Aeration

The activated sludge process

Most wastewater treatment plants are using the activated sludge process. The heart of such a process mainly consists of an aeration tank, a sedimentation tank or clarifier and a sludge recycle line.
In the aeration tank wastewater and activated sludge are mixed in the presence of dissolved oxygen. This allows the absorption and oxidation of impurities and the flocculation of the biomass. Besides it encourages the development of new micro organisms.
After the aeration water and sludge are separated by sedimentation in the final clarifier. The quiescent flow conditions in this basin let the flocculated sludge settles and concentrate. The settled sludge is returned continuously to the aeration tank. To maintain a certain biomass the sludge growth is removed from the system.

Oxygen requirements

The Actual Oxygen Requirement (AOR) in aeration tanks strongly depends on sludge quantity, sludge loads and water temperature. The aeration capacity is normally based on the oxygen transfer under standard conditions which means in clean water, at 10 or 20 oC, atmospheric pressure 1013 mBar and no dissolved oxygen in the water. To permit evaluation of different aeration systems under the same conditions and to properly size and select an aeration device, the calculated AOR must be transferred to standard conditions. In general the Standard Oxygen Requirement (SOR) is in between 1.5 2.5 times the AOR.

AERATION TANKS

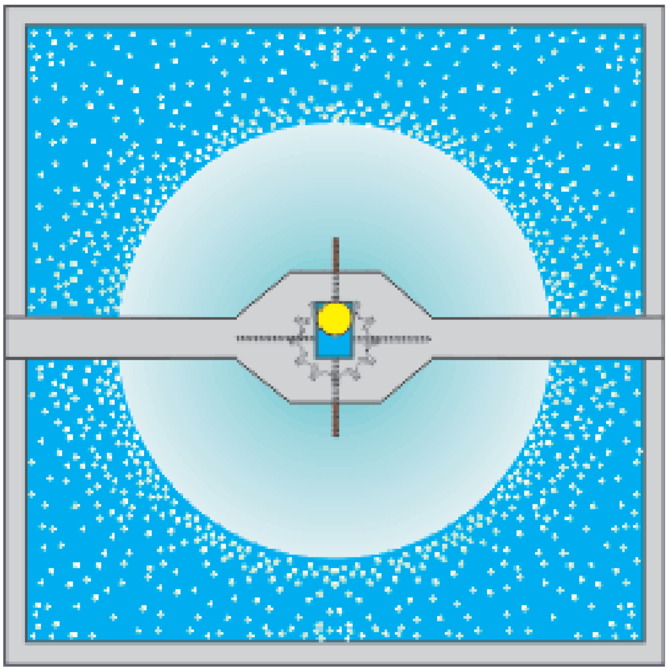
The quantity of the biomass required depends strongly on the load and the effluent quality to be met. Once the quantity of the biomass is known, the oxygen command (OC) can be determined and the aeration tank can be designed. The aeration tanks can be subdivided in complete mix, plug flow and circulator systems. In plug flow systems mixing is mainly concentrated in some parts of the tank, while in complete mix and circulator systems the mixing affects the whole tank. Therefore the concentrations of oxygen and pollutants differs much more in plug flow systems than in complete mix systems. This has important effects on the biological process.

