

The Oxidation Ditch : Principle, Results and Applications

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Introduction

In this paper it is proposed to explain briefly the principle of the oxidation ditch, the results achieved with it and its application. Oxidation ditch if applied in the correct way, is the system which gives the most complete biological purification at lowest cost. The system can be used for small and for large flows of waste (1-29).

In conventional systems the raw waste is pretreated in a primary sedimentation tank in which the solids settle. the primary effluent, that is the waste without the settled solids then is aerobically treated on a trickling filter system or in an activated sludge system, in which in some way or another the primary effluent is brought into contact with a mass of bacteria and oxygen of the air. The organic material in the primary effluent then is used as food for the aerobic bacteria. Roughly $\frac{2}{3}$ of the organic material is oxidized to CO_2 and H_2O and $\frac{1}{3}$ is converted into new bacterial substance by growth of the bacteria. After separation of the purified effluent from the bacterial mass in the secondary sedimentation tank, an effluent is obtained with only a small amount of organic material, which then may be discharged into surface water. The separated bacterial floc, is returned into the aeration tank.

In this conventional treatment process after the above treatment there are still two products left which have to be dealt with, i. e. the solids settled in the primary sedimentation tank, that is the so called fresh sludge and the sludge which is produced during the aerobic treatment of the primary effluent, the surplus sludge. These sludges do not dry easily and give very bad odour.

Therefore these sludges are digested in a digestion tank. In this tank by anaerobic process the sludge partly is disintegrated as a result methane is produced and sludge remains which dries more easily without production of bad odours.

For small plants the construction costs, of primary sedimentation tank, of the aerobic treatment facilities, of the secondary sedimentation tank, of the anaerobic sludge digestion tank and of the drying beds, together with the annual costs for maintenance and management result in a total cost which is manytimes the percapita cost in the case of a large plant. Therefore the construction of such small plants in most cases cannot be financed.

General Consideration

In the early fifties with the increase in population and an increasing rate of industrialisation, an urgent need was felt for a more economical method of treatment especially for small flows of sewages and industrial wastes. When we investigated the possibility of finding such a more economical method of treatment we thought of a one phase process of oxygenation in a plant of simple construction and of simple management. This idea has resulted in the development of "the oxidation ditch". In oxidation ditch process the raw waste is fed into the system without any preliminary treatment. The volume of the ditch and the amount of oxygenation are chosen such that not only the effluent produced is completely purified, but that also the fresh sludge present in the raw waste and the sludge produced in the aerobic bacteriological process are stabilized to such an extent that the remaining sludge dries on drying beds

without the production of a bad odour. In this way the construction of a primary sedimentation tank and an anaerobic digestion tank are dispensed with. Moreover by choosing the discontinuous method of operation the separation of the sludge from the purified effluent can be achieved in the ditch itself, and hence the construction of a secondary sedimentation tank will not be needed. Thus, what remains is restricted to an aeration basin of large volume of simple construction and drying beds. Therefore the amount of oxygen needed in the oxidation ditch system is higher and in fact is 18 Kwh per capita per year compared with the 9 Kwh of the conventional activated sludge system.

With the expense of this comparatively small extra amount of cost for energy a large saving in capital cost is attained. It is easily seen that with the capitalisation of the extra cost of $18.9 = 9$ Kwh per capita per year only a very limited amount of construction work could be financed. Experience has shown that with the method of the oxidation ditch the annual cost for treatment of the sewage of small municipalities calculated per capita is about the same as for large municipalities in the case of the conventional method of treatment.

This result together with the urgent need for such a method has resulted in the application in a few thousand of cases already since its development. Moreover where in the beginning the method was thought to be especially adapted for the treatment of small flows of sewage and wastes, the advantages of the system have led to applications also for the treatment of large flows of waste.

The simplicity of the method limited, management needed and the low cost, has given rise to the idea that the purification results could not be as good as those obtained with the conventional systems. It therefore may be stated here with emphasis, that where in the literature for the 'trickling filters generally a BOD removal is mentioned of 85-90% and for the conventional activated sludge system of 92-94%, in case of the oxidation ditch systems the BOD removal normally is 98%. No one who is responsible for the management of an oxidation ditch under normal conditions should be satisfied if a sparkling effluent is not obtained and he should not be satisfied if the BOD removal is not 98% or more. Moreover the conditions in the oxidation ditch are such that a complete nitrification of the ammonia nitrogen is achieved. With-

out any additional cost the nitrate formed is completely denitrified. In such a case an effluent is produced with a very low nitrogen content. For those cases where eutrophication of the receiving surface water should be avoided this is a very attractive aspect.

