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PERFORMANCE REQUIREMENTS OF THE TREATMENT INSTALLATION DESIGNING WITH LOWER CAPACITY

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For slight collectivity, with small flows of waste water, where the investment and exploitation costs are beard by the private financing, the choice of the cleaning technology of the waste water which would comply with correct technological performance in reliance with a minimal cost, represents an axiom for the rural treatment installation design.

The installation proposed by the authors underlines the biological treatment advantages with the aid of a biological selector and a homogeneous reactor, compared to the conventional technological scheme.

1. Introduction

For the small treatment installation with low capacity (used for communities under 5,000 peoples), the basic treatment technology configuration and great efficiency represent very important problems.

A new national and local strategy regarding the environment quality amendment and the urban comfort in the rural medium, [6], shows that from a total of 15,800 Romanian communities only 16.8% are equipped with sanitary installations.

The principal target is the promotion of the rural investments and the completion of the sanitary installation to achieve civilized conditions. In this context, it is necessary to satisfy the performance conditions of this installation, which, compared to the urban plant, must take into consideration the factors regarding the density of population, the lack of the professional personal, the limited character of financial resources and a small budget for exploitation of this installation.

The authors present the technical information necessary for designing a rural biological treatment installation, which can work with small energetically costs balanced to a conventional one.

2. Quantitative and Qualitative Particularities of the Rural Waste Water

The study of the quantitative (specific consumption, non-uniformity coefficients, discharge, etc.) and qualitative (concentration with suspended material, with organically substance, with toxic material, etc.) parameters must be analysed reported to the municipal equipment of the rural community and to the existence of the economical agro-industrial factors.

The Romanian Government strategy regarding the public services estimates that by 2017, the rural area would have the specific consumption of 170 l/habitant day, and by 2030, 30% of rural community would have treatment installations.

In the present it is difficult to choose the specific water consumption index. We can appreciate, in the first design phase, depending on the geographical position and the water resources, a rational value of 80...150 l/inhabitant day. In the great majority of European countries, it is considered a consumption of 200 l/inhabitant day drink water and waste water with a organically charge of 50...60 mg BOD5/l for a outflow more like 150 l/inhabitant day.

The hour by non-uniformity coefficients of the discharge have a variation between 0.3 and 3.0 depending on the inhabitants. For a small community the non-uniformity coefficient is great with negative effects for the treatment installation and special for Waste Water Treatment Plant (WWTP).

For qualitative parameters of this rural waste water, we can adopt the same values like the urban waste water.

3. Technological Scheme and Installation for Treatment of Waste Water

A small treatment installation is not a transformation at scale of a WWTP (proportionally with the discharge or with the transformed organically charge). The rural communities of our country have the following characteristics: small density excepting the central area for a little quantity of drinking water resulting small waste water discharge with problems for hydraulic transport at WWTP.

The treatment installation that will be designed must respect the following prescriptions:

a) upstream must be placed a basin for a quantitative and qualitative equalization;

b) the solid construction of the elements of the treatment installation;

c) the simplicity and security exploitation with minimal costs;

d) the reduction of the terrain placement at a minimal distance from the community of 300 m, in agreement with the sanitary prescriptions;

e) a financial supportability of investments and exploitation for the people community.

The majority of the treatment installations with discharge greater than 100 m^3/day, not use the primary waste water clarification and in the mechanical step use only the gravel filter equipment (grating and sediment exclusion equipment). In biological step are designed aeration rectangular basin with hydraulic piston, a great energetically consumer (with great costs and financing difficulties for rural population). The most efficient and inexpensive treatment scheme is the installation which functions in natural conditions likes self-purification of waters (biological stick ponds, mechanical aerated laguna, etc.) or self-purification of soils (underground filtration, filtrating trench, infiltration bed, etc.). Not all rural communities can derive advantage from these natural conditions for a natural purification of the waste waters and the specialists must find the efficient solutions with low costs.

4. Performance Tendency at the Biological Treatment Design with Active Sludge

The biological treatment installation is used for organically pollutant elimination (described by Biological Oxygen Demand (BOD) or Chemical Oxygen Demand (COD)) and for ammonium and phosphorus compounds elimination by nitrification–denitrification processes.

The performance demands of the biological treatment processes will be analysed using the following criteria:

a) to obtain a great elimination velocity of the organic pollutants (of the sub-layer) considering a biodegradable pollutant and his retention in a special installation (biological selector);

b) using a homogeneous biological reactor (compact mixing-(CM)) with the intensification of the mass transfer between the involved compounds: pollutants, biomass and oxygen.

