit into a receiving stream they often settle out, break down or become diluted in the stream. However, the pollution can occur if too much substances or to many substances are discharged so that it overwhelms the capacity of the stream to assimilate the substances or cleans itself. Water pollution may also occur if even just a little of a highly toxic substance is discharged into receiving stream. Water pollution can be classified in two main categories:

- Point source pollution
- Non point source pollution

The difference between the two categories is simple. Point source pollution is any type of pollution that can be identified as coming from clearly established source. This may be a factory, a previously polluted stream or other source that is obviously causing pollution. Point source pollution problem are often simpler to control because it is easier to see the cause of pollution and to do something about it.

Non-source pollution problems are more difficult to resolve. Because they often cannot be traced to one specific location. Non point source pollution includes sediment from the rainwater run off or fertilizer pollution as storms wash nutrients from fields. Now point pollution can be run off from animal waste, construction sites or mines and leach ate from land fills. Non point sources pollution could even be acid rain from atmospheric pollutants that falls to earth in polluted rain or snow and contaminates water bodies.

There are six major types of water pollutants:

1. Bio degradable wastes
2. Plant nutrients
3. Heat
4. Sediments
5. Hazardous or toxic chemicals
6. Radioactive wastes

(Fact sheet from the EPA)

Gray Water

In many arid regions of the country increasing demand of fresh water the ability of water supply agencies to provide an unlimited supply, especially during the periods of drought some cities restrict water use from the landscaping washing cars and other non essential uses. In response more and more people are recycling their household wastewater, commonly called grey water or gray water both in house and landscape irrigation. This conserve value able water lower household demand and expenses and helps to preserve landscaping vegetation. Grey water recycling also helps reduce specific system loading and sewage treatment costs for municipalities.

Generation Of Electricity

A most casual look at our civilization show the important part played by the supply and control of energy. Many functions necessary to present day living grind to halt when the supply of energy stops. While electric power is a common form of energy used in the home today, there are other forms used industrially and domestically. Energy may be sold like other commodities at so much per unit quantity.

Electrical and mechanical energies are manufactured commodities just like tangible items such as clothing, furniture or tools. All manufacturing activity processes raw materials as found in air in the form more useful for human use. Production of electrical and mechanical energy is similar, entailing the processing of natural raw forms of energy into more useful form. Raw energy is falling water, in deposits of coal, oil and gas and in certain types of refuse has yielded most readily to control and is applied commercially today. The amount of energy that may be extracted from a given source depends on its nature and ways it will be used. Despite the many practical forms of energy conversion from fuels and waterpower persistence effort are being made to extract energy from the winds, solar, solar radiation and the fissioning of uranium. Such conversions have been experimentally realized with uranium showing the most promise. Winds have been used many years as a source of mechanical energy and their use for electric generation.

Generation of Electricity from Sewerage water

As we know that water pollution is the burning issue in the present day living. The streams and rivers are being polluted from industrial and domestic sewage. It is harmful for both terrestrial and aquatic animals even for plants. Living in an industrial environment, we cannot live without making solid strategies for water pollution. Thus treatment and filtration plants are being used as a solution of this problem.

The sledge from the sewers contains many useful constituents like urea, carbon dioxide CO_2, hydrogen sulphied H_2S, methane gas CH_4, acetic acid, prop ionic acid, ammonia gas NH_3 and vitamin B12. But the extraction cost for each fraction is higher than to gain from natural resources. So it is not feasible to extract each fraction from the sludge. The production of the mixture of gases that is ignitable can be used for heating purposes like to produce steam for team turbines. Thus the production of electricity depends upon the production of steam and production of mixture of gases. In anaerobic process the production of gas rate is 0.53, which contains 65% of methane gas. Steam can be produced from this gas.

Steam Engine

The steam engine was the first type of prim mover used in the power plants but today it has been largely superseded by the turbine. In most efficient forms the engine has a better heat rate thane steam turbine at capacity less than 1000 hp.

Steam engine can be reversed and run efficiently at variable speeds. For certain applications the steam engine still offer economic advantages.

The performance of steam engine

Several ratios define the performance of steam engine.

$$\text{Brake horse power (bhp)} = \frac{2\pi nFd}{33000}$$

Where, n= rpm shaft speed
F= net brake force, lb
D= brake arm length, ft

$$\text{Indicated horsepower (ihp)} = \frac{pALN}{33000}$$

where,
p= mep,psi
A=piston area, sq in.
N=no. of cycle per minute, n
L= length of stroke, ft

$$\text{Indicated or brake engine efficiency} = \frac{2{,}545}{W\,(h1-h2)}$$

where,
W= steam rate, lb per bhp-hr
(h1-h2)= isentropic enthalpy drop for given condition

$$\text{Mechanical efficiency} = \frac{bhp}{ihp}$$

$$\text{Brake or indicated thermal efficiency} = \frac{2{,}545}{W\,(hi-hf)}$$

where,

Hi = initial enthalpy at throttles Btu per lb
Hf = enthalpy of saturated liquid at exhaust pressure, Btu per lb
W= steam rate, lb per bhp-hr or ihp-hr

The performance factor varies with load and usually is plotted on graph with load abscissa. The unit steam rate curves prove the most comparing performance. The fig. on top of next page shows typical performance curve for a 1000 hp uniflow engine with different inlet and exhaust conditions. This engine performs best at about half load. Design could make the engine perform best at full load if so desired.

