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Sewage/Wastewater Treatment Technologies with Special Reference to Oxidation Pond : A Tool For Waste Water Treatment

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ABSTRACT

This literature review examines process, design, and cost issues related to using oxidation ponds for wastewater treatment. Many of the topics have applications at either full scale or in isolation for laboratory analysis. Oxidation ponds have many advantages. The oxidation pond treatment process is natural, because it uses microorganisms such as bacteria and algae. This makes the method of treatment cost-effective in terms of its construction, maintenance, and energy requirements. Oxidation ponds are also productive, because it generates effluent that can be used for other applications. Finally, oxidation ponds can be considered a sustainable method for treatment of wastewater.

Keywords: Oxidation Pond , Waste Stabilization Pond, Tertiary Treatment. Wastewater Treatment Technologies

I. INTRODUCTION

The most common suspended growth process used for municipal wastewater treatment is the activated sludge process. The municipal wastewater treatment is the BOD-removal. The removal of BOD is done by a biological process, such as the suspended growth treatment process. This biological process is an aerobic process and takes place in the aeration tank, in where the wastewater is aerated with oxygen. By creating good conditions, bacteria will grow fast. The grow of bacteria creates flocks and gases. These flocks will removed by a secondary clarifier. In the activated sludge process, the dispersed-growth reactor is an aeration tank or basin containing as suspension of the wastewater and microorganisms, the mixed liquor. The contents of the aeration tank are mixed vigorously by aeration devices which also supply oxygen to the biological suspension. Aeration devices commonly used include submerged diffusers that release compressed air and mechanical surface aerators that introduce air by agitating the liquid surface. Hydraulic retention time in the aeration tanks usually ranges from 3 to 8 hours but can be higher with high BOD_5 wastewaters. Following the aeration step, the microorganisms are separated from the liquid by sedimentation and the clarified liquid is secondary effluents. A portion of the biological sludge is recycled to the aeration basin to maintain a high mixed-liquor suspended solids (MLSS) level. The remainder is removed from the process and sent to sludge processing to maintain a relatively constant concentration of microorganisms in the system. Several variation of the basic activated sludge process, such as extended aeration and oxidation ditches, are in common use, but the principal are similar:

II. TRICKLING FILTERS

A trickling filter or biofilter consists of a basin or tower filled with support media such as stones, plastic shapes, or wooden slats. Wastewater is applied intermittently, or sometimes continuously, over the media. Microorganisms become attached to the media and form a biological layer or fixed film. Organic matter in the wastewater diffuses into the film, where it is metabolized. Oxygen is normally supplied to the film by the natural flow of air either up or down through the media, depending on the relative temperatures of the wastewater and ambient air. Forced air can also be supplied by blowers but this is rarely necessary. The thickness of the biofilm increases as new organisms grow. Periodically, portions of the film 'slough off the media. The sloughed material is separated from the liquid in a secondary clarifier and discharged to sludge processing. Clarified liquid from the secondary clarifier is the secondary effluent and a portion is often recycled to the biofilter to improve hydraulic distribution of the wastewater over the filter.

III. ROTATING BIOLOGICAL CONTACTORS

Rotating biological contactors (RBCs) are fixed-film reactors similar to biofilters in that organisms are attached to support media. In the case of the RBC, the support media are slowly rotating discs that are partially submerged in flowing wastewater in the reactor. Oxygen is supplied to the attached biofilm from the air when the film is out of the water and from the liquid when submerged, since oxygen is transferred to the wastewater by surface turbulence created by the discs? rotation. Sloughed pieces of biofilm are removed in the same manner described for biofilters.

High-rate biological treatment processes, in combination with primary sedimentation, typically remove 85 % of the BOD_5 and SS originally present in the raw wastewater and some of the heavy metals. Activated sludge generally produces an effluent of slightly higher quality, in terms of these constituents, than biofilters or RBCs. When coupled with a disinfection step, these processes can provide substantial but not complete removal of bacteria and virus. However, they remove very little phosphorus, nitrogen, non-biodegradable organics, or dissolved minerals.

IV. UPFLOW ANAEROBIC SLUDGE BLANKET (UASB) PROCESS

UASB is an anaerobic process whilst forming a blanket of granular sludge and suspended in the tank. Wastewater flows upwards through the blanket and is processed by the anaerobic microorganisms. The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants. The blanket begins to reach maturity at around 3 months. Small sludge granules begin to form whose surface area is covered in aggregations of bacteria. In the absence of any support matrix, the flow conditions create a selective environment in which only those microorganisms, capable of attaching to each other, survive and proliferate. Eventually the aggregates form into dense compact biofilms referred to as "granules".

How does the UASB Work?

Fine granular sludge blanket acts as a filter to prevent the solids in the incoming wastes to flow through as the liquid part does. So if the hydraulic retention time (HRT) does not change, which is limited to 1-3 days (the bigger the digester, the shorter time it is, because the size costs money), the solid retention time (SRT) can be 10-30 days or more for more effective digestion, depending on the shape of the digestion chamber. It means that the digester becomes much more efficient without having to increase the size, which costs money. Wageningen University in the Netherlands has started to do R & D along these lines.

Standing and hanging baffles are used, with a conic separation with a small outlet at the center will be much more effective to keep the anaerobic sludge blanket in the lower part of the digester. This will act as a very good filter to retard the flow of solids in the wastes and prolong the solid retention time for more bacterial action. However, the digester will be more economic if the loading can be increased for a specific size of digester with the conic separation. COD reduction of 58% now obtained is adequate, and no attempt should be made to increase the bacterial action at such high costs. It is better to use much cheaper open tanks and basins for more effectiveness and efficiency, as in the IF&WMS.