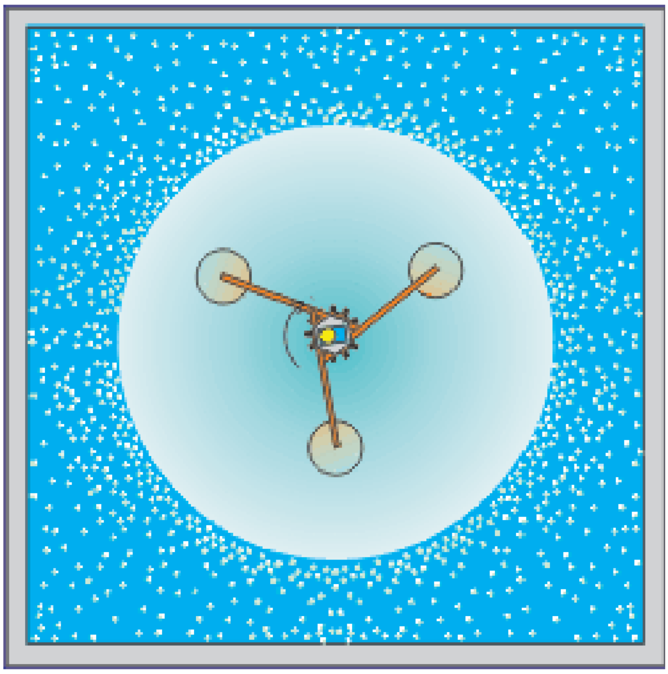
Design

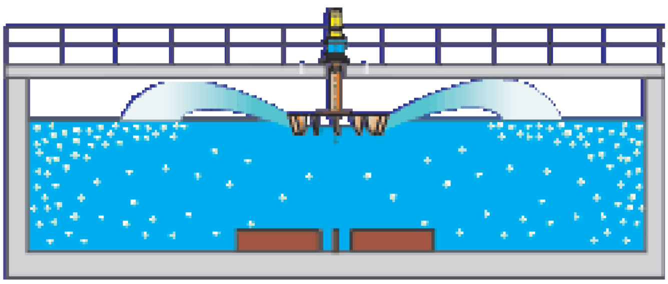
The most simple aeration tank is the complete mix tank provided with one surface aerator or with bubble aeration on the bottom. The tank can be square or circular. The rules of thumb to design a complete mix tank for just one surface aerator are as follows:

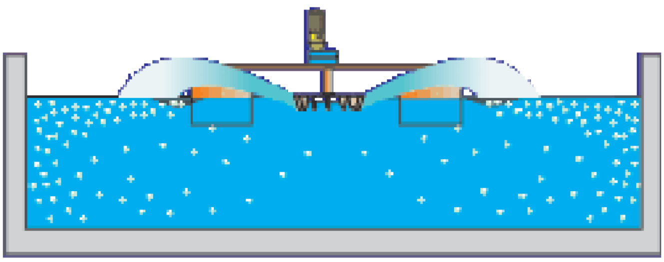
- The water depth should preferably be in between 1,2 and 2,2 times the diameter of the aerator.

- The ratio tank width versus water depth should preferably be in between 3 and 4.
- The specific aeration power installed should preferably be 20 W/m3 or more.
- Bottom baffles are required to prevent the creation vortexes which can influence the power release of the aerator strongly.
- Circular tanks often require baffles to the wall to reduce horizontal circular flow.
- The aerator can be floating or fixed to a bridge or platform. The floating aerators are often used in sequencing batch reactors (SBR) and/or in tanks with a big surface..