Design of Oxidation Ditches

For the achievement of good results with the oxidation ditch it is needed that a good design is made, with values for ditch volume and for oxygenation capacity which are not out of proportion to what they should be. It goes without saying that the base of the design must be the load, i.e. the quantity and the strength of the waste which has to be purified. The estimation of the load to be expected however often proves to be difficult. It may be taken that an inhabitant equivalent corresponds with 100 gr dichromate oxygen consumption (DOC).

Volume of the ditch

In temperate zones the ditch volume normally is chosen to be 300 l per inhabitant equivalent (100 gr DOC). In the ditch a suspended solids content of 4000 ppm is maintained, which corresponds with a floc weight of 1200 g per 300 l of ditch volume. Thus the $\text{DOC/floc load} = 100\text{g DOC}/1200\text{g floc/day} = 83\text{g DOC/kg floc/day}$.

If this floc load is compared with that of a conventional low loaded activated sludge plant, which may be 1200 g DOC/kg floc/day, then it is evident that with the very low rate of feeding of only 83 g DOC/kg floc/day, if a sufficient amount of oxygen is provided, the floc necessarily will be in an advanced stage of stabilization. The surplus sludge can then be dried on drying beds, without giving off a bad odour.

The rate of the biochemical process of course depends to a large degree on temperature. Experience in the temperature zones has shown that both in summer at a temperature of the liquor in the ditch of say up to 20°C or more and in winter at a temperature between 0-10°C, there is no difference of any practical importance in the degree of purification of the ditch effluent. If at the beginning of winter time a nitrifying flora is existent in the ditch at a temperature of 0-10°C nitrification continues to go on to completeness. The lower rate of the bacteriological process at lower temperatures shows itself by a higher percent-

age of volatile solids of the sludge. For instance if during summer in an oxidation ditch the percent age volatile solids of the sludge amounts to 65, this figure in winter may be 75 or even somewhat higher. If the difference in temperature is estimated to be at least 10°C then with an increase in rate of the bacteriological process of 2.5 times, the volume of the oxidation ditch in the tropical country could be reduced from 300 to 120 or 100 l per daily load of 100gr DOC. We cannot think of a reason why this would be otherwise.

After what is said in the foregoing it needs no further explanation that one of the first objects of research in this country necessarily will be to answer the question to what extent at the prevailing high temperature the volume of the oxidation ditch can be reduced or in other words the DOC/floc load can be increased. Of course all the advantages of the system, i. e. a complete biological treatment, complete nitrification and if needed denitrification, together with a good stabilization of the sludge must be maintained. It is obvious that such a reduction of the ditch volume under normal conditions will not affect BOD removal, nitrification and stabilization of the sludge. The robustness of the system with respect to shock-loads and to poisonous substances will however be impaired. Moreover with a reduction of the ditch volume 90% removal of nitrogen may not be possible.

Quantity of Oxygen to be supplied

For conditions in the temperate zone the experience is that per daily load of 100 gr. total chemical oxygen demand (DOC) the amount of surplus sludge produced may be 30 gr. dry solids which may correspond with 25-30 gr of total chemical oxygen demand.

It may be assumed that the amount of organic substance discharged in the purified effluent may correspond with 6 g total oxygen demand per capita per day. The organic matter discharged in the surplus sludge and in the effluent need not be oxidized. Thus the amount of oxygen needed for aerobic conversion of the organic substances in the influent is calculated to be $100-25-6=69$ gr per inhabitant equivalent per day.

Further we have to think of it that oxygen not only is needed for the conversion of the carbonaceous substance but also for the oxidation of the ammonium nitrogen. The amount of nitrogen in domestic waste in literature often is mentioned to be 12 gr per capita per day. Of this amount of

nitrogen 1.5 gr is fixed in the bacterial proteins of the surplus sludge. The amount of nitrogen to be oxidized to nitrate amounts to $12-1.5=10.5$ gr. for which 48 g of oxygen are needed ($2\text{NH}_4+8\text{O}\rightarrow 2\text{HNO}_3+2\text{H}_2\text{O}$). The total amount of oxygen needed per inhabitant per day then is $69+48=117$ gr. In case of denitrification the nitrate is reduced to nitrogen gas ($2\text{HNO}_3\rightarrow \text{H}_2\text{O}+\text{N}_2+5\text{O}$). Thus 5 atoms of oxygen out of the 8 used for nitrification, i. e. 30 g out of 48 g. become available for the oxidation of carbonaceous substance. In the case of complete denitrification $117-30=87$ g of oxygen is needed.

