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WHY THE OXIDATION DITCH DISAPPEARED IN SWEDEN?

Varför försvann Ringkanalerna i Sverige?

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Abstract

The Oxidation Ditch has played a very important role as a foregoer for a number of low load activated sludge systems in the water industry. Today different models are found around the world. The ditch system developed in the late 1950's originated in the Netherlands. Early Swedish research and development work took place in the 1960's. However in contrast to other countries the focus on the Oxidation Ditch was abandoned. This paper gives a very brief presentation of the ditch system and discusses a number of reasons why the Oxidation Ditch with very few exceptions is not found in Sweden today.

Key words – Oxidation Ditch, effluent standards, P-removal, nitrification

Sammanfattning

Långtidsluftare utformade som ringkanaler har spelat en mycket viktig roll som en föregångare till moderna aktivslamsystem med »inbyggd» kväve och fosforreduktion. Idag återfinns ett stort antal aktivtslamsystem runt om i världen som alla kan sägas vara baserade på den tidiga utvecklingen av ringkanaler i slutet av 1950-talet och början av 1960-talet. I Sverige genomfördes ett ambitiöst forsknings och utvecklingsarbete vid Chalmers Tekniska Högskola. Av olika skäl kom ringkanalen att i stort sett fullständigt överges som en lågbelastad aktivtslamanläggning i Sverige. I denna uppsats presenteras helt kort några karaktäristiska egenskaper för ringkanalen. Därefter diskuteras ett antal troliga skäl varför ringkanalernas »popularitet» blev så låg. Utvecklingen i Sverige kan tjäna som ett exempel på hur en alltför stor övertygelse om ett systems nackdelar leder till förhastade slutsatser.

Introduction

Why do technologies emerge and disappear? The fate of the Oxidation Ditch in Sweden may illustrate and hopefully provide both answers and – perhaps – some reflections on the matter, including some reconsideration. The situation in the 1960's in the Swedish water industry was characterised by an improvement of biological treatment methods, to a certain extent conducted at Chalmers Institute of Technology (CIT) in Gothenburg. A comprehensive research programme was performed and presented in a number of publications; see the reference list at the end of this paper. It may be stated that a number of the findings in these studies were more or less overlooked or just simply neglected in the following decade. The disappearance of the oxidation ditch in the 1970's may be defined as due to some main reasons:

1. New Swedish law requirements on effluent quality from municipal wastewater treatment plants;
2. A rather "stiff" exercise and interpretation of the permit policy, resulting in a limited number of "adopted" treatment "trains";
3. The performance of the Oxidation Ditches during the 1960's in Sweden;
4. The climate conditions in Sweden (cold and snowy winters) that put some restrictions on the plant configurations;

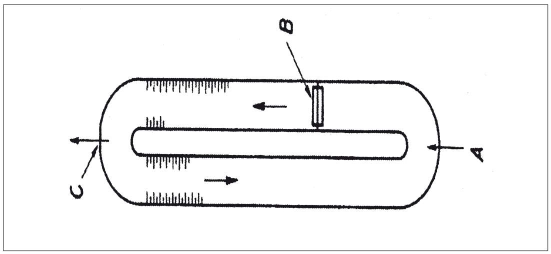

Figure 1. *Lay-out of a "Classic" Oxidation Ditch plant as built in Europe during the 1960's A = inlet point; B = brush aerator; C = discharge point.*

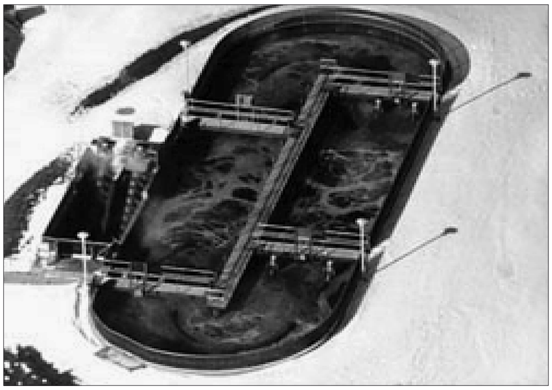

Figure 2. *Picture of the Tri- Oval® Oxidation Ditch System, installation working in winter conditions.*

5. The outlines of design conditions for the Oxidation Ditches, as presented in the CIT reports, suggesting very long Solids Residence Times as a key parameter for the family of "Extended Aeration" plants;
6. The technical and cultural environment in Sweden during these years.

These reasons will be discussed in the following. However, first of all a brief background of the Oxidation Ditch is given.