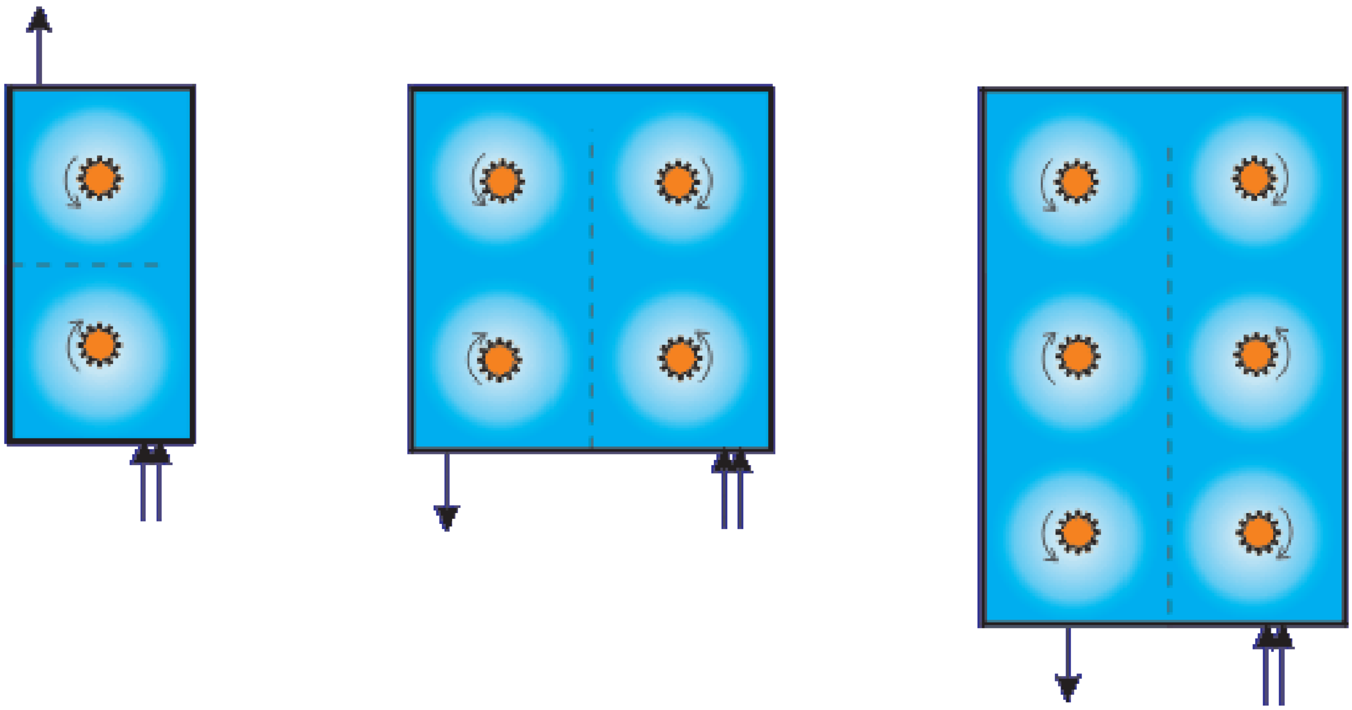


Covers

To eliminate aerosols and splashing noise the aeration tank can be covered completely. To prevent exhaustion of oxygen an air inlet close to the aerator and an air outlet in all the corners of the tank are required. The sizes depend on the aerator capacity. It is also possible to cover the aeration zone only and leave the rest of the tank uncovered. In this solution the size of the cover should be such that the water out throw of the aerator is not substantially disturbed.

More aerators per tank

A complete mix tank can be equipped with as many aerators as one likes. The design of complete mix tanks with more than one aerator can be seen as a combination of square tanks without deviding walls. Some examples:



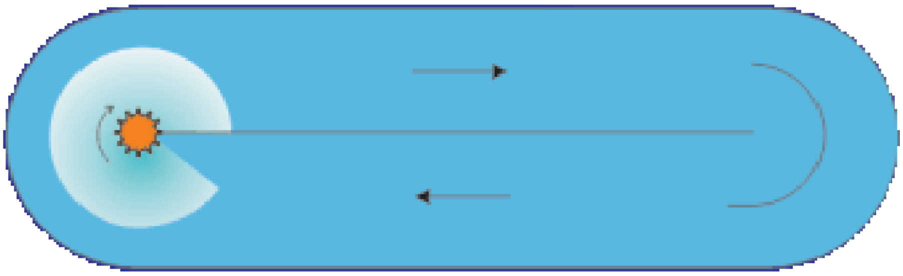
It is possible to apply intermittent walls the tank. In this way a sort of plug flow system is created. This gives less chance on short circuiting between in- and outlet of the tank.

The direction of speed of the aerators should preferably be in opposite direction with their direct neighbours to be sure about complete mix conditions in each compartment.

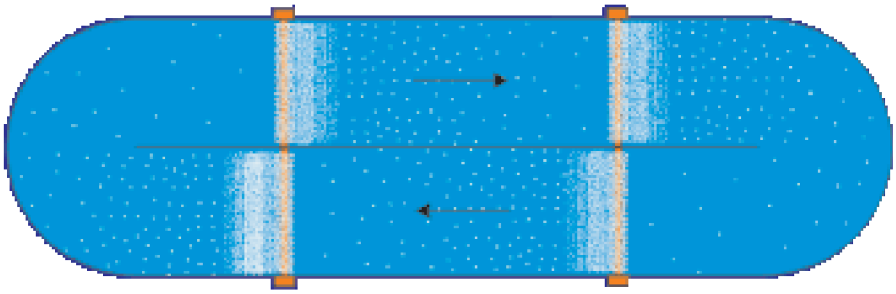
The aerators to be used can be of the floating type or fixed to a bridge or platform. When the floating type is chosen, one has to realize the power regulation can only be done by change of speed as the submergence of the aerator is not affected by the water level in the tank and will be constant.

