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A Comparison of Different Aeration Systems

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ABSTRACT

Aeration tests have been performed under operation conditions and in clean water in order to obtain information on the economy of different aeration systems. The results of investigations using jet aerators membrane diffusers and surface aerators are reported. The aeration tanks used for the tests were tanks with circulating mixed liquor. Typical α-values are reported for different systems tested and operational experiences are also included.

KEYWORDS

Aeration system; fine bubble system; jet aeration; surface aerators; α-value; operational experience.

INTRODUCTION

Most of the energy used in activated sludge plants is consumed by the aeration system. Improving the treatment efficiency from carbon removal only to nitrification for sewage will double the oxygen demand in the aerobic zone. So it is economically necessary to install aeration systems with sufficient oxygen transfer and a high specific yield.

Aeration tanks for simultaneous denitrification are often designed as tanks with a circulating flow.

Normally aeration systems are selected by means of SOTE (Standard Oxygen Transfer Efficiency) in clean water given by the supplier. In day to day operation, however, the efficiency of the system under actual operating conditions is decisive. Questions concerning operational experience, liability, maintenance and repair are in most cases not dealt with.

At the request of the suppliers of aeration equipment and the plant managers, several measurements of the oxygen uptake rate under clean water and operating conditions were made at large wastewater treatment plants. In order to minimize the influence of tank configuration only results of measurements in tanks with circulating flow will be presented in this paper.

METHODS

All clean water measurements were made by the absorption method. Some of the tests under operating conditions were made by the desorption method (Kayser, 1979) Usually six membrane sensors were installed in the aeration tank for the measurements. The data were recorded directly by a lap top computer with an A/D-converter and evaluated with the non linear regression method (ASCE, 1984).

Sodium sulphite (Na_2SO_3) was added as powder for the absorption tests and hydrogen peroxide (H_2O_2) was added as a 15 % solution. In tanks with circulating flow the circulation time was determined and the addition of the chemicals was distributed over a multiple of the circulating time.

PLANT DESCRIPTION

Plant A

The plant is designed for 70.000 PE and treats mainly domestic sewage with an industrial effluent content of approximately 20 %. The flow amounts to approximately 9.000 m^3/d with a COD load of 5.500 kg/d. The primary tanks are rectangular with a surface area of 950 m^2 and a total volume of 2.900 m^3. The two aeration tanks have a total volume of 8.000 m^3; two final tanks have a volume of 7.500 m^3 and a surface area of 2.500 m^2. The sludge is digested in an anaerobic digester with a volume of 2.500 m^3. The digester gas is used for the operation of one air blower for the production of compressed air for the aeration. The aeration system in the aeration tank consists of membrane aerators which are situated in four groups on the bottom of the tank. For the induction of flow each tank is equipped with four propellers.