4.1. The Necessity of the Biological Selector

In the kinetic of the treatment of biological processes with activated sludge, we consider only the concentration of the organic substances in soluble stage exprimed by BOD, COD or Total of Organically Carbon (TOC). In reality, in the composition of the domestic waste water we find in a great proportion the organically substances in suspended stage and colloidal dispersion. The laboratory analysis of the domestic water show that 1/3 of organic compounds are in fine suspension, 1/3 in colloidal stage and 1/3 in soluble stage [3].

It is known that the waste water, regarding the biologic treatment, can be grouped in hard average and easy bio-degradability waters, which can be expressed graphically by the curve presented in the Fig. 1.

In the case of the easy bio-degradable waters (the case of the domestic waste waters) a great quantity of organic substances in un-dissolved stage is eliminated, in a very short period of time, by its absorption on the flaky surface (the A ordinate – Fig. 1). The rest of the organic substance represents the soluble part which will be eliminated by bio-degradation processes in the bacterial cell.

From the adsorption phenomena appear the treatment process named *bio-sorption*, which consists in the mixture, in a basin, of the domestic waste water with a biomass formed by an aerobic micro-organisms population, for the absorption times up 30 min, the majority fine and colloidal suspension. The recent researches show that by the bio-absorption are eliminated up to 85% of the total BOD in a 10...15 min time contact with the biomass [4].

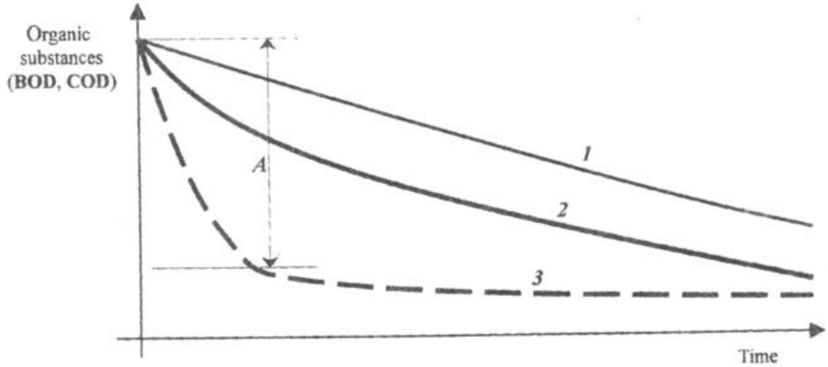

Fig. 1.– The characteristic curves of the bio-degradability of the organic substances: *1* – waste water hard bio-degradable; *2* – waste water medium bio-degradable; *3* – waste water easy bio-degradable; *A* – the elimination of the organic substances in fine suspension and colloidal dispersion stage.

This launching basin is controlled in a reactor where is assured an intensive aeration for the absorption capacity renewal of the recycled biomass from the secondary settling installation. In the literature [1] this treatment process is developed about a technologic scheme named *stabilisation by contact*, between the launching basin and the reactor being foresight a decantation installation, where is eliminated the water partial cleared, the output debit having organic charge up to 100 mg BOD/dm^3, which can not be discharged in the surface water only with special advise or a supplementary biological treatment.

The above related data show that the elimination of the sub-layer from small bio-degradable waste water can be realized using two distinct processes, like show the Fig. 2.

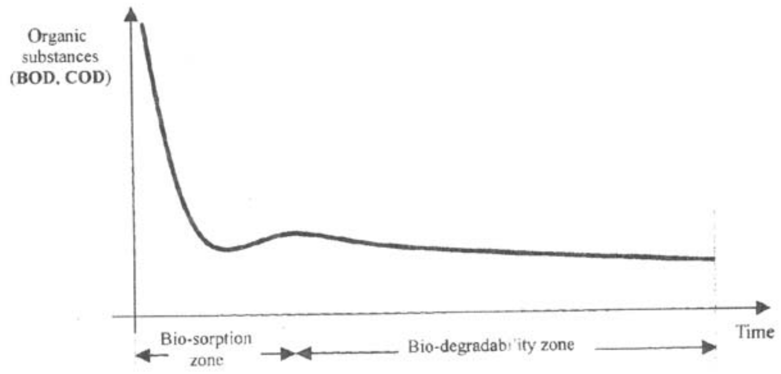

Fig. 2.– The zone of the organic elimination of the small bio-degradable water.