Bio-Chemical Activities in USAB Digesters Bacterial actions are in 3 phases in the digester and they occur IN SEQUENCE:

1. **Hydrolysis or solubilization** - The first phase takes 10-15 days, and until the complex organics are solubilized, they cannot be absorbed into the cells of the bacteria where they are degraded by the endoenzymes;
2. **Acidogenesis or acetogenesis** - The result from stage one utilized by a second group of organisms to form organic acids;
3. **Methanogenesis** - The methane-producing (methanogenic) anaerobic bacteria then use the product of (2) to complete the decomposition process.

V. WASTE STABILIZATION PONDS FOR WASTEWATER TREATMENT

Introduction

Waste water stabilization pond technology is one of the most important natural methods for wastewater treatment. Waste stabilization ponds are mainly shallow man-made basins comprising a single or several series of anaerobic, facultative or maturation ponds The primary treatment takes place in the anaerobic pond, which is mainly designed for removing suspended solids, and some of the soluble element of organic matter (BOD). During the secondary stage in the facultative pond most of the remaining BOD is removed through the coordinated activity of algae and heterotrophic bacteria. The main function of the tertiary treatment in the maturation pond is the removal of pathogens and nutrients (especially nitrogen). Waste stabilization pond technology is the most cost-effective wastewater treatment technology for the removal of pathogenic micro-organisms. The treatment is achieved through natural disinfection mechanisms. It is particularly well suited for tropical and subtropical countries because the intensity of the sunlight and temperature are key factors for the efficiency of the removal processes.

Water treatment in waste stabilization ponds

(a) Anaerobic ponds

These units are the smallest of the series. Commonly they are 2-5 m deep and receive high organic loads equivalent to100 g BOD/m3 d. These high organic loads produce strict anaerobic conditions (no dissolved oxygen) throughout the pond. In general terms, anaerobic ponds function much like open septic tanks and work extremely well in warm climates. A properly designed anaerobic pond can achieve around 60% BOD removal at 20° C. One-day hydraulic retention time is sufficient for wastewater with a BOD of up to 300 mg/l and temperatures higher than 20° C. Designers have always been preoccupied by the possible odour they might cause. However, odour problems can be minimised in well designed ponds, if the SO42- concentration in wastewater is less than 500 mg/l. The removal of organic matter in anaerobic ponds follows the same mechanisms that take place in any anaerobic reactor.

(b) Facultative ponds

These ponds are of two types: primary facultative ponds receive raw wastewater, and secondary facultative ponds receive the settled wastewater from the first stage (usually the effluent from anaerobic ponds). Facultative ponds are designed for BOD removal on the basis of a low organic surface load to permit the development of an active algal population.

This way, algae generate the oxygen needed to remove soluble BOD. Healthy algae populations give water a dark green colour but occasionally they can turn red or pink due to the presence of purple sulphide-oxidising photosynthetic activity. This ecological change occurs due to a slight overload. Thus, the change of colouring in facultative ponds is a qualitative indicator of an optimally performing removal process. The concentration of algae in an optimally performing facultative pond depends on organic load and temperature, but is usually in the range 500 to 2000 μg chlorophyll per litre. The photosynthetic activity of the algae results in a diurnal variation in the concentration of dissolved oxygen and pH values. Variables such as wind velocity have an important effect on the behaviour of facultative ponds, as they generate the mixing of the pond liquid. As Mara et al. indicate, a good degree of mixing ensures a uniform distribution of BOD, dissolved oxygen, bacteria and algae, and hence better wastewater stabilization. More technical details on the efficiency of the process and removal mechanisms can be found in Mara et al. and Curtis.

(c) Maturation ponds

These ponds receive the effluent from a facultative pond and its size and number depend on the required bacteriological quality of the final effluent. Maturation ponds are shallow (1.0-1.5 m) and show less vertical stratification, and their entire volume is well oxygenated throughout the day. Their algal population is much more diverse than that of facultative ponds. Thus, the algal diversity increases from pond to pond along the series. The main removal mechanisms especially of pathogens and faecal coliforms are ruled by algal activity in synergy with photo-oxidation.

On the other hand, maturation ponds only achieve a small removal of BOD, but their contribution to nitrogen and phosphorus removal is more significant. A report on total nitrogen removal of 80% in all waste stabilization pond systems, which in this figure corresponds to 95% ammonia removal. It should be emphasised that most ammonia and nitrogen is removed in maturation ponds. However, the total phosphorus removal in WSP systems is low, usually less than 50%.

Operation and maintenance

Starting up the system, Once the construction of the system has been completed it should be checked that all ponds are free of vegetation. This is very important if the waste stabilization pond is not waterproof. Facultative ponds should be filled prior to anaerobic ponds to avoid odour release when anaerobic pond effluent discharges into an empty facultative pond . Anaerobic ponds should be filled with raw wastewater and seeded whenever possible with biosolids from another anaerobic reactor. Later, the anaerobic ponds can be gradually loaded up to the design?s loading rate. This gradual loading period can be from one to four weeks depending on the quality of the digester used or in case the pond was not seeded during the start-up procedure. It is important to measure the pH in the anaerobic pond and maintain it above 7 to permit the development of the methanogenic bacterial population. During the first month it may be necessary to add lime, to avoid the acidification of the reactor.

Initially, facultative and maturation ponds should be filled with freshwater from a river, lake or well, so as to permit the gradual development of the algal and heterotrophic bacterial population. If freshwater is unavailable, facultative ponds should be filled with raw wastewater and left for three to four weeks to allow the aforementioned microbial populations to develop. A small amount of odour release is inevitable during the implementation of the latter method in the facultative pond.

