Treatment of Wastewaters from Livestock Farms

Erika Beilicci[1*], Robert Beilicci[1], Camelia Stefanescu[1]

Politehnica University Timisoara, Department of Hydrotechnical Engineering
300022-Timisoara, Splaiul Spiru Haret 1/A, Timisoara, Romania

Abstract
Raw wastewater from livestock farms is a mixture of faeces, urine, bedding materials, and water from washing and cannot be distributed on agricultural land in this state, and not discharged in natural emissions. That is why it is necessary to purify them, in order to retain and neutralize the harmful substances present in these wastewaters from animal farms, which are not accepted in the aquatic environment where the treated water is discharged and which allow the physical-chemical properties of the water to be restored before use.

The paper analyses the importance of wastewater treatment from livestock farms, respectively the need to build efficient treatment plants. The possibility of using the advanced hydroinformatic tool WEST, developed by DHI Holland, is presented for the design, exploitation and optimization of such a treatment plant.

Keywords: livestock farms, treatment, wastewater, water quality.

1. Introduction

Agriculture and livestock farms are extremely important for human existence and, at the same time, they are based more than other human activities on relations with the environment.

Nutrients, water and organic substances are brought to a livestock farm in the form of purchased products or own products (Figure 1) [1, 2].

Point pollution of water and soil from zootechnical sources can be caused by: semi-liquid and liquid animal droppings; manure in solid form; effluents from silos where animal feed is kept, respectively untreated or insufficiently treated uncollected wastewater.

Raw wastewater from livestock farms is a mixture of faeces, urine, bedding materials, water from washing and cannot be distributed on agricultural land in this state, and not discharged in natural emissions.

The water consumption of a zootechnical complex is established taking into account: the water needed for watering the animals, the water used for the preparation of liquid feed, the water used for washing the shelters and the transport of droppings, drinking and washing water for the staff serving the complex, the reserve necessary for extinguishing fires and the one necessary in case of interruption of the operation of the water supply installation [3].

Sewage solutions in animal husbandry complexes depend on the method of discharge of manure [4].

When the collection of droppings is done without driving with water, the droppings are stored for fermentation to be used as fertilizers.

The collection and evacuation of liquid and semi-liquid manure aims at avoiding pollution of soil and water, and inactivating the polluting potential in order to reintegrate them into the matter natural circuit. The collection of droppings no requires human intervention, and following the use of technological water for dilution, the fluid consistency allows their hydraulic evacuation [3].

The system has the disadvantage of high water consumption, which leads to large volumes of liquid and semi-liquid manure.

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* Corresponding author: Erika Beilicci,
Tel. +40 753 018 470, Email: erika.beilicci@upt.ro

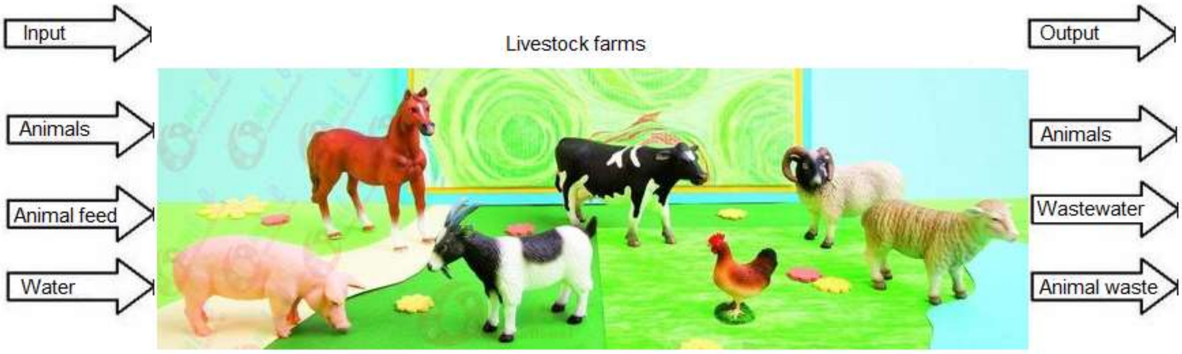

Figure 1. Nutrient balance at the livestock farm level

The water used for the hydraulic evacuation of manure from the farms is collected and discharged through a sewage system in the own sewage treatment plants or in the sewage treatment plants of the localities in near the farm. This is heavily polluted with coarse solid impurities (straw, dung, gravel) but also fine impurities (sand, earth). At the same time, the wastewater has a high chemical and biological load due to the impurity with solid and liquid droppings from animals. Wastewater from animal and poultry farms generally has the characteristics of household wastewater, the main pollutant being organic matter [3].

The treatment of wastewater from livestock farms is necessary to retain and neutralize the harmful substances present in these waters, which are not accepted in the aquatic environment where the treated water will be discharged and which allows the physico-chemical properties of the water to be restored before for use by other downstream consumers. Also, it is necessary to build efficient treatment plants, both technically and financially.

