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Numerical Simulation of Early Wastewater Treatment Within the Sewer Network

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Abstract
The subject of this paper is of a new breed, which no doubt will be successful. Due to the fact that wastewater treatment activities are generally funded and supported by the community, reductions in operating costs of wastewater treatment plants (by reducing energy requirements, reactive solutions etc.) leads to important savings.
Keywords: *sewage system****,*** *sewer network****,*** *aeration process****,*** *energy requirements, important savings****.***

1. Introduction

In order to avoid a possible contamination, such as one caused by contaminated water, the sewage system must be perfectly airtight, must be completely separated from the water distribution network, with which it must never come into contact and under no circumstance ever run over it. A sufficient drainage slope must be ensured, with bends that aren't too tight, with a proper depth (i.e. a depth below the freezing depth) and the diameters of the pipes need to be able to sustain the entire wastewater flow demands, in order to eliminate the possibility of bottlenecks and external discharges [4], [6].
Due to the large lengths that sewage pipes tend to have, and considering maintenance accessibility and costs, and also the fact that the maximum concentration value of the impurities is found at the end of any given pipe section, the best approach is to attempt section aeration at the end of each pipe section. Given the infrastructural complexity of any wastewater treatment plant, all of the physical-chemical and biological aspects of the hydrodynamic processes found in wastewater treatment installations need to be taken into account, as well as their structural and economic attributes, carefully planned and maintained in order to ensure an overall improved purified water quality while also reducing its overall treatment cost [4], [6], [7], [10]. The numerical simulations have been realized by means of utilizing the ANSYS program. The following data has been used as input:

- water flow speed = 0.1m/s;
- air flow speed = 0.5m/s;
- maximum oxygen concentration - 3 mg/l ($0.003 kg/m^3$);
- a laminar flow type has been considered;
- the fluid that is dispersed with a medium turbulence is air;
- pipe sizes: length 7m, diameter 0,3m;
- the geometrical characteristics of the air feed pipes - length 0,5m, diameter 0,02m, diameter of the air feed aperture 0,002m;
- distance between two perforated pipes - 1m.

In fig. 1 and 2 the aerobic and anaerobic zones are highlighted within the sewer network [4], [6], [11], [12].

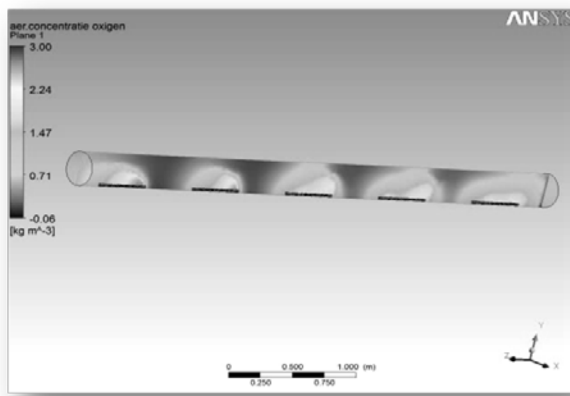

Fig. 1. Oxygen concentration variation - cross section

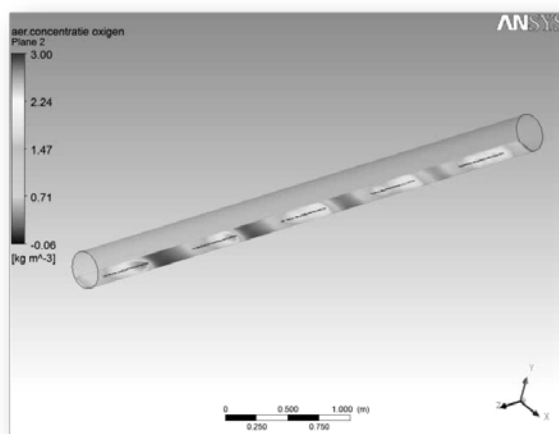

Fig. 2. Oxygen concentration variation - horizontal view

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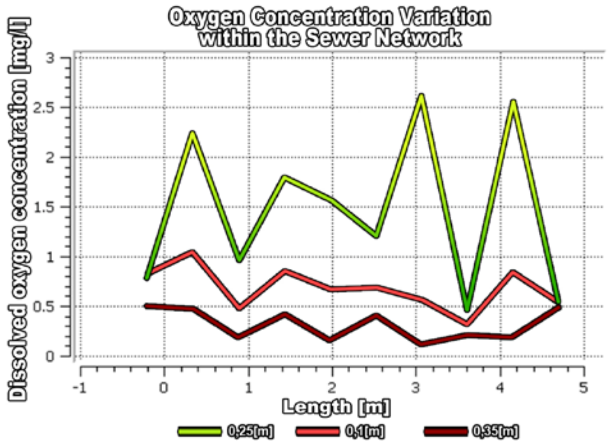