The design of the biological treatment installation must consider the obtaining of a salubrious sludge, slow sedimentable in the secondary settling installation. From the rural collectivity it result small discharges, and is recommended a solution with homogeneous reactors (compact mixing (CM)). This reactors are easy in exploitation, and the financial expenses due to the electrically energy are lower like these of the classic reactors longitudinal type (plug flow (PF)). Using the solution CM can appear the risk to not obtain sludge easy sedimentable but the sludge with the filament organisms, which affect the settling process and float up the water of the secondary settling installation. This technologic problem can be eliminated by using a biological selector placed upstream of the reactor like in the Fig. 3.

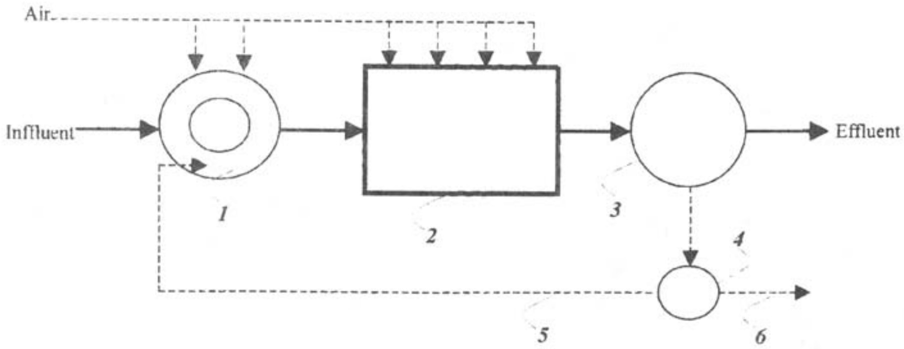

Fig. 3.– Biological treatment installations for waste water easy bio-degradable from rural community: *1* – biological selector; *2* – CM reactor; *3* – secondary settling installation; *4* – pump station; *5* – active recirculation sludge; *6* – excess sludge.

It is known that in a biological reactor, the admission of the soluble sub-layer (COD, BOD) in the bacteria cell is realized by a physical diffusion phenomena and the diffusion velocity through the pellicle which turn around the cells of suspended biomass of the reactor, represent the significant velocity of the process. The diffusion is a spontaneously alignment process of the concentrations, as a result of the molecular and Brownian movements (in the case of colloidal particles). The substances which are moved on account of gradient of concentration are displaced from the zone with great concentration towards the zone with small concentration. If the value of this gradient is low, it results that the food not enters inside the cell satisfying only the demands at the surface cell level being developed the filament of the cell and resulting a floating sludge.

In the case of the CM reactor (Fig. 3), the concentration of the sub-layer is uniform in all sides, being equal with the effluent concentration (approximate 5 mg/dm^3), so don't exist the conditions to form the necessary gradient for the penetration of the organic substances inside the flaky. It results that is necessary an external *actuating force* equivalent with a gradient of the sub-layer concentration.

Technologically, this necessity can be realized by:

a) Adopting a great length reactor type PF, where at the input exists an elevated concentration of the sub-layer and of the flaky, being performed the necessary conditions for a sub-layer gradient. This solution is frequently applied in WWTP of the great urban centre.

b) Foresight of a biological selector upstream of the CM reactor which assures a great sub-layer gradient at the reactor input and the flaky has not filament organisms. This situation is justified by the high bio-sorption capacity of the sub-layer formed by the suspensions and colloids by the existent flaky in biological selector, therefore the CM reactor will be done only with organic soluble substances.

The Design of the Biological Selector

The dimension of the bio-sorption process, indicated by the diminution of the sub-layer (expressed by BOD or COD) can be correlated with a *flaky charge* (Fl) of the biological selector. Among numerous experimental researches, the speciality literature [5] recommends the following formula for this indicator:

$$\mathrm{Fl} = \frac{Q_0 f_{\mathrm{sorp}} L_0}{Q_R f_d f_b X_v}, \tag{1}$$

where: Fl represents organic charge of the flaky, [mg BOD/mg volatile substance]; Q_0 – influent debit from biological installation, [m^3/day]; L_0 – influent sub-layer, [mg BOD/dm^3]; f_{sorp} – the fraction of the L_0 which can be biosorpted; Q_R – the debit of the recycled sludge, [m^3/day]; f_d – degradable fraction of the biomass; f_b – active fraction of the biomass; X_v – the concentration of the biomass in the volatile substances, [g VS/dm^3].