Routine maintenance

Once the waste stabilization ponds have started to operate, it is necessary to carry out regular routine maintenance tasks. Although simple, these tasks are essential to the good operation of the system.

- ✓ Removal of screening and grit retained in the inlet works during the preliminary treatment.
- ✓ Cutting, pruning and removing the grass and vegetation that grows on the embankment to prevent it from falling into the pond and generating the formation of mosquito breeding habitats. The use of slow-growing grass or vegetation is recommended to minimise the frequency of this task.
- ✓ Removal of floating scum and macrophytes (e.g. Lemna spp.) from facultative and maturation ponds to maximise photosynthesis and surface re-aeration, and prevent fly and mosquito breeding.
- ✓ Spraying the scum on the surface of anaerobic ponds (which should not be removed as it aids the treatment process). In the event fly breeding is detected this material should be sprayed with clean water.
- ✓ Removal of any accumulated solids in the pond?s inlets and outlets.
- ✓ Repair of any damage to the embankments caused by rodents or other animals.
- ✓ Repair of any damage to external fences and gates or points of access to the system.

The operator responsible should register these activities in a pond maintenance record sheet. Usually this operator is also in charge of taking samples and measurements of the pond?s effluent flow.

VI. AERATED LAGOONS ? WASTEWATER TREATMENT

The mechanic-biological purification of the waste water takes place in one or more aerated lagoons according to the size of the plant, which are followed by an non-aerated sedimentation and polishing pond. The sewage coming from the canalisation is normally led directly into the first aerated lagoon without mechanical pre-purification. So the continuous disposal of screenings, sand and sedimentation sludge and its maintenance efforts can be omitted. Coarse stuff, sand and heavy sludge settle in the inlet zone while dissolved contaminant are distributed in the whole first lagoon. Liable to putrefy matter should mainly be stabilized by aerobic processes to avoid odours and digested sludge coming up to the water surface. According to our experience sludge at the inlet zone of the first aerated waste water lagoon has to be removed at regular intervals of several years. To exhaust and bring the sludge out liquid manure-vacuum-tankers are used. Floating solids are retained by a scum board in the inlet area. They should be removed once or twice a week with a rake.

To design bigger plants (> 1,500 ? 2,000 p.e) it has of course to be considered carefully if a mechanical pre-purification of the waste water by a fine screen or a sieve offer still more advantages. Purification processes in an aerated waste water lagoon are best compared with those of a loaded water flow. Unlike activated sludge plants where suspended activated sludge eliminates the dissolved contaminant out of the waste water the active biomass is essentially as a fixed biological film at the bottom of the lagoon. Basic requirement for an extensive biological reduction of the dissolved contaminant is therefore in addition to a sufficient oxygen transfer the effective circulation and mixing of the lagoons. So stagnant zones can be avoided and an everlasting exchange of water in the area of the fixed biological film at the bottom of the lagoon is ensured.

Treatment of storm-water

Due to the long retention times (approx. 10 days) and the low load aerated waste water lagoons dispose of a high buffering capacity compared to the waste water load. Unlike activated sludge plants there is no danger that the active biomass is carried out at hydraulic overload. Accordingly a simultaneous rainwater treatment is easily possible. There are often no special measures and the whole rainwater is led through the lagoons.

It is a good solution to operate the first aerated lagoon in backwater. When reaching the maximum water level a pond overflow structure will go into operation.

In the case the first aerated lagoon is designed as a storm-water tank to retain the first amount of discharge storm-water, the storm-water overflow in front of the pond overflow will go into operation.

Aeration of waste water lagoons

FUCHS Spiral Aerators meet the requirements of an aeration system for the aeration, mixing and circulation in a special wax. For information concerning design and operation of these machines please see our prospectus « FUCHS Spiral Aerator ». If the Spiral Aerators have a suitable position in hydraulic well designed ponds an even circulation flow is formed at the lowest power requirement. It includes the whole volume of the pond and grants an even oxygen transfer and mixing. In bigger, round or square shaped ponds also the FUCHS Circulation Aerator is in operation. According to their flow pattern they are installed in the middle of the ponds. They mainly cause a vertical shifting and mixing of the waste water and complete the flow developed by the Spiral Aerators. Both aerator types have a robust construction and are almost maintenance-free. Due to their little weight a fast and easy installation without hoist is possible. It also causes no difficulties and no expenditure to dismount the machines for example for deslurrying the pond. The machines are preferably installed on a floating devices. If a constant water level is granted, the aerators can also be installed on bridges.

The machines have the following advantages : high circulation and mixing capacity minimum maintenance requirements no danger of clogging, also at intermittent operation or power failure no spray water no odour problems no noise problems no frost problems no big fan station and compressed air pipes

VII. KARNAL TECHNOLOGY

The Karnal Technology involves growing tree on ridges 1m wide and 50cm high wand disposing of the untreated sewage in furrows. The amount of the sewage/ effluents to be disposed off depends upon the age, type of plants, climatic conditions, soil texture and quality of effluents. The total discharge of effluent is so regulated that it is consumed within 12-18 hours and there is no standing water left in the trenches. Through this technique, it is possible to dispose off 0.3 to 1.0 ML of effluent per day per hectare. This technique utilizes the entire biomass as living filter for supplying nutrients to soil and plant; irrigation renovates the effluent for atmospheric re-charge and ground storage. Further, as forest plants are to be used for fuel wood, timber or pulp, there is no chance of pathogens, heavy metals and organic compounds to enter into the human food chain system, a point that is a limiting factor when vegetables or other crops are grown with sewage.