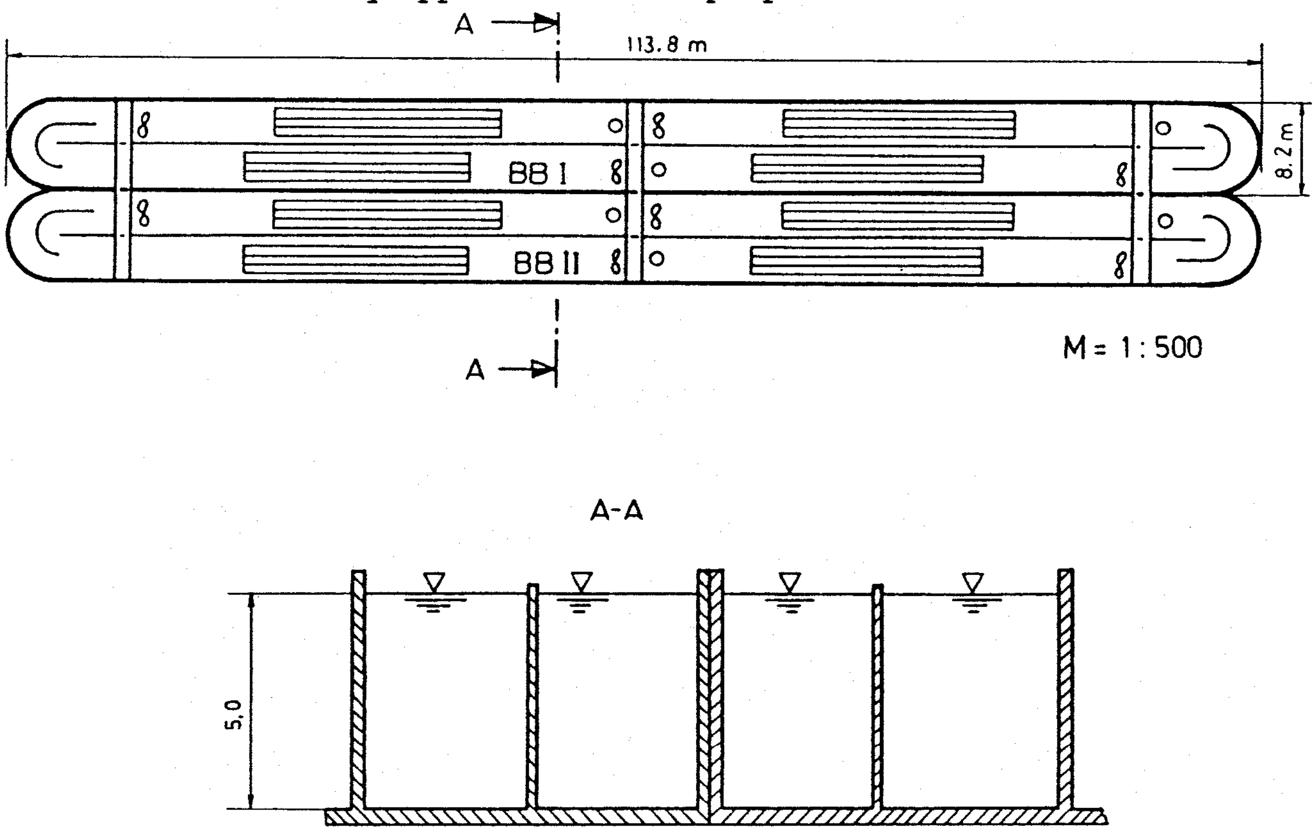

Fig. 1. Aeration tank plant A

Plant B

The plant is designed for 850.000 PE and serves a major industrial area in Austria. It also treats the effluents of a big chemical complex and an iron and steel works. The principle of the layout of the plant can be seen in figure 1. The plant has two primary tanks with a total volume 13.800 m^3, four aeration tanks with a depth of 7,5 m and a total volume of 45.000 m^3. The eight final tanks have a total volume of 55.000 m^3 and a surface area of 16.000 m^2. The sludge is treated in three anaerobic digesters, which have a total volume of 31.200 m^3. The digested sludge is stored in a sludge lagoon. The digester gas is used as energy source for the blowers which supply air to the aeration tanks. At present four turbo blowers with a total air flow of 80.000 m^3 per hour are installed.

The volumetric load is 150.000 m^3 per day, the COD-load is approximately 42.000 kg/d and the nitrogen load is 7.200 kg/d. At present the plant does not nitrify since nitrification is inhibited by substances discharged by the chemical and steel industry. The amount of industrial effluent treated in the plant is approximately 50 %.

Aeration is carried out by 120 jet aeration units per tank arranged on the bottom of the tank in the longitudinal section. All jet aerators act into the same direction which results in a circulating flow in the aeration tank.