2. Materials and methods

The purification of wastewater from livestock farms is a complex process of retaining and neutralizing substances in the water, in a colloidal or suspension state, which are not accepted in the aquatic environment where the water is discharged treated and which allow restoring the physico-chemical properties of the water before use.

Wastewater treatment has two stages: retention or neutralization of harmful or recoverable substances present in waste water; respectively the processing of the material resulting from the first operation (purified waters, to varying degrees, can be poured into the emissary or can be used for irrigation or other purposes; respectively sludge, which is processed, stored, decomposed or used as fertilizers) [3].

The technological scheme/technological flow of a wastewater from livestock farms treatment plant is presented in Figure 2.

The wastewater flow by gravity into a primary clarifier, where floating and decantable substances are retained. Anaerobic decomposition of settled substances also takes place in this compartment. The wastewater, pre-treated mechanically, then flows through an overflow into the anoxic tank where a subsequent settling is formed in the absence of oxygen.

Then it passes in the aerated tank which is used for the biological purification of wastewater. At the aerated tank is the aeration system with fine bubbles, which supplies the necessary air.

From the aerated tank, the water passes into the secondary clarifier where the oxidized waters loaded with activated sludge are calmed down, this clarifier has a special cylindrical shape with a reduction at the base, which ensures optimal decantation.

The sludge from the secondary clarifier is recirculated to the anoxic tank, through a hole provided at the base of the decanter, the clean water from the surface is discharged into the drainage. The excess sludge is evacuated [5, 6].

Excess sludge can also be used in agriculture as a fertilizer, but only in a mixture with natural fertilizer, in a proportion that which will be established after carrying out specific analyses [7].

An advanced hydroinformatic tool for the design, exploitation and optimization of such a treatment plant is WEST, developed by DHI Denmark.

WEST offers a user-friendly platform for dynamic modelling and simulation of water quality systems (such as wastewater treatment plants, rivers, sewers and urban catchments) and uses mathematical models as a reliable representation of real-world systems [8].

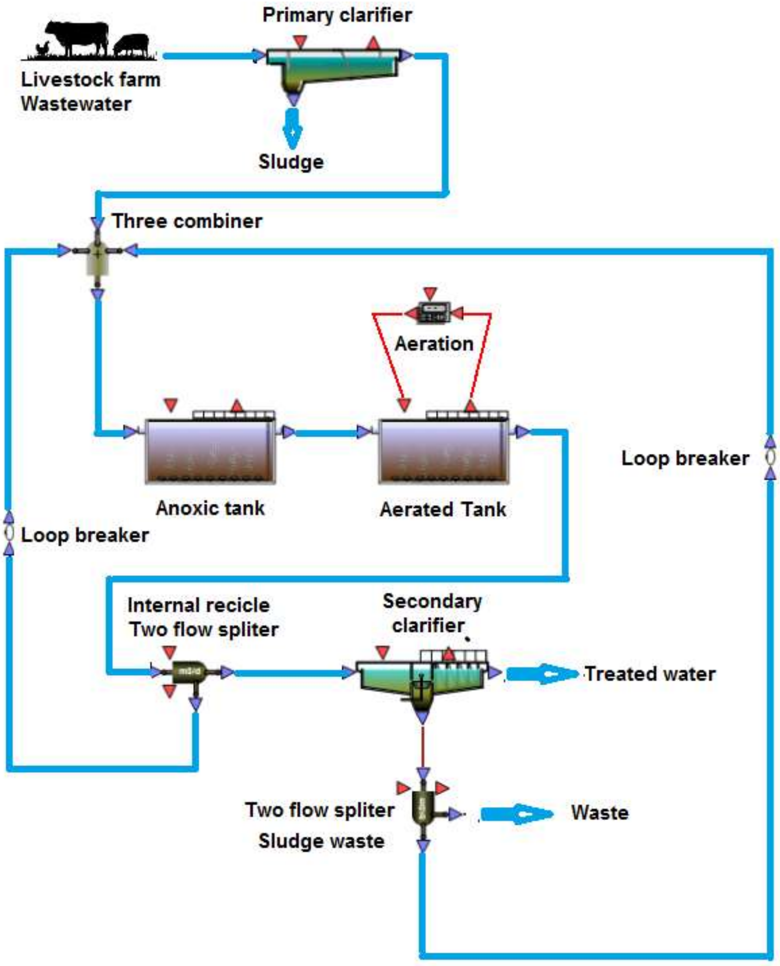

Figure 2. The technological scheme/technological flow of a wastewater treatment plant from livestock farms

WEST comprises four products that address the requirements of a specific target group of users:

-WESTforDESIGN allows for validation of design options and evaluation of different plant layouts in dynamic conditions. This is done by running scenarios (e.g. high vs. low load), and by evaluating the effect of complex control strategies;

-WESTforOPERATORS enables operators to perform short-term (e.g. storm events) and long-term (e.g. consistent nutrient removal) evaluations of their plant. The evaluations (e.g. bottle-neck identification) are carried out by running scenarios for specific influent and operational conditions and costs evaluation. The tool is also useful to improve understanding of the Waste Water Treatment Plant (WWTP) and hence for operator training;

-WESTforOPTIMIZATION enables consultants and engineers to optimize the wastewater treatment processes. With its flexibility and fully open model structure (one can change any model in the model library without limitations) in combination with specific tools for easy model calibration and plant performance evaluation (sensitivity analysis, parameter estimation, scenario analysis and uncertainty analysis) and for minimization of objective functions (e.g. costs), WESTforOPTIMIZATION is the most powerful tool of the suite;

-WESTforAUTOMATION allows for fast integration of modelling and simulation in custom applications by automation or software engineers.