The fraction f_{sorp} includes the organic substances comprised in the flaky mesh and the organic substances adsorpted on the surface of the flaky. This fraction, which is specific for the bio-sorption zone, is established by experimental researches.

The fraction f_d express the degradable part of the suspended biomass from the biological selector which contains only soluble sub-layers and can be calculated with relation:

$$f_d = \frac{f'_d}{1 + (1 - f'_d) k_d T_N}, \tag{2}$$

where: f'_d is the maximal degradable fraction of the biomass which have a variation in function of the age of sludge and of the measure of the organic charge; frequently the value of 80% is accepted; k_d – the coefficient of the endogen respiration of the biomass, [day^{-1}]; T_N – the age of the sludge, [days].

In these conditions, the relation (2) can be expressed under the form:

$$f_d = \frac{0.8}{1 + 0.2 k_d T_N} \tag{2'}$$

The active fraction of the biomass (f_b) represents an indicator which shows that only a part of the biomass sits in the process – the part formed by the live micro-organisms which assure the viability of the active sludge. This fraction, with sub-unitary values, is difficult to be quantized analytically, being established by experimental researches or indirectly, in function of the other indicators (the age of the sludge, k_d, f_d, etc.).

As a conclusion, the efficiency of the bio-sorption, calculated with relation (1), depends on the active mass of the selector biomass, on the organically charge and on the age of the sludge. For flaky charge of 100...150 mg COD/g VS, the experimental studies put in evidence an elimination of the COD of 65...80%, after a retention time of 15 min [7].

4.2. The Design of the CM Reactor

For a CM reactor – if there is no biological selector – the velocity of elimination of the sub-layer is reduced with the reduction of the organically concentration and of the biomass. The sub-layers and metabolites mixing which result during the process will be heavy, with negative consequences for effluent quality and for the sedimentability of the sludge.

The existence upstream of a biological selector gives an improved quality of the process in the reactor. With the view of intensifying the transfer mass process between the compounds involved in epuration reaction must be taking the following measures:

a) the pneumatic aeration with fine bubble;

b) the increase of the depth of reactor with the view of advancing the contact time between the air bubble and the liquid phase, that leads at the utilization of the following reactors type: column type (tower) 10...25 m high or well type (well drilling) with depth up to hundred meters, method which enlarge two times the solubility, respectively assure a utilization efficiency of the oxygen up to 90% by the enlargement of the hydrostatic pressure; concomitantly, by the activated excess sludge production is reduced with 50% and is necessary a little pump station for sludge evacuation;

c) the advance of the biomass concentration by the introduction inside the reactor of a solid support for micro-organisms fixation (fixed biomass) and which together with the suspended biomass from the reactor intensifies the bio degradation process of the soluble sub-layer; by this method the energetic costs are reduced and results a small specific construction, which directly influences the investment costs and build area.

The designing parameters of a CM reactor can be known from speciality literature [3]. If in the composition of the water, the Kjendahl's ammonium concentration falls under the elimination limits, it is recommended the application of the ammonium elimination by the nitrification–denitrification process, and the biological selector functioning in anoxic conditions.

5. Conclusions

The proposed installation assures the performance parameters of the biological epuration process of the domestic waste water satisfying the economical and exploitation demands with the specificity of the rural community. In the biological selector are eliminated 80% of the organic substances, in 15...20 min, so that in the reactor, where is produced the bio-degradation of the organic substances in soluble stage, will take place a nitrification process of this substances, obtaining an effluent which can be used for irrigation of the arable farming.

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CERINŢE DE PERFORMANŢĂ LA PROIECTAREA
INSTALAŢIILOR DE EPURARE DE MICĂ CAPACITATE

(Rezumat)

Pentru colectivităţile restrânse, cu debite reduse ale apelor reziduale şi unde cheltuielile de investiţii şi de exploatare sunt suportate de populaţie, alegerea tehnologiei de epurare a apelor, uzate care să satisfacă cerinţa de performanţă tehnologică în condiţiile unor costuri minime, reprezintă o axiomă la proiectarea instalaţiilor de epurare din mediul rural.

Instalaţia propusă pune în evidenţă avantajele epurării biologice cu ajutorul unui selector biologic şi al unui reactor omogen, în comparaţie cu schema tehnologică convenţională.