Background

The development of the Oxidation Ditch started in the Netherlands in the 1950's. One of the first reports on performance was presented by Pasveer (1959). The original design of the Oxidation Ditch was based on an "extended aeration concept", predominantly aimed for small plants. In this context "small plants" was defined as a "design population" of < 5 000 pe. The plant configuration may be characterised as a shallow basin (water depth 1.0 – 1.5 m), shaped as a horse track; see *Figure 1* and *2*. The cross section of the ditch had normally a trapezoidal shape. The Ditch was operated as the sole main treatment facility, and the reactor was aerated by a brush aerator, operated intermittently. Time was left for settling and decant of treated water. The "paradigm" for the design was to create a simple and reliable treatment unit, especially aimed for small plants. In Sweden the early work in the 1960's followed these outlines, with one major exception: the intermittent operation was omitted, and a final settling basin was included in the treatment train; see Weijman-Hane (1960), Weijman-Hane and Fristedt(1960 and 1962), Weijman-Hane and Nilsson (1964) and Nilsson (1963, 1963, 1965, 1965 and 1965). A larger plant was built as a "temporary" unit for Märsta, north of Stockholm in 1961, sized for 6,000 pe; see Widing, Å (1961). This plant was in operation for about 8 years and was shut down when the new Käppala plant was taken into operation in 1969. Apart from this example the basic idea of using the Oxidation Ditch for small communities was mainly maintained.

On the other hand, the Oxidation Ditch model was used in the Netherlands, Denmark and Australia, where technical development of the system gave the pathway to very competitive modifications of the extended aeration family of plants. The Oxidation Ditch served in this perspective as a "technical" inspiration. It's importance for emerging technologies may be illustrated as shown in *Figure 3*. The Carousel System that was directly developed from the Ditch in the Netherlands and Germany, and now is widespread within the water industry. In Denmark the operation of Oxidation Ditches was the basis for the "Biodenitro" system that has been further developed by Krüger A/S into a modern biological nutrient removal system; see Tetreault et al (1986). In Australia important development of the Oxidation Ditch took place, eventually leading to the so called CASS system (Cycle Activated Sludge System); see Goronszy (1979). Later on the fundamental process considerations linked to the Oxidation Ditch operation became a part of the SBR-development in the US and Canada; see for instance Irvine (1983). In this context it was especially the intermittent operation in one single reactor that was the main issue.

Discussion

Law requirements

The first point – and perhaps the most important one in most cases – is the defined demands and needs for a specified performance (adopted effluent standards). In

Sweden the debate regarding the water environment and especially the status of the lakes and rivers during the 1960's resulted in a firm conviction that phosphorus was the limiting factor for the receiving water bodies, rather than nitrogen.

The environmental law from 1969 gave specifications on limitations in effluents to water bodies from municipal and industrial activities. The normal standards were as follows for municipal discharges (it would be observed that for the Swedish situation BOD_7 instead of BOD_5 has been used):

BOD_7 < 15 mg/l, as mean values over a defined period;
Total – P < 0.5 mg/, accordingly defined as a mean value.

Sometimes a more "process performance" oriented effluent standards model was expressed by a percentage removal requirement. A rather popular expression in those years was to define the requirements as a "90/90-plant", indicating 90 % removal of BOD and phosphorus.

Nothing was said about nitrogen, nor was given any restrictions on SS or COD in the case of municipal discharges. For the main polluting industries were given far more specific permits with respect to various polluting agents.

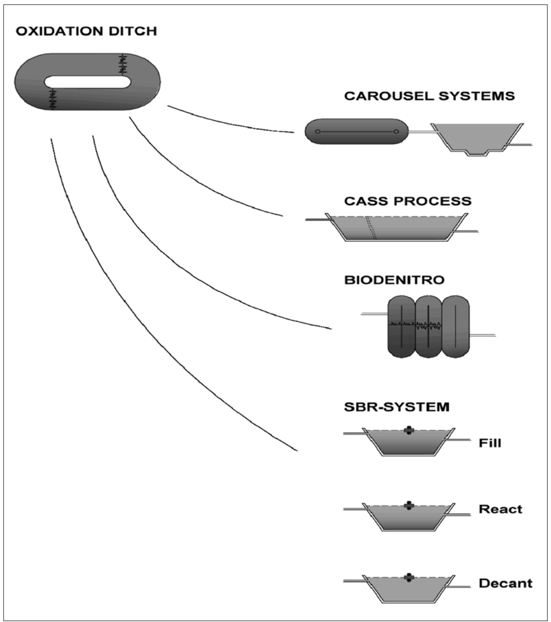

Figure 3. *The Oxidation Ditch influence on other activated sludge systems.*

Permit policy and "adopted" plant configuration

The permit policy during the early 1970's may be called "stiff", when a large number of new treatment plants were built. The Swedish Environmental Protection Agency published in 1971 a draft guideline for the design of wastewater treatment plants; see SNV (1971). This document was a compilation of the (Swedish) knowledge within wastewater treatment technology, elaborated by the contribution of most of the proliferated engineers in Sweden at that time.