Though most of the plants are suitable for utilizing the effluents, yet, those tree species which are fast growing can transpire high amounts of water and are able to with stand high moisture content in the root environment are most suitable for such purposes. Eucalyptus is one such species, which has the capacity to transpire large amounts of water, and remains active through out the year.

Other species suitable for this purpose are poplar and leucaena. Out of these three species, eucalyptus seems to be the best choice as poplar remains dormant in winter and thus cannot bio-drain effluent during winter months. However, if area is available and the volume of effluent is small, a combination of popular and eucalyptus is the best propagation. This technology for sewage water use is relatively cheap and no major capital is involved. The expenditure of adopting this technology involves cost of making ridges, cost of plantation and their care.

This system generates gross returns from the sale of fuel wood. The sludge accumulating in the furrows along with the decaying forest litter can be exploited as an additional source of revenue. As the sewage water itself provides nutrients and irrigation ameliorates the sodic soil by lowering the pH, relatively unfertile wastelands can be used for this purpose. This technology is economically viable as it involves only the cost of water conveyance from source to fields for irrigation and does not require highly skilled personnel as well. This technology seems to be most appropriate and economical viable proposition for the rural areas as this technology is used to raise forestry, which would aid in re-storing environment and to generate biomass.

VIII. DUCKWEED

Duckweeds are very common in Iowa waters. These aquatic plants are the world smallest and simplest flowering plants. Duckweeds are floating plants that grow on the surface of still or slow moving waters during warmer weather. Because duckweeds usually reproduce by budding, they can multiply very quickly and cover the entire surface of a pond in a short amount of time. Small numbers of duckweeds will not harm a pond, but large numbers will block sunlight from entering the pond and upset the ponds oxygen balance, placing the fish population in danger. The Lemna spp. are the most common duckweeds. Lemna grow up to 4 mm (5/32 in) wide and have a single root dangling from the ÒleafÓ of the plant. Duckweeds do not have true leaves or stems; the roundish, flattened Òleaflike Ó part of the plant is called a frond.

Another type, watermeal (Wolffia spp.), are the smallest of the duckweeds. These plants are so tiny that they look like grains of green meal floating on the water surface. They are generally less than 1 mm (1/32 in) wide and barely visible as individuals. This type of duckweed does not have roots.

Control

Many times control is necessary because the duckweeds reproduce rapidly and can cover a pond causing oxygen problems.

Biological Control

Biological control refers to the use of one organism to control the growth of another. Biological control of duckweeds may be accomplished through the use of grass carp, koi, or goldfish. These fish will all eat duckweed, but results are highly variable. Biological control is much more effective if implemented before the duckweed become a problem; once established, biological controls are not effective since duckweed reproduce so quickly.

Lemna spp. of duckweed are tiny plants that can quickly spread over a pond?s surface. Wolffia spp. of duckweed are so tiny, they look like green grains of meal sprinkled on the pond surface.

Chemical Control

Chemical control (using herbicides) is probably the most effective way to control the duckweeds. Diquat and 2,4-D (liquid ester formulation) are sold under various trade names and both have good control of duckweed. Sonarä (fluridone) has excellent control of duckweed. Only fluridone applications allow for fair to good control of watermeal. Both 2,4-D and diquat have varying water use restrictions depending on formulation and rate. Fluridone does not have restrictions on drinking (by humans or livestock), swimming, or fish consumption after application. However, a restriction of 30 days is required before irrigation with treated water. For good control of Duckweed, 2,4-D must be used as a liquid ester formulation; however, the liquid ester formulation is toxic to fish. Therefore, 2,4-D formulations should be used with extreme caution when treating ponds with fish or only used for ornamental ponds without fish. 2,4-D is a translocated herbicide and kills plants over time. Treatment with 2,4-D formulations cost approximately $50-100/surface acre.

One trade name of diquat, Rewardä, is applied at a rate of 1 gallon/surface acre of water. At this rate, approximate cost of treatment is $150-250/surface acre. However, diquat is a contact herbicide and may be used as a foliar application, which could reduce the cost of treatment substantially. When using diquat as a foliar application, an approved nonionic surfactant is required. Also, diquat is tightly bound to clay and is not effective in muddy water. Diquat kills plants quickly, so only small areas at a time should be treated when dense vegetation is present. Small treatments help to avoid pond oxygen depletion when large amounts of vegetation are killed. Sonarä (fluridone) is a translocated herbicide that kills plants over a long period of time (30-90 days). Fluridone is not effective as a spot treatment; the entire pond must be treated to control duckweeds. In water, Sonarä is applied at the rate of 0.16 Ð 0.40 quarts/surface acre. The cost of treatment is approximately $100-250/surface acre. The rates and prices given are only approximations and will vary depending on the manufacturer, supplier, and extent of vegetation coverage. As always, read and follow label directions of the particular herbicide being used.

The **user** is always responsible for the effects of herbicide residues on livestock and crops, as well as problems that could arise from drift or movement of the herbicide from his or her property to that of others. Prepared by Joe Morris, extension aquaculture specialist and Charles Mischke, Department of Animal Ecology, Iowa State University.

The information given herein is for educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Cooperative Extension Service is implied.

IX. FLUIDIZED BED REACTOR

Aerobic fluidized bed reactors (FBRs) are used as a new technology in wastewater treatment. An aerobic fluidized bed reactor with granulated activated carbon (GAC) as carrier material can be operated under different conditions, including batch-loading, semi continuous loading, and continuous loading.