Plug flow systems

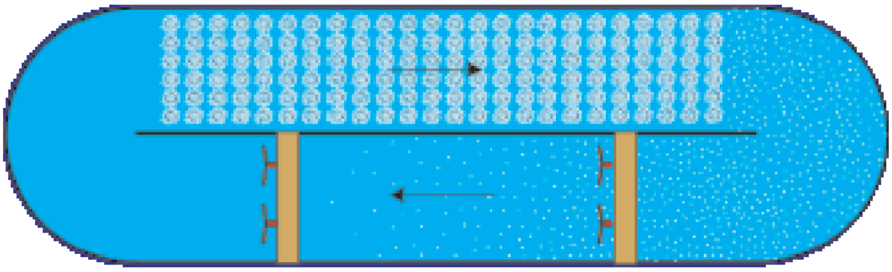
In plug flow systems almost all aeration systems can be applied. Some examples:



With vertical shaft aerators.



With horizontal shaft aerators.

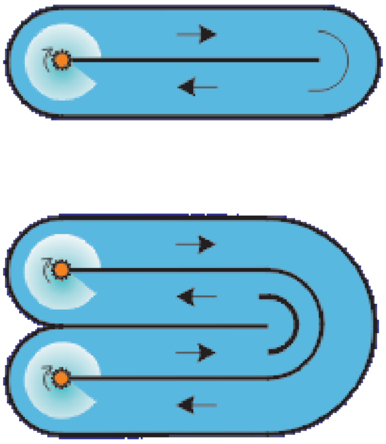


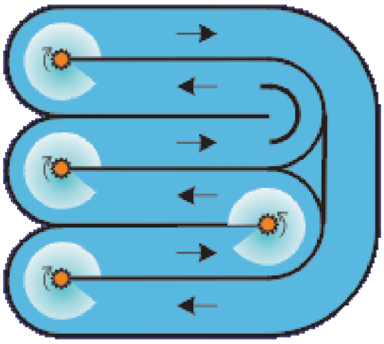
With bubble aeration.

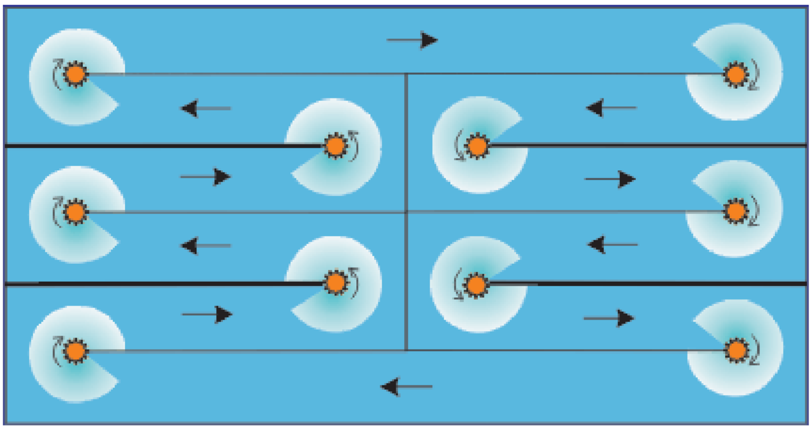
Oxidation ditch

One of the most important types of plug flow systems is the oxidation ditch. The oxidation ditch is characterized by a very low sludge load. In the aeration zone the oxygen content is normally above 2-3 mg/l. In this oxygen rich area nitrification (oxidation of ammonia to nitrite and nitrate) takes place. This is done by nitrifying bacteries. Downstream of the aeration zone the oxygen content decreases gradually and the nitrification is slowing down.When the oxygen content reaches a level below about 0,5 mgO2/l nitrification will stop almost completely and denitrification by denitrifying bacteries occurs. Denitrification is the reduction of nitrite and nitrate into nitrogen and oxygen. The nitrogen escapes to the air and the oxygen is used by the microrganisms for their energy management. The process of nitrification and denitrification is typical and very important for the design and operation of an oxidation ditch. It improves the effluent quality and reduce the energy consumption.