This SNV document had a very strong influence on the design of treatment plants for a number of years, and served as a matter of fact as a normative, far beyond the normal influence of guidelines. A very typical – and dominating – plant configuration was based on the following treatment parts:

- Pre-treatment containing automatic screens followed by aerated sand traps;
- A primary sedimentation (sometimes excluded, especially at small and medium sized plants);
- An activated sludge stage, designed for carboneous BOD-removal. A typical (mean) hydraulic retention time for the aeration basin was 2–2.5 hours at design flow conditions. The following intermediate clarifier was typically sized for a hydraulic loading of 1.0–1.3 m/h (deep, upflow basins);
- A final chemical precipitation stage, based on flow proportional addition of mainly alum or ferric salts; flocculation basins, sized for 0.5 h retention time at design flow, followed by either a final clarifier, or in some noticeable cases by dissolved air flotation or even lamella sedimentation. A typical final sedimentation was sized for 1.0 m/h, when a deep upflow tank was employed.

For small or medium sized plants sludge treatment included aerobic stabilisation or in a few cases lime treatment of the sludge, followed by mechanical dewatering by centrifuges. Filter band presses were used at very few plants. Anaerobic digestion was found mostly at large treatment plants. The adopted treatment models showed to fulfil the requirements with respect to treated water quality. A fairly normal "average" discharge quality from the Swedish plants designed for carboneous BOD and total P removal was as follows:

BOD_7 < 10 mg/l;
Total – P < 0.35 mg/l

The main conviction that the chemical (post) precipitation would safeguard the effluent standards at varying load conditions was one driving force for the "adopted philosophy".

The concept did not leave any room for nitrogen removal, however unintentionally some plants experienced nitrification when running at loads far below the design conditions. Very few plants were built with the "extended aeration concept" in those years.

As a consequence, the Oxidation Ditch configuration from a process point of view had no "competitive edge" in the Swedish theatre at that time.

Critical points on Oxidation Ditch performance

Some technical weaknesses within the chosen designs of the Oxidation Ditches in Sweden contributed to the falling interest and finally abandonment of this concept:

- A too simple treatment train – no pre-treatment facilities caused problems with accumulating sand, grit and trash in the reactor. Evidently, at least in some occasions this accumulation also caused an unwanted settling of activated sludge, mixed with the coarse matters;
- The often inefficient aeration provided by the installed aerators; the operation mode did not include an intermittent operation that would have improved the aeration efficiency – and in correctly designed systems also a denitrification (although this aim was not relevant in those days);
- The harsh winter conditions in Sweden that gave freezing problems, especially with the brush aerators developing ice build-up on the blades;
- The ditches were normally built as very shallow channels, the typical water depth was about 1.0 m, thus giving limited space for solids separation in the ditch, when operated as an intermittent reactor without a separate settling facility;
- Problems with inefficient solids separation in the final sedimentation stage.

It should be underlined that not one of these critical points should be addressed as "shortages linked to the system itself". The points presented above may be classified either as "design errors"; or operation problems related to climate conditions.

Another possible (false) critical point is linked to the analysis procedure at that time: the extended aeration systems, including the Oxidation Ditch, were said to perform a less efficient BOD-removal than the "classic" activated sludge system. It is likely that this belief was linked to the absence of nitrification inhibition of the BOD analysis. This in turn would result in BOD levels in the discharge substantially higher than the true BOD value. It is more than likely that a nitrification in the analysis influenced the result.