The basic idea behind the Fluidized Bed Reactor is to have a continuous operating non-clogging bio film reactor which requires (1) no back-washing, (2) has low head loss and (3) high specific bio film surface area. This is achieved by having the biomass to grow on small carrier elements that move with the liquid in the reactor. The movement within the reactor is generated by aeration in the aerobic reactor. These bio-film carriers are made of special grade plastic density close to that of water.

The fluidized bed reactor employs fixed film principle and makes the treatment process more user friendly because it does not require sludge recycle i.e. synonymous with conventional ASP. The absence of sludge recycle frees the operator from the enormous task of measurement and monitoring MLSS levels in the tank and adjusting recycle rations continuously, due to fluctuating inlet COD loads. FBR produces small quantity of sludge which requires no further treatment.

Fluidized Bed Reactor technology is used in small Sewage Treatment Plants for treating city wastewater, industrial sewage treatment plant from food waste, paper waste and chemical waste etc. Due to fixed film nature, these plants accept shock loads much better than those employed for suspended growth process. Fluidized Bed Reactors are generally tall (6 m and above), thereby reducing cross-sectional area further.

X. SEQUENTIAL BATCH REACTOR

In this process, the raw sewage free from debris and grit shall be taken up for biological treatment for removal of organic, nitrogen and phosphorus. The activated sludge bio-system is designed using Advanced Cyclic Activated Sludge Technology which operates on extended aeration activated sludge principle for the reduction of carbonaceous BOD, Nitrification, Denitrification as well as phosphorus removal using energy efficient fine bubble diffused aeration system with automatic control of air supply based on oxygen uptake rate.

In this form, the sequences of fill, aeration, settle and decant are consecutively and continuously operated all in the same tank. No secondary clarifier system is required to concentrate the sludge in the reactor. The return sludge is recycled and the surplus is wasted from the basin itself. The complete biological operation is divided into the following cycles:

- Fill ? Aeration
- Settlement
- Decanting

These phases in a sequence constitute a cycle. During the period of a cycle, the liquid volume inside the Reactor increases from a set operating bottom water level. During the Fill-Aeration sequence mixed liquor from the aeration zone is recycled into the Selector. Aeration ends at a predetermined period of the cycle to allow the biomass to flocculate and settle under quiescent conditions. After a specific setting period, the treated supernatant is decanted, using a moving weir Decanter. The liquid level in the Reactor is so returned to bottom water level after which the cycle is repeated. Solids are separated from the reactor during the decanting phase. The system selected is capable of achieving the following:

I. Bio-degradation of organics present in the wastewater by Extended Aeration Process.
II. Oxidation of sulphides in the wastewater
III. Co-current nitrification and denitrification of Ammonical nitrogen in the aeration zone.
IV. Removal of phosphorous

C. Advanced/ Tertiary treatment

Tertiary and/or advanced wastewater treatment is employed when specific wastewater constituents which cannot be removed by secondary treatment must be removed. The treatment processes are necessary to remove nitrogen, phosphorus, additional suspended solids, refractory organics, heavy metals and dissolved solids. Because advanced treatment usually follows high-rate secondary treatment, it is sometimes referred to as tertiary treatment. However, advanced treatment processes are sometimes combined with primary or secondary treatment (e.g., chemical addition to primary clarifiers or aeration basins to remove phosphorus) or used in place of secondary treatment (e.g., overland flow treatment of primary effluent).

Chrome Recovery System

This system based on ion exchange principle, will remove both Hexavalent chromium as anion and Trivalent chromium, Nickel, Iron etc. as cation, in a two bed ion exchange system.

The static rinse after chrome palting drag out tank, containing Hexavalent chrome ions and othe cationic impurities like trivalent chrome, Nickel, iron, copper etc. is pumped through chrome recovery coloumns. The strongly acidic cation exchanger removes trivalent chromium (and other cations) while the macroracticular weak base anion exchange resin removes the haxavalent chrome. This produces deionised water which can be recycled in a closed loop system.

The hexavlent chromium is eluted from anion exchanger with sodium Hydroxide in a concentrated solution. This solution is further passed through a third column containing strongly acidic resin in the hydrogen form. to recover chromic acid which can be recycled to the plating bath after concentrating in an evaporator.

Chrome Recovery and Recycling

A proportion of pollution generated from leather manufacturing can be contributed to the inefficiency of chemical use in leather processing and to organic substances derived from the hides during processing. In particular, the overall tanning processes performed in drums can be characterised by a high consumption of water and tanning agents, most of which are found in the final wastewater. To increase the efficiency of leather production, chromium is added in excess and is only partly taken up by the leather. Significant chromium savings can be achieved by applying modern chrome recovery and recycling technologies, thus reducing environmental impacts.

The novel chrome recycling process uses robust and easy maintainable microfiltration membranes. The porous Polyester cloth retains and concentrates alkaline chrome hydroxide, achieving chrome concentrations of up to 30 g/l Cr^{3+} and a volume reduction of up to 90 %. The highly concentrated chrome hydroxide can be then acidified with sulphuric acid and polished with the same membrane plant. Fats, proteins and fibres are retained and high quality chrome liquors are ready for re-use for tanning.