Fig. 3. Oxygen variation concentration by depth level

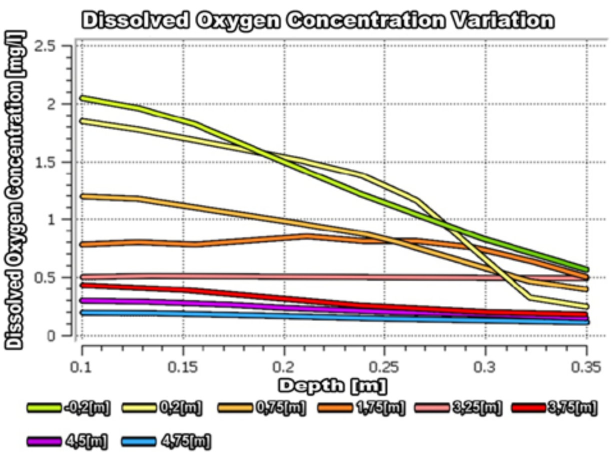

Fig. 4. Oxygen concentration variation
over the length of the sewer pipe
(Main focus on the variation of dissolved oxygen
in the aerobic and anaerobic zones)

The general household wastewater treatment process is generally carried out by means of eliminating the microorganisms that are present in the fluid, utilizing the ***aeration process*** [4], [6], [11]. For this purpose, the household wastewater is stored within a tank in which it then becomes stationary relative to its environment for a given time frame.

2. Proposed solution for early wastewater treatment within the sewer network

When we mention aeration, we mainly refer to the process in which air is introduced under pressure or about the gaseous oxygen in its purest form (atomic oxygen).
The following is the presentation of a method and the specifications of a handful of systems aimed at reducing the oxygen quantity that is necessary in the solid particle control process within an aquatic medium, while also highlighting the reduction of the solid particles located within the aeration tank. One procedure of wastewater treatment comprises the introduction of slurry within a volume of water that is located within the aeration zone, followed by the actual aeration process, removal of the solid suspended particles from the water taking place within a given area of the eliminated volume of water, by means of it accumulating on the surface of a mobile porous layer. The accumulated layer is then carried over to a disposal area [4], [6], [7], [10], [11].
The necessary systems for this type of treatment comprise an aeration tank, which includes a filtration layer (which serves by being partially submerged within the given wastewater volume), a continuous screen which is dotted with pores with an average size of 20 microns, which is guided within the tank and which, by getting in contact with the filtration layer, accumulates the solid particles, thus treating the water with which it comes into contact with.
In the process of household wastewater treatment, the water, which contains insoluble solid suspensions, or under colloidal form, is transported directly towards an aeration tank. By means of aeration of the tank's content at atmospheric temperature, or at higher temperatures, with the purpose of present microorganism disposal, the discharge of a significant quantity of required biochemical oxygen is also a consequence. In such cases, if no microorganisms are introduced within the given water volume, the entire process requires an extended activation period, before the necessary biochemical oxygen discharge can take place, and the average necessary biochemical oxygen discharge ratio is approximately 60%.
The necessary biochemical oxygen discharge can also be made in an accelerated fashion in the case in which the given wastewater volume is transferred to an aeration tank while it is also mixed with microorganisms by means of residual sludge, which was recycled within a decanter. In activated sludge installations, although the oxygenation rate and the reduction of the necessary biochemical oxygen are improved, the sludge quantity from within the decanters (clarification tanks) represent the determining factor in the efficiency of the entire process.
It has now been discovered that household wastewater can be processed with a significant reduction in required biochemical oxygen loss, by means of eliminating solid suspension from a given area within the aeration tank, while the overall tank surface aeration process is continuous, and the liquid is maintained within a turbulent state, resulting the discharge of a water that is clear of solid suspensions from within the aeration tank, rendering decanters (clarification tanks) obsolete within the overall system [1], [2], [4], [6], [7].
The time frame in which the water is put under the aeration process is dependent on a variety of factors,