Table below shows average performance levels for engines of several types. The economy depends upon steam condition, as indicated for the uni flow engine.

Table 5: Reciprocating – Engine Steam Rates

Engine Type	Dry-inlet stream pressure, psig	Full-load stream rate, lb per ibp-hr
Simple, high-speed, single -value, non-condensing	80-100	30-35
Compound, high- speed, single- valve:	150-200	24-26
Non-condensing	150-200	19-22
Condensing	80-100	24-26
Four-valve, simple, counter low:		
Non-condensing	80-100	20-22
Condensing		
Four- valve, compound, counter flow:	150-200	20-22
None condensing	150-200	14-16
Condensing		

Costs

Depending on how sophisticated the system is cost range from \$10,000 to \$20,000 the amount is in US dollars.

Annual maintenance cost must also be factor in when calculating the total investment.

The system must confirm to health regulation, maintain the full functionality of the conventional sewage system and produce low cost of electricity.

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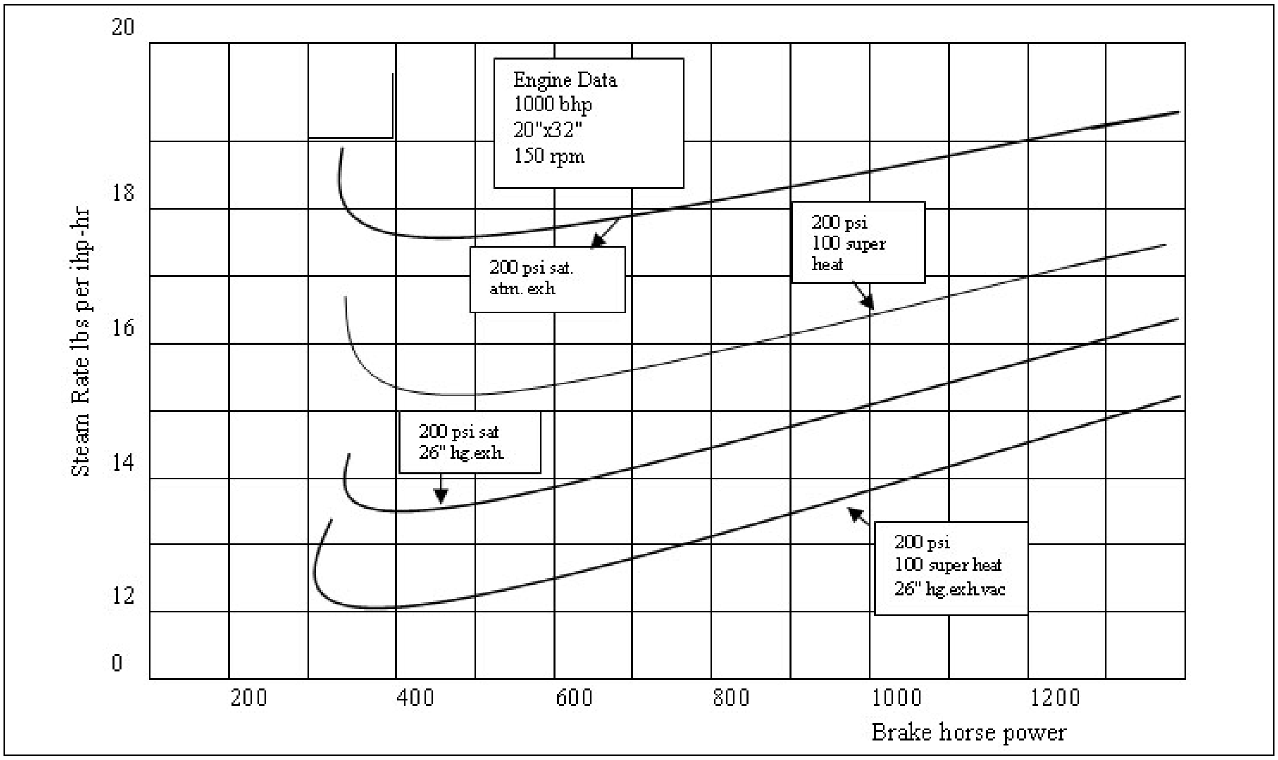

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