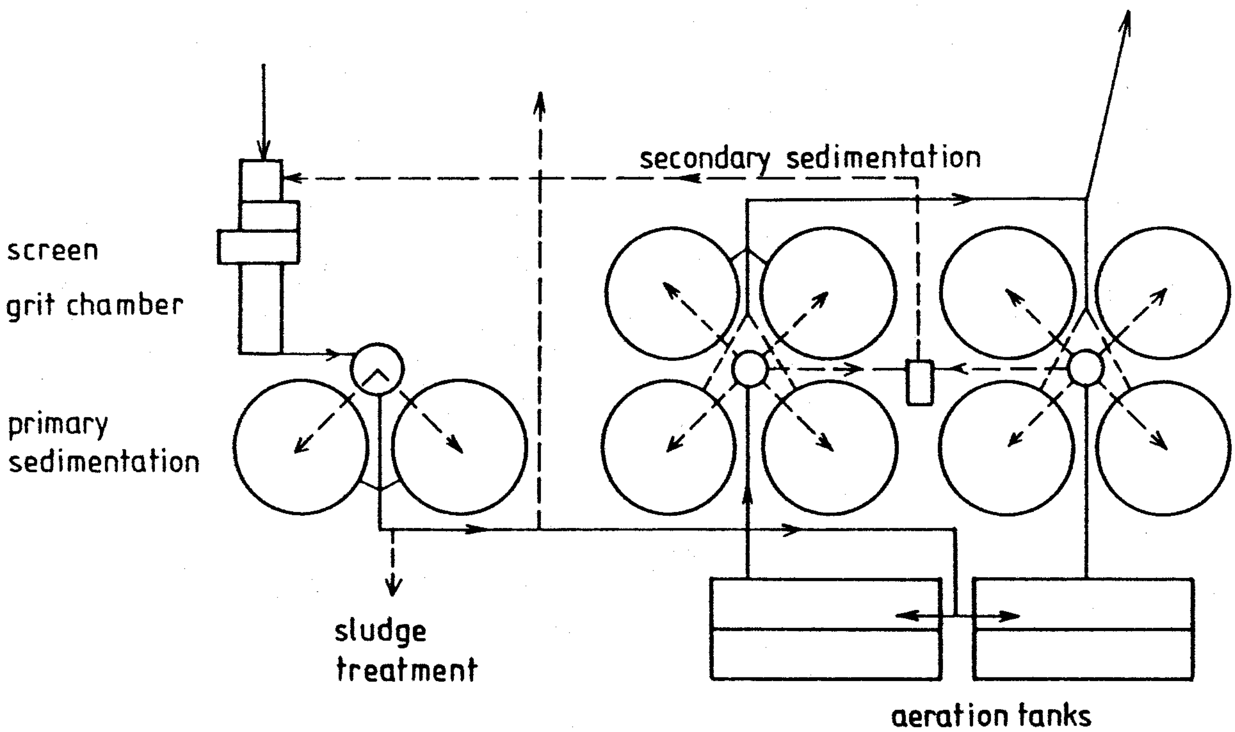

Fig. 2. Configuration plant B

Plant C

This plant is the second stage of an anaerobic-aerobic treatment plant for a citric acid factory. In this plant approximately 14.000 m^3/d of wastewater with a COD-load of 25.000 kg/d and a nitrogen load of 1.200 kg/d are treated. The aeration tank consists of 3 units with a total volume of 15.000 m^3 and 3 final tanks with a total volume of 6.300 m^3 and a surface area of 2.100 m^2. The sludge is dewatered by belt presses and is stored temporarily on a landfill site, which belongs to the company. Each aeration tanks is equipped with 10 rotors (Ø 1 m; length 9 m; 40 kW). In addition, 4 propellers (Ø 2 m; 4 kW) are installed in each tank for mixed liquor circulation.