averaging between 1-24 hours, the optimum interval being between 1-6 hours. By means of preference, the water can be subjected to the aeration process at temperatures between 45 and 65^0 Celsius.
The bulk of the solid particles that are removed from the household wastewater can be in turn removed as well by means of incineration or storage within toxic residue barrels [3], [4], [6].
The filtration materials are, by preference, metallic fabrics. The most commonly used the polyester monofilament fabric. The factors that dictate the efficiency of the filters are the size of the pores of the filters and the agglomeration degree of the solids within the aeration tank.
During the aeration process, having a relatively high concentration of solid particles, a filter with a dimension of 660x1000 cm and a nominal hole size of 20 microns will generally produce a 40-80 ppm (parts per million) filtration of solid particles. A filter with a hole size of 10 microns is thus capable of producing filtration with a reduced quantity in solid particle concentration.
The removal rate of solid particles is controlled by a series of factors, such as the speed at which the water passes through the filter and also its volume as well. In principle, the removal of solid particles is limited by the total accumulated weight of the solid particles that are necessary for maintaining a predetermined weight of the solid suspensions in the aeration tank. In cases where an excess accumulation of solid particles is produced on the filter, these can be removed from the filter's surface by means of sprinklers or by means of pressurized water currents.
On average, the quantity of removed solid particles from the contents of a fluid that contains 3300 mg/liter of solid particles is of $0{,}48 g/m^2$ of wastewater, with the flow speed being of 8,7m/minute and of $0{,}57 g/m^2$ at a flow speed of 4,75m/minute. After the solid particles are transported outside of the aeration tank, they are removed from the filter's surface, and the cycle begins anew. The method in which they are disposed of heavily depends upon the way they are to be recycled [2], [4], [6], [10].
A wastewater treatment plant with such specifications is capable of sustaining operations with different outcomes. It can, for example, have a faster startup time of the whole process, aiming at reducing the loss of necessary biochemical oxygen.
Fig. 5 present a vertical cross-section of a structure which produces continuous aeration, with cleaning tanks and a continuous filter that traverses both tanks, while Fig. 6 presents a perspective view of an aeration tank and a concentration tank for solid particles [4], [6], [7].
Fig. 5 contains a tank (1) in which household wastewater is discharged into by means of an effluent channel (2) which allows the distribution of the water within the tank by means of a weir (3). The tank (1) is divided into an aeration compartment (4) and a digestion compartment (5) by means of a separation wall (6).

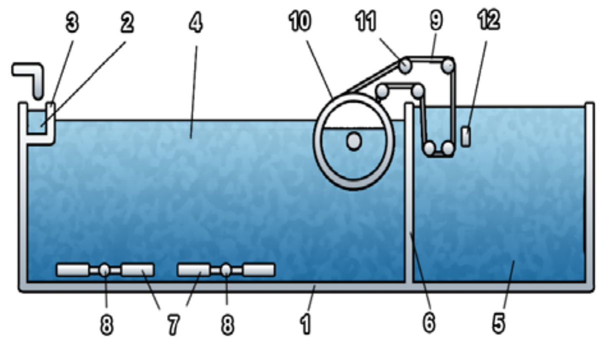

Fig. 5. Vertical cross-section of a structure that produces continuous aeration

The aeration takes place in compartment (4) by introducing air with the aid of diffusers (7) over a period of 1-3 hours. The diffusers (7) are sustained by the bonds (8) which are in turn placed over the surface of a continuous mobile filter (9) which is in contact with a perforated rotor (10) which is assembled partially submerged. The filter is mechanized by means of an electric engine which is not included in the schematic. Solid particles are transported toward the digestion compartment (5) where they are removed from the filter's surface by means of ultrasonic waves (12). After the solid particles are removed, the filter (9) is redirected by means of pulleys back toward the aeration compartment (4) where a new cycle begins.
The drum (10) and the continuous screen (9) that would undergo their activity in such an aeration tank would have a width of approximately 0,6m.
When the biochemical oxygen demand (BOD) load is of 131kg of BOD/day per $100m^3$ aeration tank capacity, the induction rate of the air within the mixture will be of $4m^3$/minute.
When the continuous screen is composed out of polyester monofilament, with a fabric of 260x400 meshes/cm, the nominal dimension of the pores is of 20 microns, while the suspended solid particle load within the aeration tank is of 500mg/liter. In the end, the treated effluent will contain 20mg/liter of BOD. The solid sludge particles on the screen can be removed and redirected toward the fermentation compartment (14) in quantities of 3-4.5 kg of dried solid particles/day.
Fig. 6 showcases a tank in which wastewater is reversed by means of an influent channel (1), which allows the drainage over an overflow tank (2). The tank is divided into an aeration compartment (3) and a solid particle

accumulation compartment (4) by means of a separation wall (5).