One of the most popular aeration systems for an oxidation ditch is the low speed surface aerator with vertical shaft. More than thousand are built all around the world. The size varies from several hundreds to over seven million (!) population equivalents. Possible lay outs are:





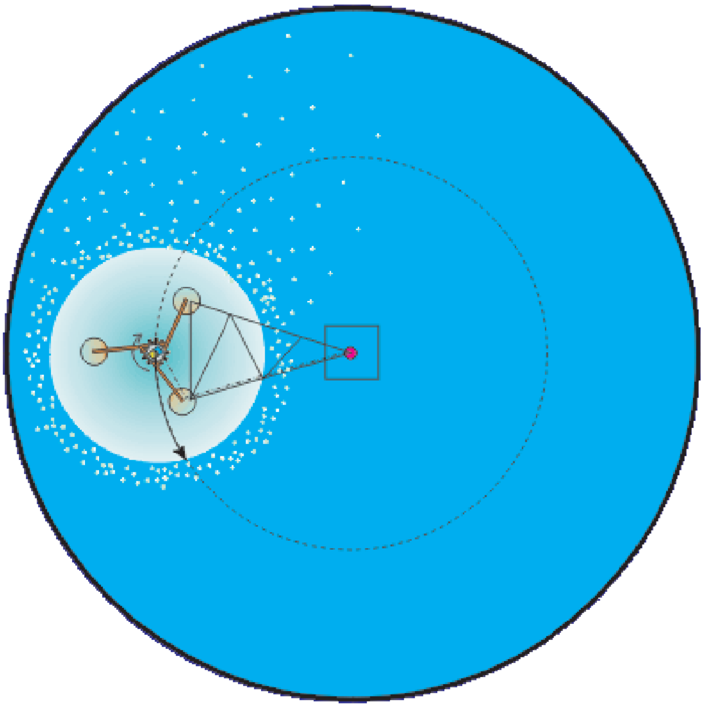


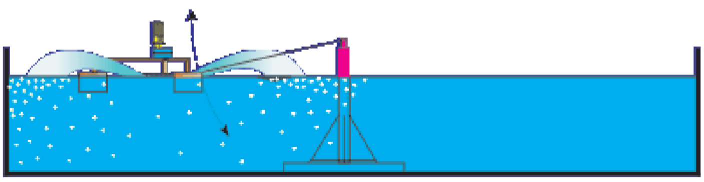
The choice of the lay-out depends the number of aerators and the dimensions of the site. From hydraulical point of view the lay-out with the lowest number of subchannels is the best as the hydraulical resistance is low due to the small number of bends.

The low speed aerators are designed such that the oxygen command required is met and that the flowvelocity in the channels is high enough to keep all sludge in suspension. The aeration unit with the highest power ever applied in an oxidation ditch, is 250 kW. The oxygen transfer capacity of such aeration unit is about 450 - 500 kgO2/h under standard conditions.

The channel sizes of an oxidation ditch depends on the size of the aeration unit. The ratio between channel width and waterdepth should preferably be equal to 2, because that gives the lowest hydraulical resistance and the best flow velocity.

The circulator In situations where a shallow tank with a big surface, such as lagoons, have to be aerated, the rules of thumb lead to the application of a large number of small aerators In this way the power input can be distributed complete mix conditions can be created at all locations in the tank. Starting from a certain water depth the application of a much smaller number of aerators of higher capacity increases the ratio width/depth and there will not be complete mix conditions in all parts of the tank, by which sludge settlements may occur. To prevent sludge settlements in such situations, the application of a so called "circulator" is advised.





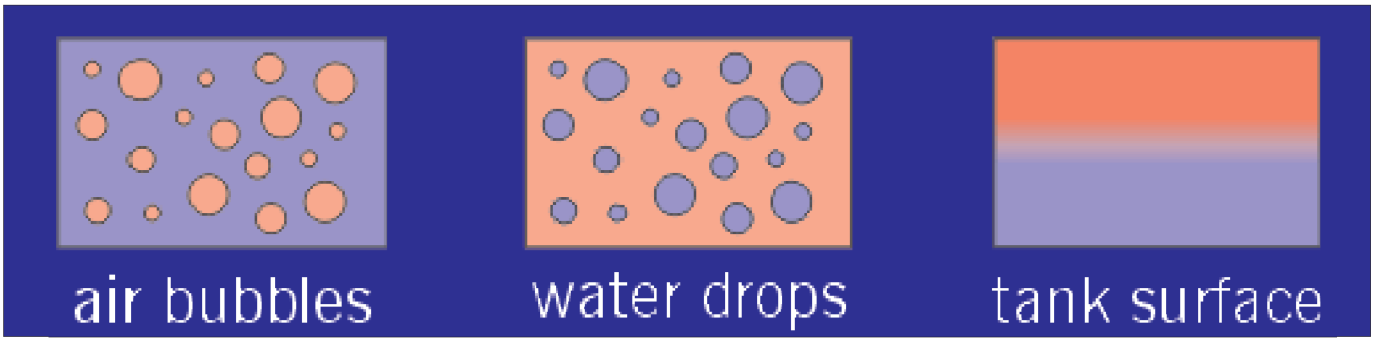
A circulator consists of a square or circular tank in which a floating aerator is fitted by bars to a central column. The connection of these bars to the floats of the aerator and to the column is flexible so that the complete unit can follow any change in water level. The power is supplied by a commutator at the top of the column.