If we assume that the oxygen input takes place at an oxygen deficit of 100%, which in most oxidation ditches will not be very far from reality, the oxygenation capacity to be applied thus is 87 g per capita per day. For design purposes it is safe to install somewhat more, f. i. 110 g OC per daily load of 100 g DOC. In fact this amount, i. e. 110 g OC per 100 g DOC practically corresponds with the well known OC/BOD load ratio=2, which since the beginning of the development of the oxidation ditch has been used as a design figure and has been found to be satisfactory.

When the DOC design load in some way has been ascertained, either by accurate sampling and determination of DOC values and of quantity of flow or by a more or less reliable reasoning, then for the calculation of the needed length of aeration rotor, the oxygenation capacity of the aeration rotor has to be known.

Based on determinations in the Netherlands, in Germany and in the U. S. we may assume that one meter of the aeration rotor (cage rotor) with a diameter of 70 cm, a number of 75 revolutions per minute and 16 cm depth of immersion will deliver an oxygenation capacity (OC) of 2800 gr/hr. From this it can be calculated that in the case of 24 hour aeration one meter of aeration rotor delivers the oxygenation capacity needed for a daily load of $\frac{24 \times 2800}{110} = 600$ inhabitant equivalents.

In case of a discontinuous schedule of operation with 16 hours of aeration per day, this figure is 400 inhabitant equivalents.

Especially in those cases where the expected load is not accurately known, which may often be so, it will be preferred to install an extra length of aeration rotor and/or to make the design in such a way that when needed an

extra length of aeration rotor can be installed without difficulty.

Velocity of Circulation in the Ditch

A third principal point in the design is the velocity of circulation. At a velocity of flow of 30 cm/sec the bacterial floc is kept in suspension. Experience has shown that one meter of aeration rotor provides for enough circulation for a ditch volume of 120-150 m³. At high velocities of flow the oxygen-input of the rotor is reduced. It then may be needed to place baffles in the ditch in order to reduce the velocity of circulation.

Separation of Floc and Purified Effluent

With the design of correct volume, oxygenation and circulation of flow we have a guarantee for a complete biological treatment of the waste. What we have achieved is a so called mixed liquor, which consists of the purified waste in which there is a large quantity of bacterial flocs, the suspended solids, which may be maintained at a level from 4000-5000 mg/l.

Before the purified effluent can be discharged it has to be clarified, i. e. it has to be separated from the suspended solids,

A good separation of the flocs is very important, a small quantity of floc remaining in the purified waste, may spoil the effect of all our efforts for the production of a harmless effluent with a low content of organic material.

In the beginning of the development of the oxidation ditch system discontinuous schedule of operation was preferred mainly based on the economical consideration. In the further application and development of the oxidation ditch the civil engineers generally showed a preference for the continuous system with the clarifier, especially for the larger flows of waste. With these continuous flow ditches also excellent results are obtained.

Apart from this development, it is in the last two or three years that we have increased our bacteriological knowledge of the system. With this knowledge it has become clear that the discontinuous schedule of operation of the oxidation ditch has some very important advantages viz. with the discontinuous schedule it is possible to achieve a high degree of denitrification without additional costs and moreover this type of system is a help in the control of the phenomenon of filamentous sludge which sometimes may cause a problem.

Based on this increase in knowledge the most recent development, which has not yet come into realisation, is an effort to find a synthesis of the advantages of the discontinuous system with those of the continuous system.

Summary and Conclusion

With the oxidation ditch extremely good results can be obtained. A removal of 98 or 99% of 5 day BOD is normal. In the undiluted effluent often BOD is only a few parts per million. Often a part of this BOD proves to be a so called nitrification BOD, because in the BOD bottle small amounts of ammonium-N in the effluent are oxidized. The amount of organic substance in the effluent is very low. DOC-figures normally are always below 80 ppm, often between 50 and 60 mg/l.

In the ditch system there is a very large amount of bacteria to do the work under conditions of ample supply of oxygen and ample time.

Because of the simple construction and maintenance the total cost of the treatment is low. The system may be used for every kind of organic waste.

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DISCUSSION

Shri R. V. S. Murthy (Bombay): Is there any basis in selecting the diameter of the rotor? What is the effect of detergents on the efficiency of the performance of the rotor?

