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Manipulation of Ecosystems that Are Being Formed in the Wastewater Purification Installations

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Abstract: The paper presents the characteristics of differents biological treatment steps of waste water purification - both aerobic (aerotanks, biofilters, sewage treatment lagoons and installations to cultivate aquatic plants) as well as the anaerobic (methantanks) - both from functionally and efficiently point of view. In these biological treatment plants spontaneously are created, but also with the conscious contribution of humans, quite complex ecological systems, which function well afterwards only under strict human control. These ecosystems are ecotechnological models that contribute to the protection of the environment and increase indirectly the productivity of agrarian ecosystems. Five biological treatment systems are briefly analyzed in this paper.

Key words: sewage treatment, biological treatment, man-made aquatic ecosystems.

Wastewaters are freshwaters taken by man from nature and which are used in various purposes (in agriculture, industry, for household or for recreational purposes) and which, after their use, are restituted to natural environment, but being load with various solid, liquid or gaseous substances, of different types, of which people wants to discard. These wastes are usually foreign to natural environment and so they may disturb natural equilibria and nature in its whole. More, wastewaters may be reused by people only in the case accumulated pollutants are eliminated through different procedures.

In present, when water requirements of mankind are in accelerated increase, polluting of a water and to have no possibility to reuse it is an unacceptable option. In economically developed zones the water is used, purified and reused repeatedly (sometimes 4-5 times successively), before to be restituted to nature, at a quality as acceptable as possible.

For nearly two centuries mankind is concerned to create purifying installations for different types of wastewaters, in which, using mechanical, physical, chemical and biological systems the contained pollutants are eliminated (Fig.1)[2].

Fig. 1 – A complex wastewater purification station

Once the development of purifying

technologies there were obtained higher and higher efficiencies, sometimes reaching even 95-98 %; control systems of each purifying step were developed, there were also achieved automatic and self-control systems, together with a maximum shortening of purifying processes duration.

From ecological poimt of view, the wastewater purifying installations represent a sort of specialized ecosystems, which are intented to uptake from that waters all the pollutants eliminated by humans and which, reaching natural water bodies may have a negative effect, both these water bodies and neighbouring ecosystems (natural or antropic), diminishing or canceling in full eventual further use by mankind of respective waters [2].

Wastewaters have physical, chemical and biological peculiarities very different from that of natural waters; they are not transparent, have different colors, their fluidity and opacity are modified, their pH values vary between 1-2 and 13-14, they contain an extraordinary variety of chemical compounds which may interact in a total uncontrollable manner; they have also higher temperatures than that of their original water bodies, contain both natural and synthetic physical and chemical compounds (e.g.biologically active complexes, different enzymes etc) and, also, different organisms - resulted from human activities. As a consequence, it is practically impossible to determine, at a given moment, very accurately, their precise chemical composition and in what manner it will be modified in subsequent moments, because, through the continuous reactions, the chemical composition of these waters is changed not only as a result of simple chemical processes, but also as a consequence of the activity of decomposing microorganisms, which decay some substances and synthesize other, perform biosynthesis and biodegrading processes almost impossibly to watch [2].

Into wastewaters get a lot of various organisms (especially microorganisms – degrading, saprophytic, decaying or pathogen) whose developing may affect negatively, even catastrophic, the biocoenoses from natural water bodies in which these wastewaters are to be discharged, becoming true culture media for microorgenisms. Through their multiplication, different types of bacteria triggers degradative – aerobic or anaerobic – processes, from which may result toxic or inhibiting substances, influencing the usual processes from natural water bodies, as hydrogen sulfide, methane or cyanides.

As a result, in wastewaters there is a quasyinfinity of particulate, colloidal, liquid or gaseous organic substances which continuous interact one to another.This situation results in emergence of a lot of uncontrollable chemical reactions, which in their turn, stimulate the activity of degrading bacteria, which find here a very convenient culture media for their multiplication. It is not a surprise that within the biological step of purifying bacteria multiplication reach an extraordinary pace; their spectacular diversity makes impossibly to know precisely each of the species participating to purifying processes.