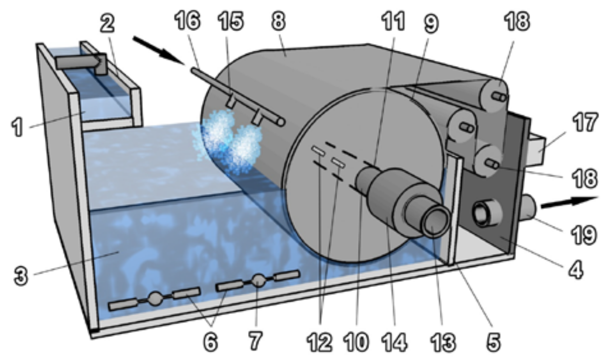

Fig. 6. Perspective view of an aeration tank and of a solid particle concentration tank

In this configuration, the aeration is produced by injecting air within the compartment (3) by means of the diffusers (6), over the course of 2-6 hours. The diffusers (6) are sustained by the bonds (7) which inject air from an unmentioned source. The solid particles are suspended within the aeration compartment (3), they are then deposited over one side of the filter (8) which is in contact with the peripheral area of the rotor (9). The rotor's peripheral area is perforated. The rotor is positioned partially submerged within the aeration compartment, in order for the liquid found herein to have a higher altitude in contrast with the purified water discharge channel. In this case, the central shaft (10) of the rotor (9) has a central axial passage (11) and has access to channels (12) that communicate with said passage. The central shaft (10) is linked to a discharge channel (13) by means of a rotating seal (14) [4], [6], [7]..

While the screen (8) exits the mixture, the surfaces that contain solid particles enter within an area designated for their removal, for instance sprinklers aimed at removing solid particle layers. A water jet is directed at the screen's surface by means of nozzles (15) which are attached to a water supply pipe (16). Water is pulverized through the nozzles (15), under pressure, and then dislodges the solid particles adhering on the screen, finally these being reintroduced in the aeration tank for further processing.

The nozzles can be positioned to cover any predetermined area within the screen's width. If they cover the entire width of the screen, then their operation is preferred to be intermittent, thus the screen (8) shall periodically transport solid particles in the accumulation compartment (4). Solid particles found on the screen's surface during its submersion within the accumulation compartment (4) are removed by means of an ultrasonic transducer (17), which produces sonic vibrations. The principle schematic for the ultrasonic emitter (17) is presented in **Fig. 7.**

The mobile screen (8) is engaged by means of a mechanic motor that is not demonstrated in the figure, with guiding pulleys (18). After the solid particles are removed from its surface, the screen (8) is directed by these pulleys (18) toward the aeration compartment (3) where a new cycle begins.

The concentrated solid particles from compartment (9) are removed by means of a pipe (19).

When the focus is set on sludge treatment within a device such as the one presented in Fig. 6, having a processing capacity of 37,854 liters/day of raw sludge, the aeration tank will have an aqueous solution maintained at approximately 3000 ppm, which will be aerated for 4 hours and a volume of 88m^3.