Different Software Development Kits containing comprehensive and extensive documentation and sample sets, allow for linking WEST with SCADA systems or other modelling software (MATLAB, CFD, MIKE URBAN, etc.) [8].

The WEST advanced hydroinformatic tool, the WESTforDESIGN module, ASM1Temp method was used to simulate the operation of the wastewater treatment plant that has the technological scheme shown in Figure 2. The activated sludge unit models in this category are based on the ASM1 (Activated Sludge Model No. 1, IAWQ) model published by the International Association on Water Quality (IAWQ) Task Group on Mathematical Modelling for Design and Operation of Biological Wastewater Treatment Processes.

The ASM1 model has been extended with temperature correction and ammonium limitation for aerobic and anoxic growth of heterotrophs (organisms that need external Carbon sources for growth and gain of energy) [9].

The used model takes into account carbon removal, nitrification and denitrification at a specified temperature. To model the process, the system is divided into separate components. There are two large groups of components, the carbonous organic matter, expressed in COD (Chemical Oxygen Demand), and the nitrogenous components [8].

The input data are:

i). The characteristics of the influent wastewater are to be generated through the Influent Generator, will be water (flow rate) and COD, TKN (Total Kjeldal Nitrogen - the ammonia concentration, both as free ammonia and in saline form, the nitrogen parts of the soluble and particulate matter; those three are measured with the Total Kjeldahl Nitrogen. Total Kjeldahl Nitrogen is a determination method for organic and ammonia nitrogen.

The organic nitrogen is destructed to ammonia in sulphuric acid and then the ammonia is distillated with a strong alkali) and TSS (Total Suspended Solids), (concentration) [8].

The variables values are: COD=610 g/m^3, TKN=45 g/m^3, TSS=409 g/m^3, Water=200 m^3/d. The parameters values are [8]:

-f_S_I (fraction of Inert soluble organic matter/S_COD)=0.25
-S_O (dissolved oxygen)=0.01 g/m^3
-f_S_NH (total ammonium nitrogen, NH_4+NH_3 fraction of TKN)=0.65
-S_ALK_In (alkalinity)=30 g/m^3
-f_X_ND (fraction of soluble biodegradable organic nitrogen)=0.6
-F_TSS_COD (conversion factor TSS/COD)=0.75
-S_NO_In (nitrate and nitrite)=0.01 g/m^3
-X_BA_In (autotrophic biomass)=0.01 g/m^3
-X_P_In (particulate products resulting from biomass decay)=0.01 g/m^3
-f_X_BH (heterotrophic biomass)=0.1

ii). The relevant dimensions: the volume of the anoxic and aerated tanks (150 and 300 m^3 respectively), the internal recycle (5 m^3/d), the sludge underflow in the secondary clarifier (12 m^3/d), the sludge waste (16 m^3/d) and the DO set-point for the aeration controller (1.5 mg/l), under flow rate for primary clarifier 15 m^3/d, anoxic unit Temp 20°C, aerobic unit Temp 20°C.

iii). The effluent characterization will be specified in ASM units that is: in terms of model components (and as loads, i.e. mass per unit time). This is in most cases not convenient, as the effluent quality is to be compared against environmental standards for specific components expressed in concentration units. An effluent file containing the characteristics of the effluent wastewater can be generated through the Effluent Generator [8].

-F_BOD5_BOD20 (conversion factor Biochemical Oxygen Demand BOD5/BOD20)=0.25
-F_TSS_COD (conversion factor TSS/COD)=0.75
-i_X_B (N/COD in biomass)=0.086
-i_X_P (N/COD in product formed)=0.06.

3. Results and discussion

Following the simulation of the operation of the wastewater treatment plant (30-day dynamic simulation), the variation graphs of the concentrations of different substances in each of the plant's units are obtained.

For example, are presented the variation of: soluble COD, nitrate and ammonium concentrations in the anoxic and aerated units respectively; the oxygen concentration from anoxic and aerated units; the mass of solids in each layer of the secondary clarifier.