XI. OXIDATION PONDS

Oxidation Ponds are also known as stabilization ponds or lagoons. They are used for simple secondary treatment of sewage effluents. Within an oxidation pond heterotrophic bacteria degrade organic matter in the sewage which results in production of cellular material and minerals. The production of these supports the growth of algae in the oxidation pond. Growth of algal populations allows furthur decomposition of the organic matter by producing oxygen. The production of this oxygen replenishes the oxygen used by the heterotrophic bacteria. Typically oxidation ponds need to be less than 10 feet deep in order to support the algal growth. In addition, the use of oxidation ponds is largely restricted to warmer climate regions because they are strongly influenced by seasonal temperature changes. Oxidation ponds also tend to fill, due to the settling of the bacterial and algal cells formed during the decomposition of the sewage. Overall, oxidation ponds tend to be inefficient and require large holding capacities and long retention times. The degradation is relatively slow and the effluents containing the oxidized products need to be periodically removed from the ponds.

Ponds System for Treatment of Wastewater

It is a shallow body of water contained in an earthen basin, open to sun and air. Longer time of retention from few days to weeks is provided in the pond. The purification of wastewater occurs due to symbiotic relationship of bacteria and algae. The ponds are classified according to the nature of the biological activity which takes place within the pond as aerobic, facultative and anaerobic. These are cheaper to construct and operate in warm climate as compared to conventional treatment system and hence they are considered as low cost wastewater treatment systems. However, they require higher land area as compared to conventional treatment system.

Classification of Ponds

Aerobic Ponds: In aerobic pond the microbial population similar to ASP exists along with algae. The aerobic population release CO_2, which is taken up by the algae for their growth. Algae in turn release O_2, which helps in maintaining the aerobic condition in the pond. Very shallow depth of aerobic pond (0.15 to 0.45 m) is used for the treatment of wastewater for removal of nitrogen by algae growth. For general wastewater treatment depth of 0.5 to 1.2 m may be used. The solar radiation should penetrate to the entire depth of the pond to support photosynthesis to keep entire pond content aerobic. When shallow ponds (0.5 m deep) are used for tertiary treatment of wastewater, they are very lightly loaded and such ponds are called as maturation pond. These maturation ponds may release oxygen in atmosphere during day time.

Facultative stabilization Ponds: Most of the ponds exist in facultative nature. Three zones exist in this type of ponds (Figure 19.14). The top zone is an aerobic zone in which the algal photosynthesis and aerobic biodegradation takes place. In the bottom zone, the organic matter present in wastewater and cells generated in aerobic zone settle down and undergo anaerobic decomposition. The intermediate zone is partly aerobic and partly anaerobic. The decomposition of organic waste in this zone is carried out by facultative bacteria. The nuisance associated with the anaerobic reaction is eliminated due to the presence of top aerobic zone. Maintenance of an aerobic condition at top layer is important for proper functioning of facultative stabilization pond, and it depends on solar radiation, wastewater characteristics, BOD loading and temperature. Performance of these ponds is comparable with conventional wastewater treatment.

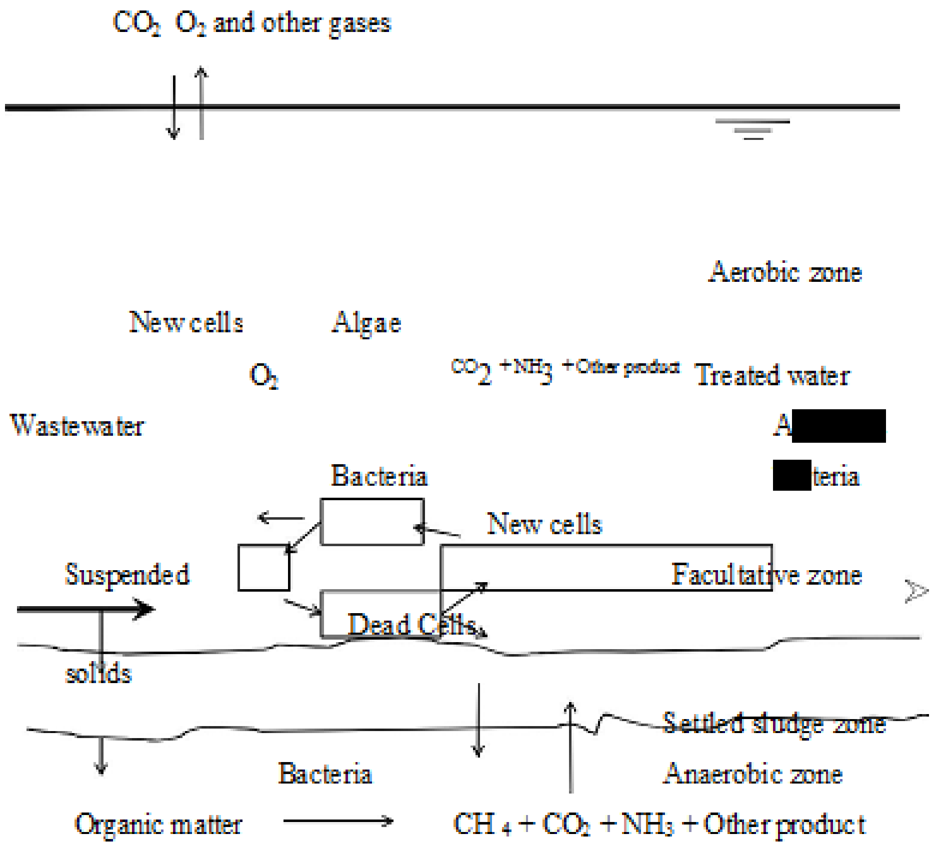

Figure 1 Facultative stabilization pond

Anaerobic pond: In anaerobic pond, the entire depth is under anaerobic condition except an extremely shallow top layer. Normally these ponds are used in series followed by facultative or aerobic pond for complete treatment. The depth of these ponds is in the range of 2.5 to 6 m. They are generally used for the treatment of high strength industrial wastewaters and sometimes for municipal wastewater and sludges. Depending upon the strength of the wastewater, longer retention time up to 50 days is maintained in the anaerobic ponds. Anaerobic lagoons are covered these days by polyethylene sheet for biogas recovery and eliminating smell problem and green house gas emission in atmosphere.