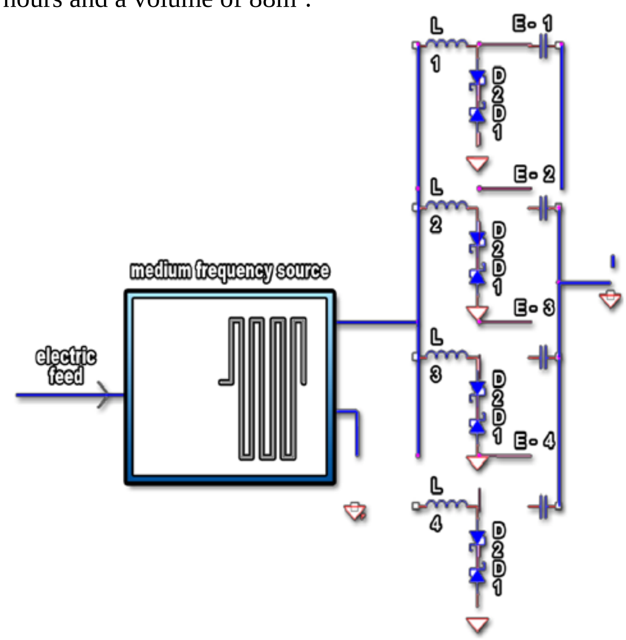

Fig. 7. Principle scheme of ultrasound emitter

The continuous screen from within the aeration tank runs by means of a drum that has a diameter of 1m and a width of approximately 1m and can be washed of solid particles over a 40 minute window of each hour of aeration by means of sprinklers that spray a jet of water having a pressure of 11liters/min of decanted water over the surface of the screen [4], [6], [10].

When the BOD charge is of approx. 45kg BOD/day per 304m^3 aerated within the tank, the effluent that is separated by means of the perforated drum can be discharged with a rate of 1600 liters/hour and will have less than 20mg/liter of BOD.

The sludge that is removed during the 20 minute transfer periods toward the accumulation tank by means of continuous operation of the screen at a speed of 304cm/min will have an accumulation share of 0,65-0,85g/0,3m^2 of the screen's surface.

These solids can be removed within an aqueous medium that is ultimately discharged within a solid particle accumulation zone, a zone of which 2% of the sludge can be periodically removed [4], [6], [11].

3. Conclusions

The proposed method and specifications of utilizing select apparatus with purpose of reducing the necessary oxygen quantity in the control process of solid particles within an aquatic medium, as well as reducing solid particles found within the aeration tank, has led to the following conclusions:

1. The sludge treatment process by means of introducing the sludge suspensions within an aqueous medium contained within an aeration zone consists in the separation of the solid particles from said medium by means of a porous, mobile, continuous surface, which transports said suspensions from the aeration zone toward a processing zone, the porous surface then being guided back and reintroduced within the aqueous medium, starting a new cycle aimed at removing future solid particles from said medium.
2. Utilizing the process that is described in Fig. 5, the solid suspensions found within the aqueous sludge represent raw sludge and is aerated over a period of 1-3 hours.
3. Utilizing the process that is described in Fig. 6, the aqueous medium is a liquid mixture and is aerated over a period of 2-6 hours.
4. According to the procedures presented in the two figures, the solid particles that accumulate on the surface of a mobile, porous medium, being transported outside the reaction zone, are removed from the surface of the porous medium before it reaches a removal zone, where the porous medium is to be reintroduced in the mixture.
5. The whole removal process of a predetermined quantity of solid particles from the surface of a porous medium is done by means of pressurized water jets which act directly on the surface of the porous medium.
6. The process described above, in which a porous medium transports, through submersion, a layer of solid particles accumulated within a digestion zone, allows the removal of solid particles by means of sonic vibrations.
7. The described sludge treatment system, composed out of a wet sludge tank - with the ability to aerate the sludge contained within - a perforated drum mounted partially submerged under the mixture's level, a mobile continuous screen which has a surface with pores of size of 20 microns, being guided through the tank and having a partial contact with said drum, having the ability to remove solid particles away from the screen within a zone outside the said tank, and the ability to guide said screen back to the drum as well as the ability to discharge the processed liquid within the drum.
8. The system described sludge treatment has the screen composed out of polyester monofilament (weave) with pores that have a dimension of 10-20 microns, while the solid particle removal mechanism is found outside of the aeration tank.
9. According to the specifications at points 7 and 8, there is another fluid retention tank which is placed in the vicinity of the main tank, while the continuous screen can move between and through both tanks (the wet sludge tank and the fluid retention tank) and the removal of solid particles away from the surface of the screen, once the screen has entered the retention tank, is performed by means of an ultrasonic transducer that send shockwaves toward the screen's surface.

Due to the fact that the main concern of field specialists is focused on finding new solutions to reduce energy consumption, as well as ensuring all the conditions for meeting the discharging indicators of processed water within the environment, one of the identified variants is the possibility of utilizing the sewer network as early wastewater treatment zones.

With the obtained data, the simulation of the functionality of the network have been realized using the simuff function of the Matlab software, as well as modeling and simulating the processes within the sludge processing plant using the BioWin software.

The subject of this paper is of a new breed, which no doubt will be successful. Due to the fact that wastewater treatment activities are generally funded and supported by the community, reductions in operating costs of wastewater treatment plants (by reducing energy requirements, reactive solutions etc.) leads to important savings.

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