Climate influence on plant configuration

One dominating factor with respect to wastewater treatment in Sweden is the climate. Virtually half of the year the wastewater temperature is low or even very low in relation to advantageous conditions for both biologic and chemical treatment methods. In addition to the process oriented limitations, the climate affects the working environment at a treatment plant during wintertime if built in the open. This reason was the main one why most of the Swedish plants in the 1970's were built as "in door" plants. A typical model was developed, sometimes called the "compact plant". Such a plant layout is shown in *Figure 4.* By contrast the typical "classical" Oxidation Ditch layout is shown above in *Figure 1.*

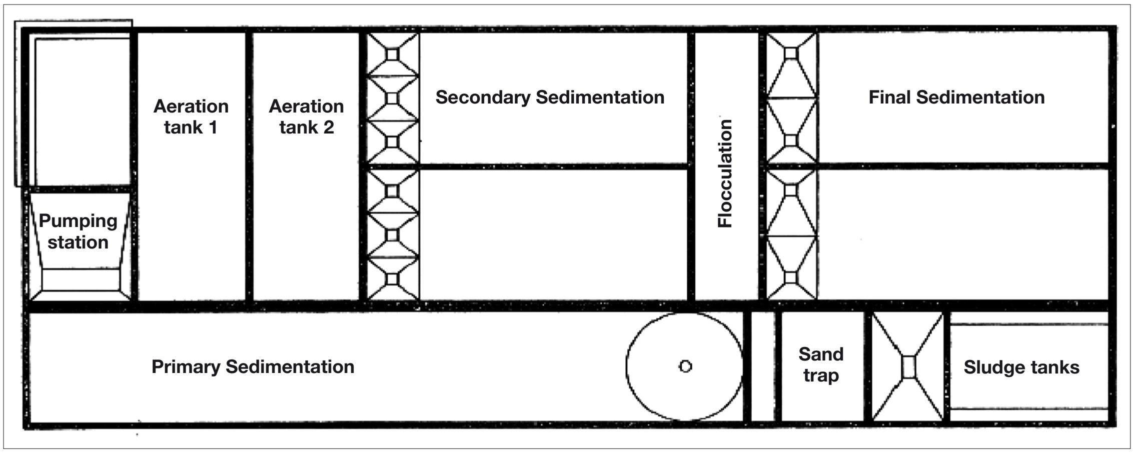

Figure 4. *Typical lay-out of a "compact plant" built at many sites in Sweden during the 1970's (a plant sized for about 6,000 inhabitants, for the Munkfors community in western Sweden).*

Design conditions for the Oxidation Ditches

The typical design outlines for the Oxidation Ditches in Sweden indicated SRT:s (Solids Residence Time) of about 35 days, and hydraulic retention times of 1–3 days; see for instance Nilsson (1965). A conventional activated sludge system was designed for a SRT of 3–6 days, and the hydraulic retention time was 2–4 hours. The F/M ratio for the oxidation ditch (relation between the BOD and the total activated sludge amounts in the reactor) was set at 0.04–0.06 kg BOD_5/kg MLSS/d. This value should be compared with a "conventional" aeration basin in an activated sludge system, normally chosen in the range 0.3 to 0.5 kg BOD/kg MLSS/d. In comparison with these design values for a conventional activated sludge plant the Oxidation Ditch was considered not feasible; especially as the needs for sludge stabilisation at small plants was not an imposed directive in Sweden. In addition to this fact it must be remembered that nitrogen removal was considered "not needed" in those days and would not become an environmentally acknowledged issue until about 15 years later in the Swedish theatre.

The technical and cultural environment

As in most technical development processes far more complex considerations than the "rational mind" of scientists and engineers play important roles when the pathways for this development are laid out.

Economic incitements, market evaluations, even more "unaccounted" perspectives such as human vanity, curiosity, too superficial verdicts on certain issues (sometimes called prejudice) also influences to a larger or a lesser extent the technical development.

The new demands on the wastewater treatment plants in Sweden in those years constituted a challenge for the engineers to develop technologies, and also a very stimulating "intellectual environment". In this perspective strive for good – or – sometimes "advanced" technologies overshadowed by far the concept of "simplicity". The Oxidation Ditch was in this perspective regarded as an "obsolete technology" with dubious performance figures. In other words the originally seen merits of the concept – simplicity and reliability – were not regarded as valuable or valid arguments for the Oxidation Ditch. At best the ditches remained as an aeration basin, integrated in a "modern" plant. The normal "fate" however, was either demolishing of the ditch or conversion to an equalisation basin for high flows.

Conclusions

The "fate" of the Oxidation Ditch in Sweden may illustrate a "risk" for many technical and cultural environments: whenever a dominating trend directs the development, other important perspectives are easily overlooked and competing technologies to the preferred one are disregarded. This phenomena may in the worst case become a hindrance for a constructive dialogue and threaten the technological development. The main development of the Oxidation Ditch in other countries, as mentioned above, was during the 1960's and 1970's and was instrumental in creating "pathways" to understand the biological nutrient removal processes. By deviating strongly from this option, Sweden "overlooked" the potentials in development that were initiated by the work done in CIT in the 1960's.

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