Dr. A. Pasveer: With the largest diameter, a higher depth of immersion may be used. Thus the O. C. per M length of rotor is increased. Moreover in the case of larger diameter rotors, the bearings are in a safer position i. e. further away from the water surface.

The effect detergents on the value found for oxygenation capacity is a very complicated phenomenon. Gene-

rally (at lower O. C. values) a considerable increase is observed. At higher O. C. values, the influence of detergents seems to be much less. In case the effect is studied in an aeration tank, an important point for giving our attention is whether in the presence of detergents, the circulation of the water in the tank is normal.

Shri R. G. Patel (Baroda): Would you please let me have more details of vertical axis rotors used in an oxidation ditch? I wish to know the physical dimensions of rotor like diameter, length, immersion recommended, type of blades, power consumed and oxygenation capacity.

Dr. A. Pasveer : At the moment, there may be 14 to 16 types of rotors with vertical axis in the market. A recent study also with this rotor showed that there is no reason to assume that the efficiency achieved is different from the rotors with horizontal axis. The capacity of one unit of vertical rotor may be as high as to serve a population of 25,000.

Shri D. R. Singhal (Bombay) : Will the change of temperatures i. e. about 35° F in winter and about 110° F in summer which means a variation of about 75° F, have any effect on the working of the oxidation ditch?

Dr. A. Pasveer : Because of the large volume and the high suspended solids (Bacterial flow) content the amount of bacterial is sufficient to give the same high BOD removal in winter as in summer, in spite of the reduced rate of growth at the lower temperature.

The influence of temperature shows itself in the ash content of the sludge. At the lower temperature, the rate of endogenous respiration is much lower, therefore in winter the volatile solids content is higher and the quantity of surplus sludge in winter is higher than in summer. (More assimilation less dissimilation).

Shri C. R. Rama Rao (Hyderabad) : I believe the efficiency of oxidation ditches depends to a considerable extent on the design of the Rotor. Could you kindly tell us what shapes and apertures give high efficiency? What are the materials most suitable for manufacture of rotor specially in view of the corrosive effect of sewage and wastes? Have any norms been established for design and construction for these oxidation ditches?

Dr. A. Pasveer : By its larger diameter and higher depths of immersion, the OC/M length of the cage rotor is 4 times higher as compared with the OC of the Kessener brush. It was not possible by variation in shape to increase the efficiency (CC/KWH) over that of the original Kessener brush to any considerable extent.

For the manufacture of cage rotor cast iron is used. Though the corrosive effect of sewage waste normally is not very high, the rotor is often protected by some bituminous product. Norms have not been established.

Shri S. R. Kshirsagar (Bombay) : The COD in the final effluent is stated to be 50 to 60 mg/l. This may represent 25 to 30 mg/l of BOD. The BOD in raw sewage is about 300 mg/l. Thus the efficiency of BOD removal comes to 90% and not 98% as claimed elsewhere in the paper.

Dr. A. Pasveer : A COD in the final effluent of 50-60 mg/l redrepresents in an oxidation ditch effluent a 5 days BOD of only a very few mg/l. The magnitude of the BOD value is of the same order or less than the error of its determination. In oxidation ditch effluents, the ratio, DOC/BOD may vary from 5-40.

Shri G. P. Kukreja : You have all the time been talking of positive i. e. favourable points about this process. I am interested to know what the limitations of this process are. In other words can phenols and cyanides be removed effectively by this process?

Dr. A. Pasveer : In deed, there are very few limitations to the oxidation ditch process. If a waste has BOD it can be removed. Phenols and cyanides are very easily removed and completely disintegrated. Because of the large volume, the incoming waste is diluted to such an extent that these poisonous substances do not do harm to the bacterial floc and these are disintegrated. Intensive investigations of the Dutch State Mines with large pilot plants have shown that in an activated sludge process, the microflora was completely destroyed and that the oxidation ditch continued to deliver a perfect BOD removal. The influence of shock loads of phenol and cyanides would hardly be detected in the effluent.

Shri N. M. Awinashe (Gorakhpur) : Our Industry i. e. Fertilizer Industry is facing a problem of removal of ammonia, free as well as combined from the effluent stream we have used air stripping method as an aeration method. This has brought down the ammonia to minimal of 800 ppm. However beyond this it is not coming down. Can this oxidation ditch method be successfully used for the same? Is there any party who is using this method to remove NH_3 . Please note that effluent contains 500 to 100 ppm of Urea, and pH is 9.5.