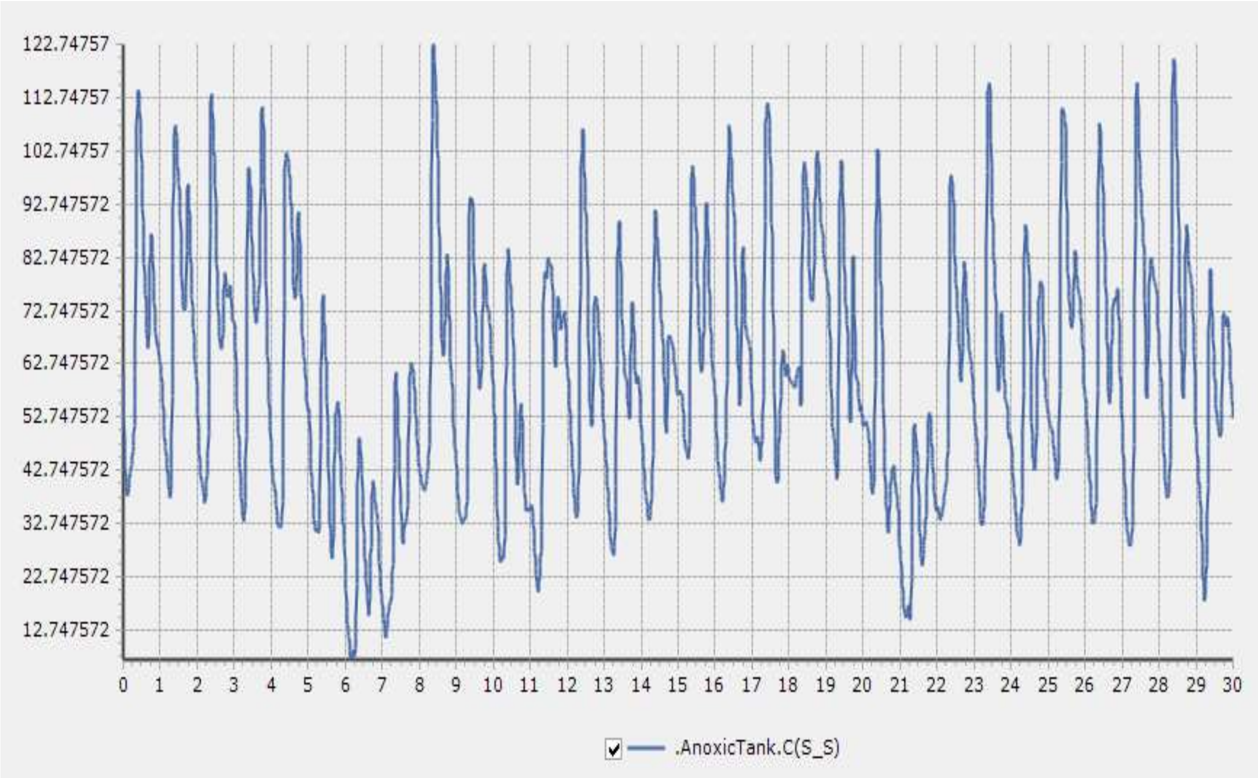

Figure 3. Variation of soluble COD concentrations in anoxic tank (g/m^3)

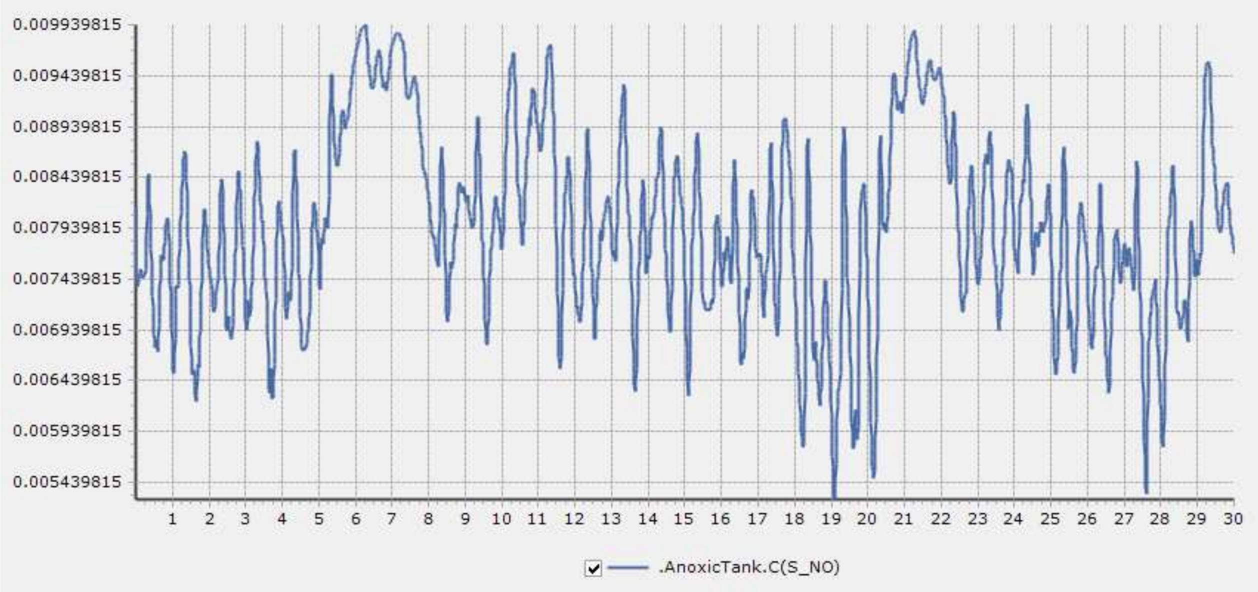

Figure 4. Variation of nitrate concentrations in anoxic tank (g/m^3)