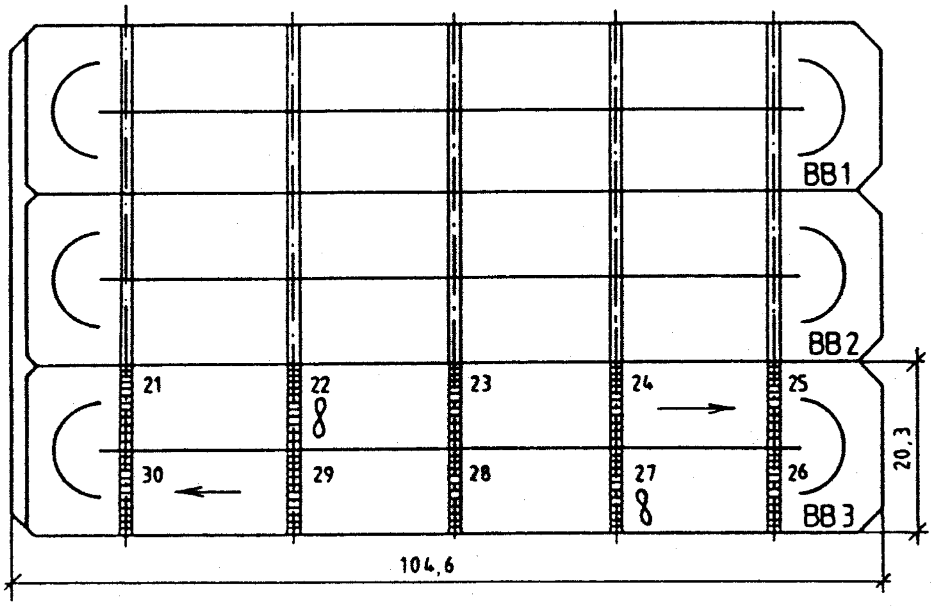

Fig. 3. Aeration tank plant C

RESULTS

On treatment plant A the Standard Aeration Efficiency (SAE) was in the range 3,5 to 4,0 kg/kWh. At the treatment plants B and C with different aeration systems but the same energy density of 20 to 40 W/m^3, the SAE was only 1,6 to 2,3 kg/kWh.