Fish pond: It can be part of maturation pond or altogether separate pond, in which fish are reared. Sometimes, fishes are also reared in the end compartment of primary pond.

Aquatic plant ponds: These are secondary ponds in which aquatic plants e.g. hyacinths, duckweeds, etc. are allowed to grow either for their ability to remove heavy metals and other substances from wastewaters, or to give further treatment to wastewaters and produce new plant biomass. This recovered biomass can be used for biodiesel, bioethanol, combustible gas recovery as fuel or many other chemicals can be recovered using these plants as feed stock.

High-rate algal ponds: The high rate algal pond (HRAP) is potentially an effective disinfection mechanism within the requirements of sustainability. In addition to disinfection, nutrient removal mechanisms are also active in the HRAP, specifically those involved in the removal of phosphate. These ponds are not designed for optimum purification efficiency but for maximum algal production. The algae are harvested for a variety of uses, principally high quality algal protein. The ponds are shallow lagoons 20–50 cm deep, with a retention period of 1–3 days. The whole pond is kept aerobic by maintaining a high algal concentration and using some form of mechanical mixing. Mixing is normally carried out for short periods at night to prevent the formation of a sludge layer. Mixing may be required for short periods during the day to prevent a rise in pH in the surface water due to photosynthesis. The pond is commissioned in the same way as a facultative pond except that continuous loading should not be permitted until an algal bloom has developed. Loading depends on solar radiation, and the average loading throughout the year could be 100 to 200 kg BOD $ha^{-1}d^{-1}$. Strong organic sewage inhibits the photosynthetic action due to high ammonia concentrations, which results in the pond becoming anaerobic. High rate algal ponds are designed to promote the symbiosis between the microalgae and aerobic bacteria, each utilizing the major metabolic products of the other. Microalgae grow profusely releasing oxygen from water by photosynthesis. This oxygen is immediately available to bacteria to oxidize most of the soluble and biodegradable organic matter remaining from the facultative pond. HRAPs are shallower than facultative ponds and operate at shorter hydraulic retentions times (HRTs). At the rapid growth of algae, the pH can raise to above 9 since at peak algal activity. Carbonate and bicarbonate ions react to provide more carbon dioxide for the algae, leaving an excess of hydroxyl ions. A pH above 9 for 24 hours ensures a 100% killing of E. coli and presumably most pathogenic bacteria.

Primary and secondary ponds: Ponds receiving untreated wastewaters are referred as raw or primary waste stabilization ponds. Those receiving primary treated or biologically treated wastewaters for further treatment are called as secondary waste stabilization ponds. Maturation pond is the secondary pond receiving already treated wastewater either from the ponds or other biological wastewater treatment process, like UASB reactor or ASP. The detention time of 5 to 7 days is provided in these ponds, with the main purpose of achieving natural bacterial die-off to desired levels. In warm climate they often constitute an economical alternative for chlorination. They are lightly loaded in terms of organic loading and the oxygen generated by photosynthesis may be more than the oxygen demand.

Typical Flow Chart of Pond Based Treatment Plant

The typical treatment flow sheets for different types of ponds in use are illustrated in the Figure 19.15. The ponds can be used in series or in parallel. Chlorination of the treated effluent is optional. The primary treatment after screen can be combined in the ponds along with secondary treatment. In all the flowcharts of the ponds in the Figure 19.15, screens are provided ahead of the first pond. **Factors Affecting Pond Ecosystem**

The principal abiotic components of ponds ecosystem are oxygen, carbon dioxide, water, light and nutrients; while the biotic components are algae, bacteria, protozoa, and variety of other organisms. Various factors affect the pond design, such as (Arceivala and Asolekar, 2007):

Wastewater characteristics and fluctuation,

- Environmental factors such as solar radiation, sky clearance, temperature, and their variation,
- Algal growth pattern and their diurnal and seasonal variation, Bacterial growth pattern and decay rates,
- Hydraulic transport pattern,
- Evaporation and seepage,
- Solids settlement, liquefaction, gasification, upward diffusion, sludge accumulation, Gas transfer at interface.