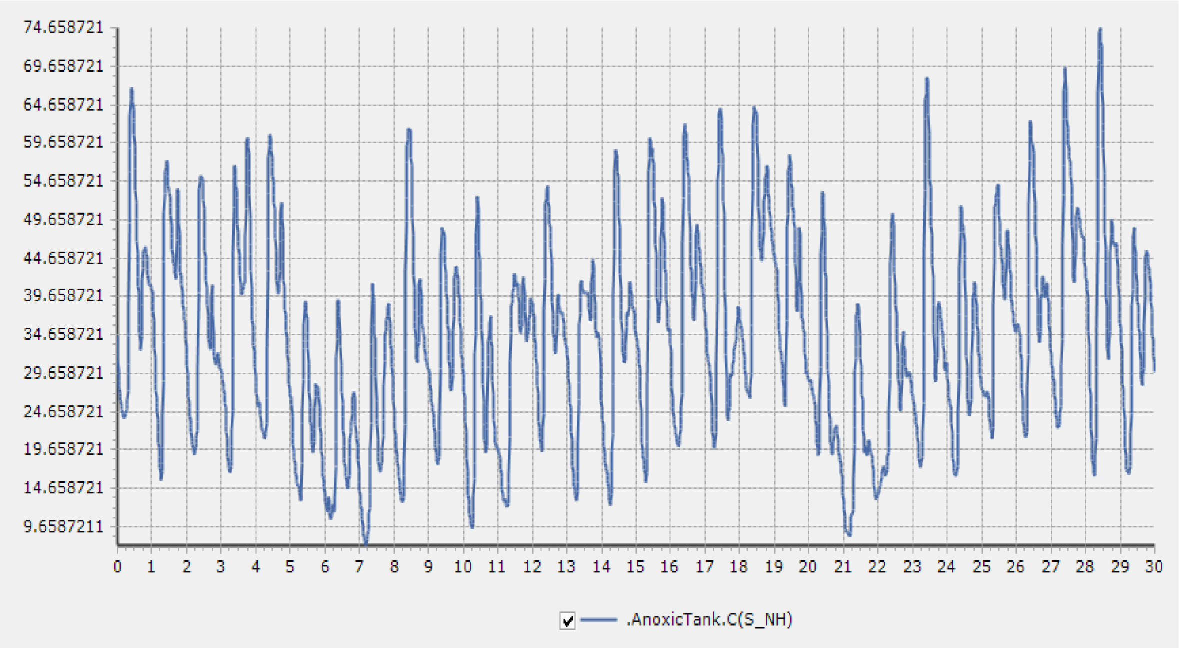

Figure 5. Variation of ammonium concentrations in anoxic tank (g/m^3)