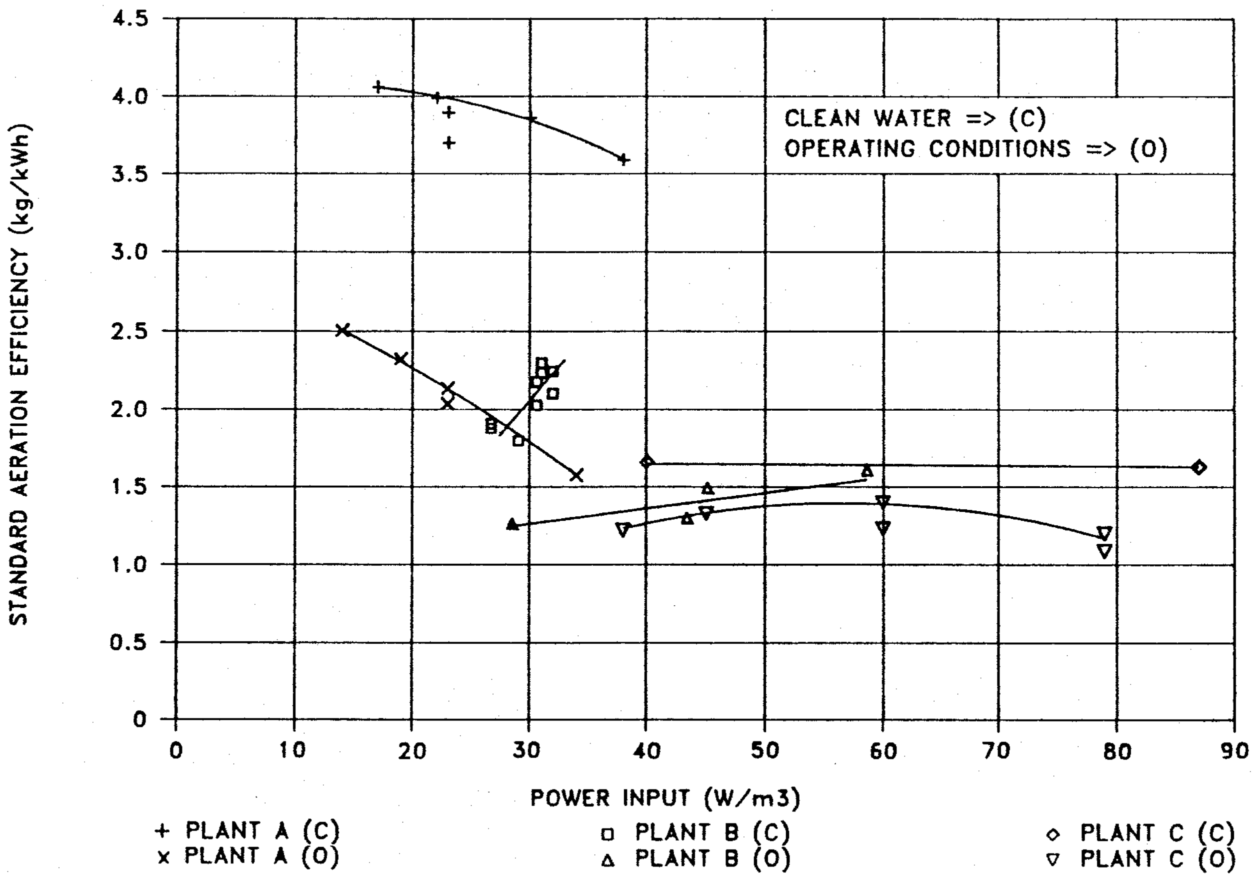

Fig. 4. SAE vs Power Input

In the range 30 - 40 W/m^3 the systems investigated are more or less equal regarding the oxygenation efficiency under operating conditions. Efficiencies obtained (αSAE) are in the range 1,3 to 1,6 kg/kWh. At the treatment plant A, however, it seems that specific constituents in the incoming waste water decreased the transfer rates. Therefore relatively low α-values were measured at this plant. The higher the energy density the lower the α-value with both jet aerators and membrane diffusers. With surface aerators these values are approximately constant. In table 1 the measured α-values are given for different energy densities.

TABLE 1 α-values at different energy densities

W/m^3	Plant A	Plant B	Plant C
15	0.61	-	-
20	0.61	-	-
25	0.56	(0.74)	-
30	0.47	0.60	-
35	0.42	(0.50)	-
40	-	-	0.76
60	-	-	0.81
80	-	-	(0.72)

OPERATING EXPERIENCE

The membrane aerators in plant A have been operating for approximately six months between the measurements in clean water and the measurements under operating conditions. Originally the plant should have been equipped with porous filter plates, but later the decision for membrane diffusers was taken. Technically this could easily be performed since the producer of both systems uses the same basis for the mounting of the different aerators. The decision for the exchange was taken because the airflow had to be interrupted in order to obtain denitrification and this would have resulted in a blockage with filter plates. With proper combination of the 4 blowers of the plant the amount of air supplied to the aeration tank can be varied almost continuously in a range of 1 - 6. By means of this operation the aeration capacity can by varied in a range of 1 - 4. The largest of the four blowers on the plant is driven by a gas engine. In case of the maximum oxygen consumption in the plant all 4 blowers have to operate. Under this condition the air pressure in the airpipe rises, which causes problems with the gas engine. Probably due to a non-optimal selection of the orifice plate the resistance increases and the number of revolutions is reduced which causes a failure in the operation of the gas engine after some time (10 to 30 minutes). Another problem arises from the fact, that during the design and construction of the pipe system for the air supply of the plant vibration problems had not been considered properly resulted in many problems with noise originating from the pipes. Oxygenation control is currently achieved by means of oxygen probes which are located close to the aeration tank outlet. In order to have better use of the big flexibility of the aeration system an improved control strategy based on concentrations of nitrogen compounds (NH_4-N, NO_3-N) in the aeration tank should be used. Additionally the turning on and off of different groups of aerators should be done automatically. This is presently being done manually on the basis of DO measurements and therefore does not allow optimal operation of the plant.

The jet aeration of plant B is also already the second generation of aerators that are installed on this particular plant. After checking the aeration system (usual control after emptying the tank) it could be observed, that the mountings of the jet aerators to the pipes were broken in many cases. The reason for this was an unfavourable shape of the aerator. Additionally it was found, that the material used for the jets units was too brittle. After a period of approximately two years the new jets were inspected again. This time a significant erosion was observed, but it was not possible to find out the reason for it, i.e. if it was cavitation, abrasion or corrosion. A few jet aerators were also blocked. The reason for this blockage was probably the waste water quality originating from the steel production company. This blockage did not, however, influence the operation of the whole system significantly. Usually a life time for jet aerators of 8 - 10 years is expected. The experience on other treatment plants equipped with jet aerators after two years of operation has shown that the mineral content of waste water can have a significant influence on the erosion (abrasion of the aerators). Furthermore, frequent blockage problems due to coarse solids in the wastewater have been observed. Solution to this problem could be obtained by the use of finer screens ahead of the recirkulation pump.