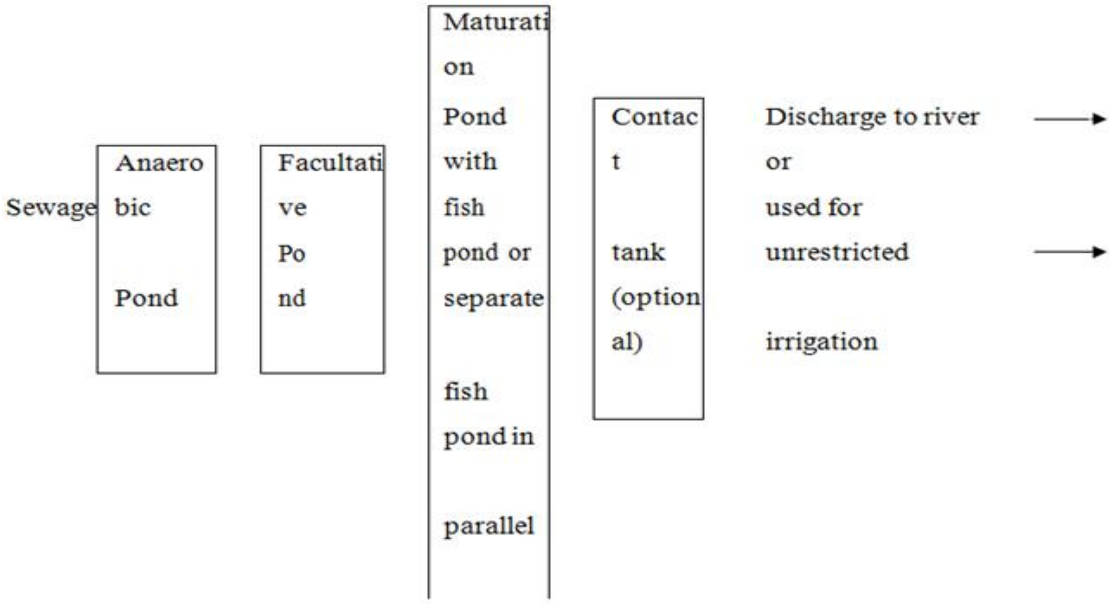

Figure 2. Flowcharts of the waste stabilization ponds

Design Guidelines for Oxidation Pond

1. Depth of Pond: It should be within 1 m to 1.5 m. The ponds are designed with such a shallow depth to provide proper penetration of light, thus allowing growth of aquatic plants and production oxygen. When these ponds are used for sewage treatment the primary objective is organic matter removal and a depth of 1 m to 1.2 m is used. Shallow ponds experience higher temperature variation than deeper ponds. So, an optimum pond depth is necessary.

2. Surface area of Pond: Sufficient surface area must be provided so that oxygen yields from the pond is greater than the ultimate BOD load applied. NEERI gives photosynthetic oxygen yield for different latitude in India:

Latitude (^{0}N)	Yield of photosynthetic O2 (kg/ha.day)
16	275
20	250
24	225
28	200
32	175

Individual pond area should not be greater than 0.5 ha. If any system requires more area then it is desirable to have more than one pond. 25 % more area is provided than that calculated to account for embankments.

4. Substrate removal rate: Substrate removal rate Kp varies from 0.13 to 0.20 per day at 25 0C and 0.10 to 0.15 at 20 0C. For other temperature it can be calculated as:

$$K_p (T^oC) = K_p (20^oC)(1.035)^{(T-20)} \quad (1)$$

The size of the pond will be half when plug flow pattern is maintained rather than completely mixed conditions. This can be achieved by providing ponds in series.

5. Detention time (T): It should be adequate enough for the bacteria to stabilize the applied BOD load to a desirable degree.

6. Sulphide production: Sulphide production in oxidation ponds can be calculated from the following empirical relationship (Arceivala and Asolekar, 2007): S^{2-} (mg/l) = (0.0001058 * BOD_5 – 0.001655 * T + 0.0553) * SO_4^{2-} Where, BOD_5 is in kg/ha.days,

T = detention time in days, SO_4^{2-} in mg/l.

Sulphide ion concentration should not be greater than 4 mg/L. At

concentrations higher than this algal growth is inhibited.

- Coliform removal: To use the pond effluent for irrigation Coliform concentration should be less than 1000/100 ml. Coliform removal follows the first order rate equation (Arceivala and Asolekar, 2007):

$dN/dt = K_b.N$, (2)

where, N = Number of organisms at any given time, t

K_b = Death rate per unit time (1 to 1.2 per day at 200C)

7. Sludge accumulation: Sludge accumulation occurs in the pond at the rate 0.05 to 0.08 m3/capita/year. Sludge accumulation causes decrease in efficiency of the ponds, so they require cleaning every 7 to 10 year.

8. Pretreatment: Medium screens and grit removal devices should be provided before the ponds.

9. Inlet pipe with the bell mouth at its end discharging near the centre of the pond is provided.

10. The overflow arrangement is box structure with multiple valve draw-off lines to permit operation with seasonal variations in depth.

11. If the soil is pervious it should be sealed to prohibit seepage.

Example

Design an Oxidation Pond with efficiency 85 % for a wastewater stream of 2 MLD with a BOD of 200 mg/L and the effluent coming out of the pond should have a BOD less than 30 mg/L. Temperature of the influent wastewater is 30^0C and the oxidation pond is located at a place having latitude 22^0N.

Solution

At 220N, oxygen production by photosynthesis = 235 kg/hectare.day, And Kp = 0.23/day.

The oxidation pond is designed for plug flow conditions. For plug flow conditions, dispersion number, D/UL = 0.2

Kpt (for efficiency = 85%, D/UL = 0.2) = 2.5 (Arceivala and Asolekar, 2007) Therefore, detention time, t = Kpt/Kp = 2.5/0.23 = 10.87 days.

Now, wastewater flow = 2 MLD = 2000 m3/day

Therefore, pond volume = detention time * flow = 2000 * 10.87 = 21739.14 m3 Maximum BOD load that can be applied on the pond = 235/0.85 = 276.47 kg/day Influent ultimate BOD = (1/0.68) * 200* 2 = 588.2 kg/ha.day

Therefore, minimum pond area required = 588.2/276.47 = 2.13 ha Gross land area required = 1.25 * 2.13 = 2.66 ha

Minimum pond depth = (Pond Volume)/(Pond area) = [21739.14/(2.13*10000) = = 1.02 m

Provide length = 225 m, breadth = 118.2 m, free board = 1m, Therefore depth of the pond = 2.02 m

To maintain plug flow conditions the pond is divided into 3 cells along length with each cell length = 75 m.