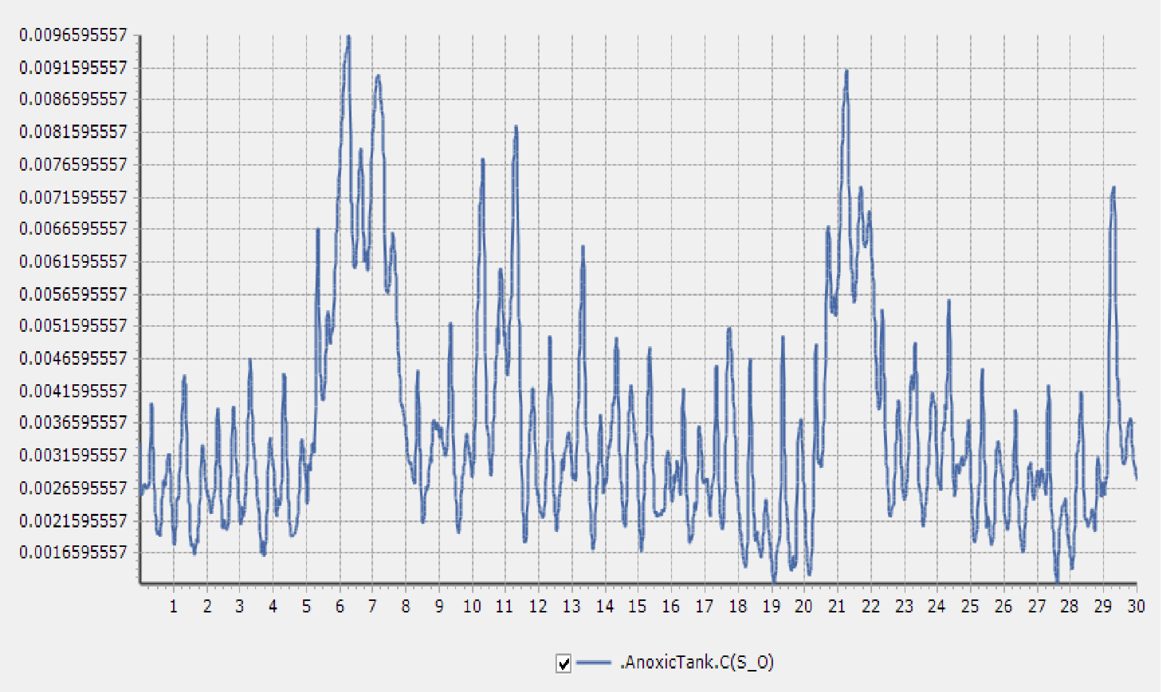

Figure 6. Variation of oxygen concentrations in anoxic tank (g/m^3)

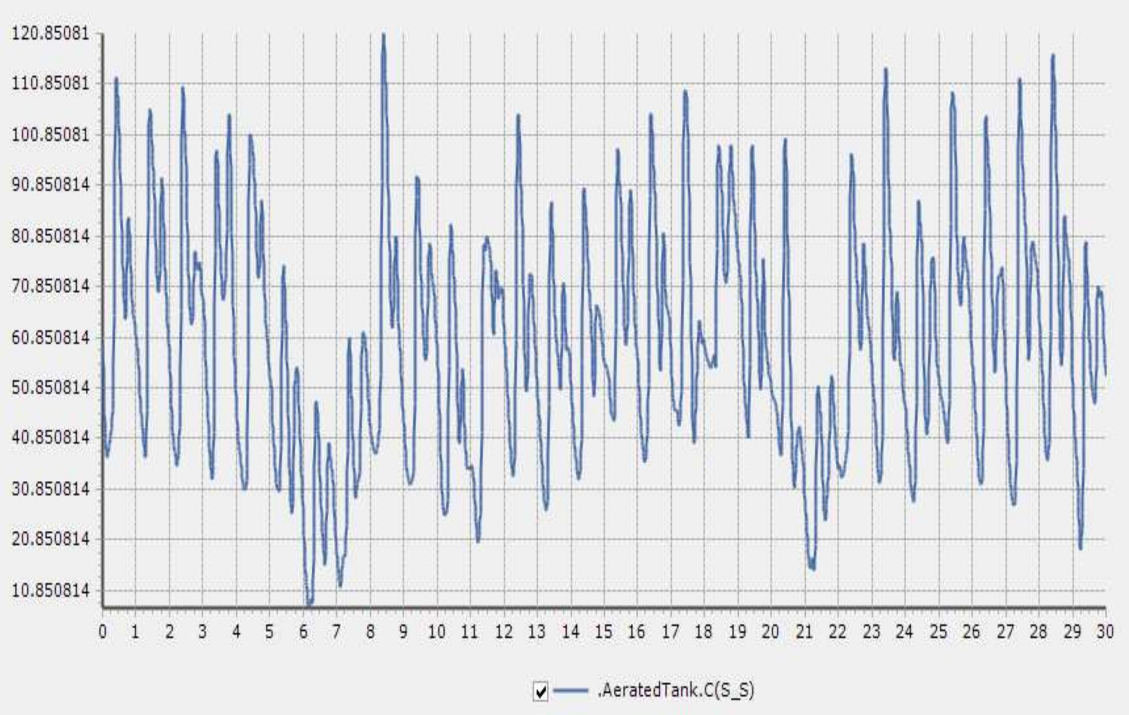

Figure 7. Variation of soluble COD concentrations in aerated tank (g/m^3)