When the aerator is put into operation, the reaction force on the motor pushes the aeration unit such that it is turning around the column in the opposite direction of the speed of the aerator. The velocity depends on the aeration unit but is about 10 - 30 cm/s. In this way a large tank surface can be aerated with one floating unit only, which is in general much more economical than the application of more aeration units of a smaller size. An other advantage is that during every circulationion of the aerator unit both proccesses nitrification and denitrification will occure.

AERATION CAPACITY

The aeration capacity is strongly depending on the situation and choice of a system. For a better understanding some basics concerning aeration or oxygen transfer:

Oxygen transfer only takes place at the contact area air-water. This contact area can show up in three different ways:



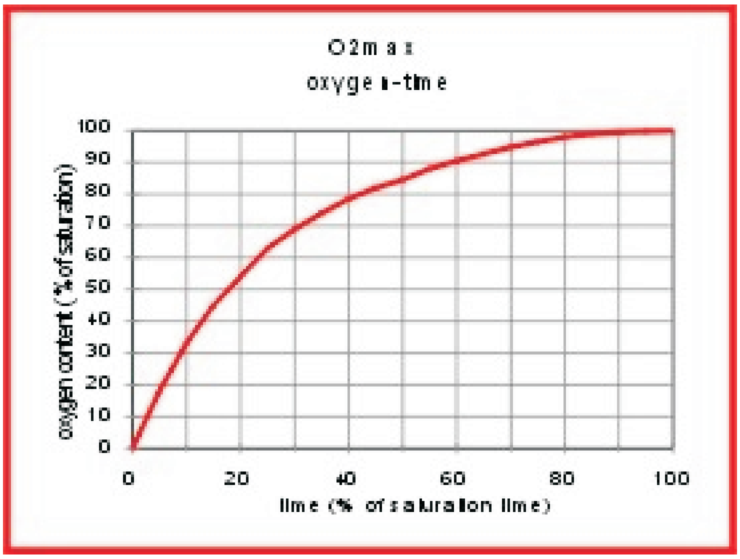
The oxygen transfer is influenced by following circumstances:

Contact area
The bigger the contact area is, the bigger the oxygen transfer will be. Therefor fine air bubbles, fine drops and a big tank surface are favourable in this respect.

Renewing of contact area
Oxygen transfer however is not only influenced by the size of the contact area, but also by the speed with which the contact area is renewed. The water at the boundary layer becomes saturated almost immediately after exposing to the air. However, in stand still water the diffusion of dissolved oxygen to deeper water layers goes very slowly. A fast and constant renewing of the contact area is required to get a high oxygen transfer.

Oxygen deficit

The oxygen deficit is the difference between the actual oxygen content and the oxygen saturation value of the water. The bigger the deficit is, the better the oxygen transfer will be. The maximum deficit is met when the actual oxygen content is zero. In the graph the increase of oxygen content (vertical axis) versus time (horizontal axis) of a water sample, being aerated with a constant capacity, is shown. From the graph it can be seen that the increase of the oxygen content is slowing down when oxygen content is higher.