Dr. A. Pasveer : There are no examples of ditches where wastes with such high amounts of ammonia (urea) are nitrified. In principle the oxidation ditch must be applicable. Each cubic metre of waste with 600 grains of urea needs 1.28 mg of oxygen. From each cubic metre, 20 gr molecules (-1.26 mg of nitric acid) will be produced. Neutralisation will be necessary.

Shri Ambawane, G. B (Nasik) : While desludging the sludge from the ditch, it may happen that some flora of the bacteria will also be removed during the operation of desludging. Will not this process of desludging reduce the efficiency? Then what fraction of the sludge should be removed at a time? Is there any specificity about the speed of the rotor? or it will be a trial error method? Is there any specificity and about the shape of the puddles of the rotor? It is necessary that the shape of the ditch should be an oval one?

Dr. A. Pasveer : Sludge (bacterial floc) is removed (continuously or discontinuously) to such an extent that the suspended solids content in the ditch maintained at a certain level (4000 ppm). Variations in the suspended solids contents i. e. from 3000-7000 ppm will not do any harm to the efficiency in BOD removal.

Experience has shown that in order to obtain optimal results the linear circumferential speed should be in the order of 2.5m/sec.

The puddles should have sharp edges.

The oval shape of the ditch is often practised. How it is not a must.

Shri. B. N. Ghosh (Jamshedpur) : Nothing has been mentioned about indicator organisms like coliform and enterococci in the final effluent from an oxidation ditch. It will be interesting to know the rate of reduction of these indicator organisms in an oxidation ditch during different seasons of the year. Is it not necessary to chlorinate the final effluent from an oxidation ditch before

discharging the same to a stream, the raw water from which is used by the villagers on the downward side for drinking purposes? How far an oxidation ditch should be placed from a dwelling place in order to avoid smell nuisance if any?

Dr. A. Pasveer: Though the removal of coliform organisms amounts to a percentage between 99 to 99.99%, we think it a necessity that the effluent should be chlorinated if the water into which the effluents disposed of may be used for swimming or other purposes.

Though the ditch itself cannot give a smell nuisance the fresh domestic waste may give. For hygienic reasons our advice is that the ditch may be placed at a distance of 200 m from the nearest dwelling place.

Dr. P. V. R. Subrahmanyam (Nagpur): When oxidation ditch is used for the treatment of Industrial wastes deficient in nitrogen it is essential to supplement nitrogen. On what basis the nitrogen requirements are calculated? What from of nitrogen, whether ammonium salt or nitrate, is recommended? Since we have to take nitrogen for O_2 requirement calculations is it advantageous to use NO_3 so that oxygen requirement for nitrogen can be eliminated? It is known that some inorganic chemicals such as chlorates, arsenites etc. are known to interfere with nitrification process. When such chemicals are present in industrial wastes, how far the oxidation ditch process is effected?

Dr. A. Pasveer: For more cases where an industrial waste shows a deficiency in nitrogen content ammonium sulphate may be used. The following consideration may give an insight in the nitrogen requirement.

If we assume in the oxidation ditch assimilation/dissimilation ratio of 30/70, then from 1000 mg DOC in the influent, 300 mg DOC will be found in the bacterial sludge

This may compare roughly with 200--250 mg of volatile sludge solids. These solids may have a nitrogen content of 8 to 9%. Thus the amount of nitrogen in the sludge would be from 16--22 mg. per 1000 mg/of DOC in the influent.

As the nitrogen supplied will be used for assimilation into bacterial substance, ammonium salts may have the performance with nitrate there may be the possibility of denitrification and liberation of nitrogen gas.

We have no experience with the influence of larger amounts of chlorates or arsenites in the oxidation ditches.

Shri B. V. Rotkar: When oxidation ditch is an aerobic process it is quite in order that there is complete nitrification. But then how is it possible that this nitrified organic matter is again denitrified in the same process. If settling conditions are allowed to occur, the activated floc may be damaged in activity.

Dr. A. Pasveer: There are two possibilities of denitrification. In the so called discontinuous process, the nitrification proceeds in the second half of the aeration and the denitrification takes place in the beginning of the next aeration process.

Experience has shown that also in a continuously operated ditches, denitrification may take place to a considerable extent. We think that at least a part of this denitrification takes place in the inner side of the floc, where oxygen is depleted.

Experience has shown that even when an oxidation ditch regularly is put out of operation, overnight no harm is done to the activated floc to such an extent that it has an influence on purification results.