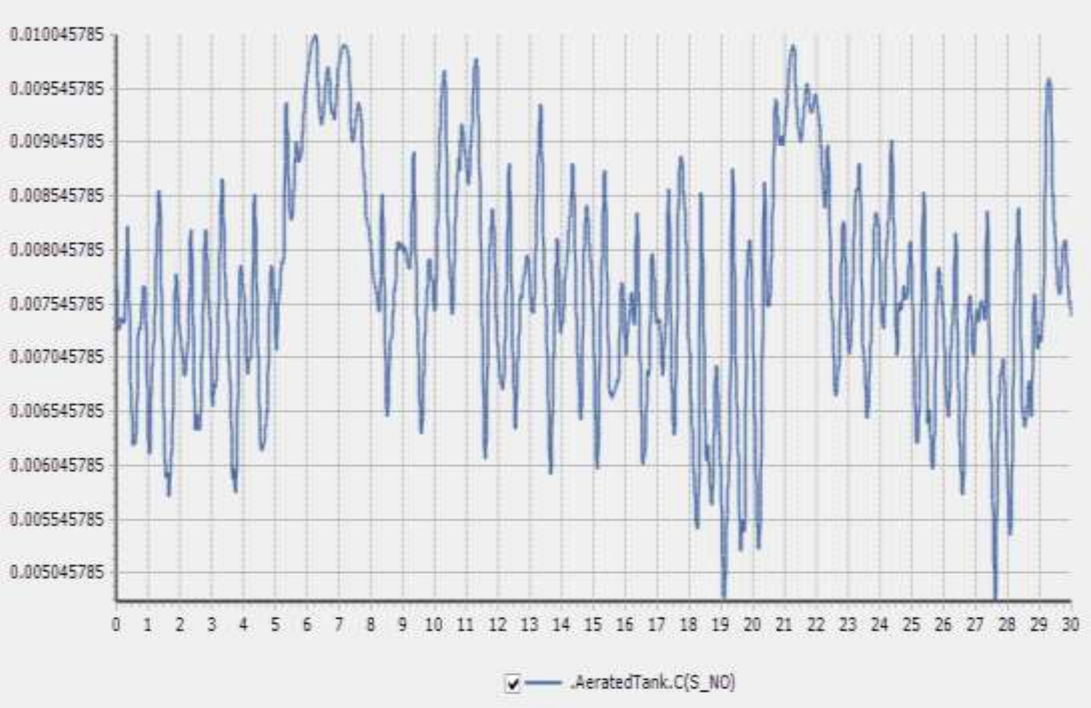

Figure 8. Variation of nitrate concentrations in aerated tank (g/m^3)

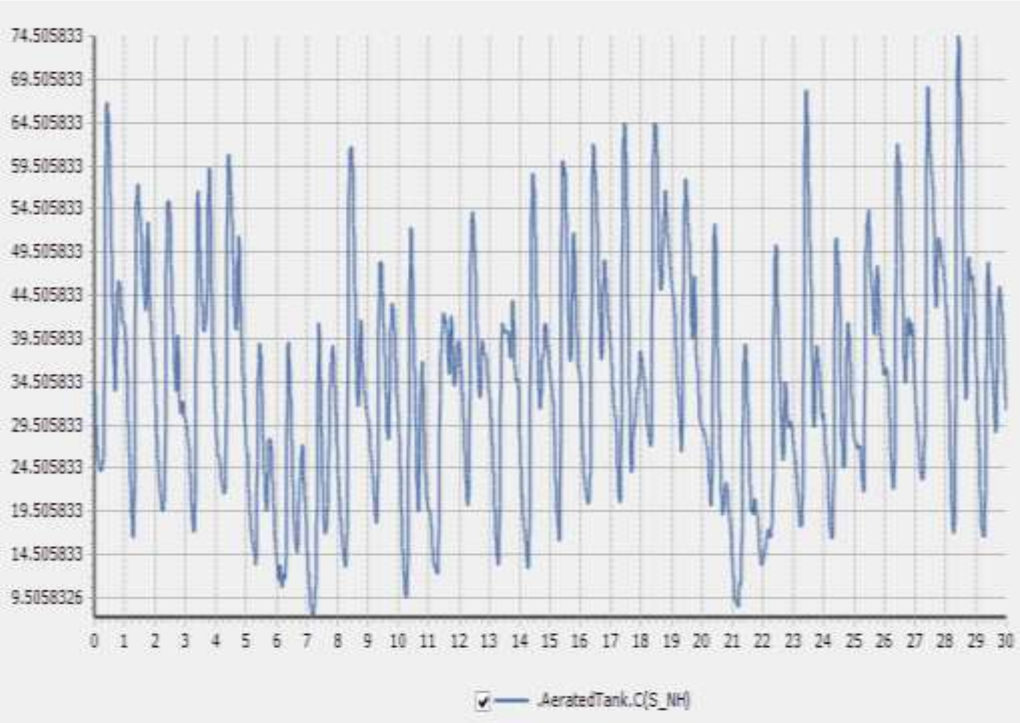

Figure 9. Variation of ammonium concentrations in aerated tank (g/m^3)