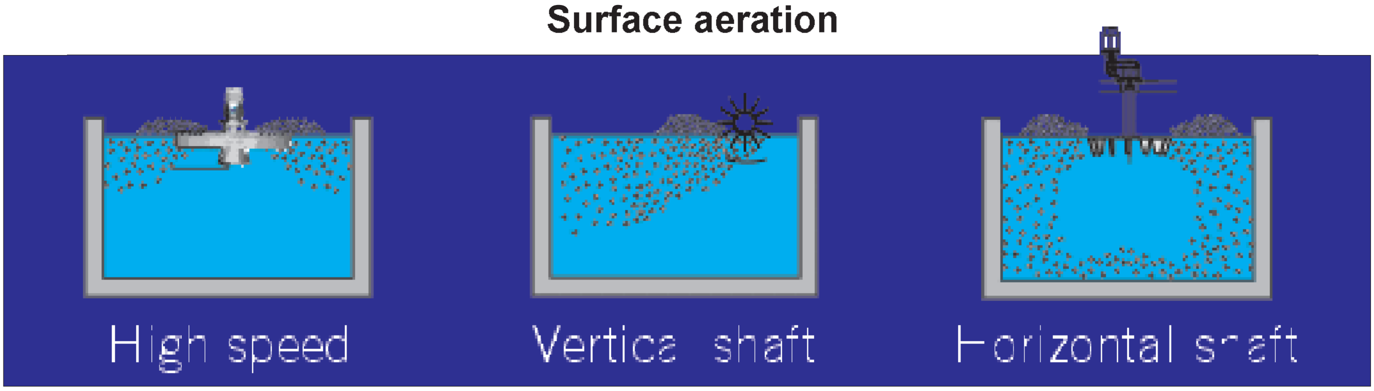
Alpha- and Beta factor

The alpha- and beta factor respresent the ratio of oxygen dissolving capability in process water and clean water. It is influenced by a great number of process conditions including surfactants, turbulency, power input per unit, geometry, scale, bubble size, sludge age, degree of treatment, and other wastewater characteristics. It has to noted that these factors is normally not constant for a given wastewater stream, therefore a range of alpha and beta factors should be considered.

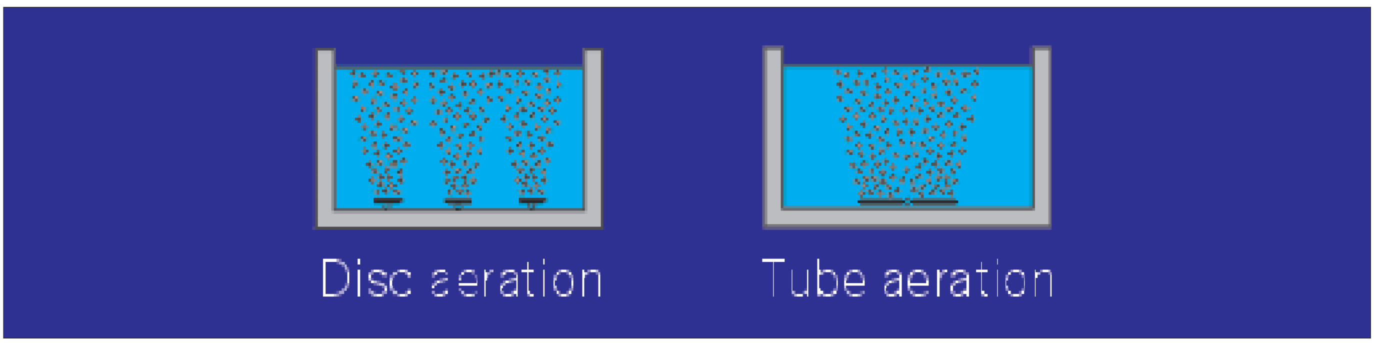
AERATION SYSTEMS

The aeration systems can be subdivided in surface aeration and bubble aeration

Surface aeration



Bubble aeration



The main differences between these systems are as follows:

1. Oxygen transfer efficiency (OTE)

The oxygen transfer efficiency under standard conditions (SOTE) in clean water is for fine bubble aeration bubble aeration better than for surface aeration. However under field conditions the efficiency decreases. The alpha-factor varies for bubble aeration from 0.3-0.8 and for surface aeration from 0.7 1.0.

2.Noise and aerosols

Bubble aeration has lower noise and aerosol production than surface aeration in open systems. At present the complete aeration zones of surface aerators are covered mostly, which reduces the noise and aerosol production to about the same level like fine bubble aeration.

3.Sizing of the aeration tank

The sizing of the aeration tank for fine bubble aeration is restricted to a certain minimum water depth, which is about 4 m. A lower water depth will reduce the effectiveness of the system. Surface aerators have limitations with respect to the maximum water depth. Depending on the type of surface aeration the maximum water depth can vary from about 3-4 m for brush aerators to about 6-7 m for vertical shaft aerators. A bigger water depth may cause problems with mixing and/or aeration efficiency.