A disadvantage of the aeration system applied in plant A and plant B is the fact, that an inspection or repair of the aeration system can only be performed after the tank has been emptied, which is in many cases difficult and costly. In plant B another major problem was caused by leakage of the main 1m diameter air supply pipe. The material of it was asbestos cement and this pipe was leaking at the bend. After a period of approximately 8 years the pipe leaked so much that it had to be replaced by a steel pipe (airlosses of up to 30 % had been observed).
The plant is equipped with turboblowers which have also incurred major costs. The blowers are driven by gas engines via gearboxes. As a result of small irregularities in the rotary speed of the gas engine, a reaction is produced on the turbo blowers. This caused a force on the bearing and finally resulted in a breakdown of this bearing on several occasions. A breakdown or other problems in the bearing are the reason for destruction of the rotary wheel of the turoblower. These expensive breakdowns could only be avoided after new control systems had been im-

plemented. These can be summarised as intensification of maintenance of the blowers and a decrease in the inspection intervals for service work. A project is being developed at present which includes the use of digester gas just to produce electricity and electrical motors for all blowers. The extra costs for the conversion are more than offset by the higher flexibility and reliability of the air supply when using electrical engines for the operation of the blowers. Presently the airsupply can be varied in a range of 1 : 3 in order to meet the oxygen demand for the actual loading.

The rotor aerators of plant C have been in operation for six months. The only problem that occurred was the breakdown of one special rotor due to overloading which seemed to be a problem of this special electrical engine. The other 29 rotor aerators are completely satisfactory. The plant is operated with the three aeration tanks connected in series. Control of the aerators is performed by a continuous measurement of ammonia in the last aeration tank. High flexibility was a prerequisite for the selection of the aeration system in order to cope with different loading conditions. These variations in the loading can occur due to disturbances in the anaerobic stage which is a pretreatment stage of the wastewater. With the installed system, variations in the load in a range of 1 : 10 can be handled. If less than two rotors are in operation per aeration tank, it is necessary to operate propellers in the tank in order to avoid sedimentation of sludge.

In another large treatment plant treating the waste of a beet sugar factory, sixteen similar rotor aerators are in operation in a 16.000 m^3 tank. These aerators are only in operation for one hundred days per year during the sugar campaign. In spite of this irregular operation no adverse effects have been experienced. The aerators are put in operation at the begin of the campaign and operate without any problems immediately after a period of 200 days without operation.

SUMMARY AND CONCLUSIONS

The oxygenation capacity of different aeration systems under operating conditions relevant for typical operation is within the range 1,3 - 2,5 kg O_2/kWh and is therefore in a much narrower range than the results that have been obtained in clean water experiments. The reason for this is principally the different α-values which have been determined experimentally. Values of 0.8 for surface aeration with mammoth rotors and 0.4 for fine bubble aeration were determined. The selection of aeration equipment which is only based on oxygenation capacity values for clean water seems therefore not a relevant procedure. The following selection criteria should be taken into consideration:

- In the future stringent effluent quality criteria will have to be maintained even during maintenance and repair of aeration equipment. Therefore it should be possible to maintain and repair the aeration equipment also during full operation of the treatment plant while keeping the effluent standards. In case the maintenance work demands an emptying of tanks it is necessary to have a corresponding tank volume as reserve available in order to keep up with the demands. Due to this extra volume additional costs arise which have to be taken into account with the respective aeration system.

- For the judgment of the reliability of an aeration system the complete system including all components has to be taken into consideration. As shown by the example of plant B, problems can arise with the blowers and the connecting pipes can have a significant influence on costs for maintenance and operation.

- A comparison of the economy of different systems should not only include costs for construction but also the total costs for an elongated period (one year). It is certainly very difficult to evaluate such costs for treatment plants that not only have different aeration systems, but differ also in size, loading and effluent quality etc.

- The adaptation of the aeration equipment for different loading conditions is a prerequisite for economic operation of an activated sludge plant. The ranges of regulation of the different investigated plants varied from 1 : 4 for plant A with fine bubble aeration, to 1 : 3 for plant B with jet aeration and 1 : 10 for plant C with rotor aeration.

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