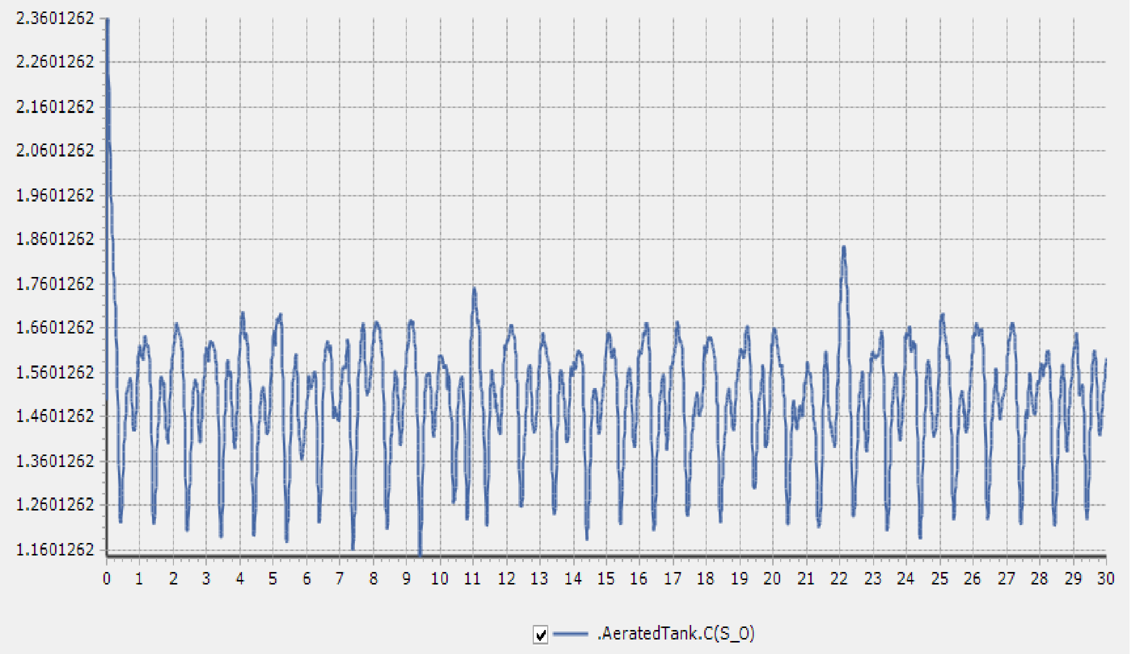

Figure 10. Variation of oxygen concentrations in aerated tank (g/m^3)

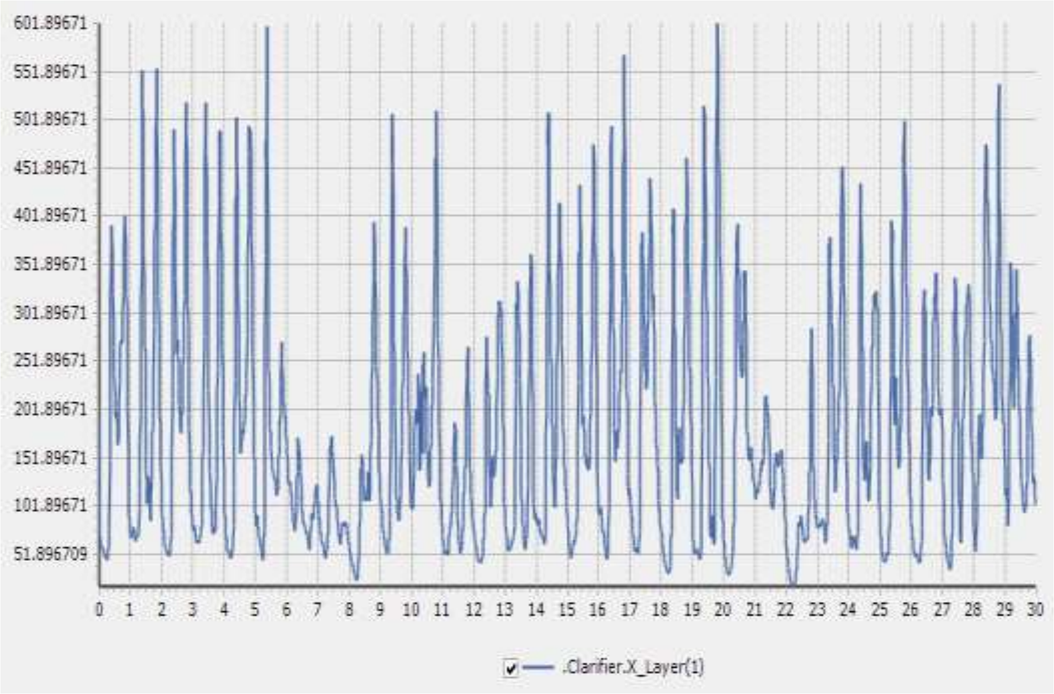

Figure 11. Variation of mass of solids in layer1 of the secondary clarifier (g/m^3)

From the graphs, it can be seen that while the variation of the concentrations of soluble COD, nitrates and ammonium has about the same pattern in the two tanks (anoxic and aerated), a big difference is observed in the case of the oxygen concentration, which has an irregular variation in the anoxic tank, while in the aerated one it has a uniform shape. Table 1 shows the input values to the treatment plant (influent flow), respectively the output values for COD, TKN and TSS in effluent flow.

Table 1. Input and output values of water

	Input (g/m^3)	Output (g/m^3)
COD	610	207.270
TKN	45	42.538
TSS	409	101.828

A significant reduction is observed in the case of COD and TSS.

4. Conclusions

Access to an adequate quantity and quality of water for personal and domestic use is a fundamental human right. Where there are no treatment plants, in areas with potential pollutants, i.e. with large water users (urban agglomerations, various industries, livestock farms, etc.) the water is contaminated and can be a source of spread of various diseases, such as cholera, dysentery, typhoid fever and poliomyelitis. Considering this situation, the implementation of treatment plants for water quality and safety are crucial for human health and the environment.

It is also necessary to maintain an adequate quality of environmental factors (water, air, soil).

Hence the need to create efficient treatment plants, both economically and technically. This can be achieved by using advanced hydroinformatics tools, in order to ensure a quality of purified water that corresponds to the national standards in force.

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