The target of wastewater purifying is the extraction or neutralization of polluting substances and getting closer to the peculiarities of purified waters as close as possibly to the features and chemical composition of natural water bodies. This process is performed in wastewater purification units, whose technical structure is established function of the origin of wastewater, their nature and chemical composition, their rate of flow, climatic peculiarities of the region where the units are placed and, also, function of the outlet water quality requirements established by supervising authorities.

In almost all modern purification units wastewater treatment goes through three stages: mechanical step, physico-chemical step and biological step. This process results in solid material, which is collected and sent to drying filters or to sludge beds.

Mineral material (gravel, sand), is separated, cleaned; only this material may be used in constructions. Waste purification efficiency is about 40-60 % in mechanical step, almost 100 % in physico-chemical step and about 90-95 % in the biological step [6].

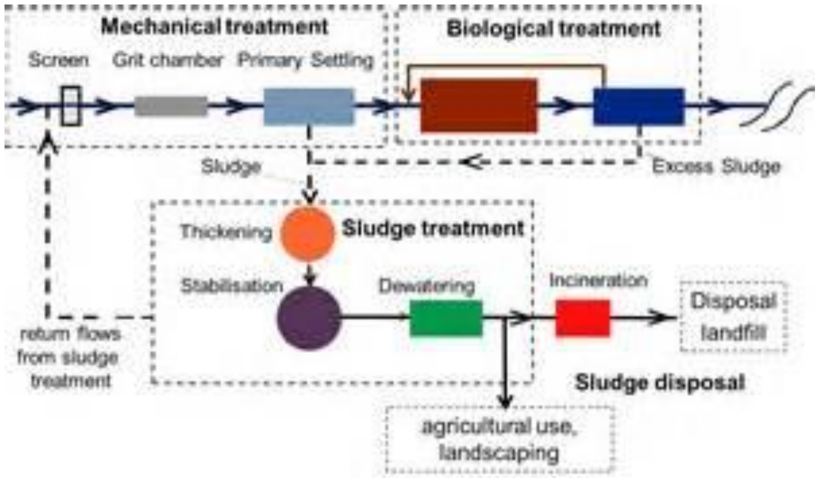

Fig. 2. – The scheme of a complex purifying step

In the first step – the mechanical one - there are separated and retained mineral and big organic suspensions, which are more easily sedimentable. Mechanical step includes gratings, sieves, sand and fat separators and primary settlement tanks (decanors) (Fig.2).

In the physico-chemical step water pH may be modified, approaching its values to neutral ones (pH value around 7), systems for chemical precipitation of very dangerous pollutants, precipitation of colloidal substances, systems for neutralizing of some very toxic products, which could endanger the activity of microorganisms from the biological step. Although this step has a high efficiency, the costs needed for neutralizing, for the reagents used in precipitations etc. limit the use of chemical step especially in several cases (wastewater from petroleum industry, chemical industry, or for some products which must be maximally recuperated, as rare metals, gold, silver, very strong toxics, pesticids etc).

In the biological treatment step situation is different [7],[9] because its role is to extract from wastewaters all what physico-chemical procedures could not perform: elimination of colloidal and liquid organic compounds which are dissolved or too thin particulated, of some elements ot compounds on which microorganisms can grow, can decompose or to bioaccumulate them, and this way they will be eliminated from water together with the microorganisms in which they were accumulated (Fig.2). In the biological step there are retained a lot of substances as a consequence of the ability of some microorganisms to split up several organic compounds to more simply chemical substances, easier to be assimilated, with which microorganisms create their own bacterial mass, organic pollutants which no chemical reaction may eliminate as well as bacteria can do it [7],[9]. This way organic pollutants are recuperated at much lower costs (as compared to chemical methods), and they are transformed in organic compounds similar to that from natural waters; these compounds can be extracted and then valorified as agricultural compost. The compounds containing heavy metals although are rarely bioaccumulated; they can be later extracted from bacterial masses in which were accumulated through burning resulted organic matter and then may be separated from ash through chemical methods. Hence, the biological step is based on the activity of some living organisms, mainly bacteria and saprophytic fungi, but also of other creatures which feed on the first ones, as are some protozoans, worms, several crustaceans or insects.

The organisms present in biological purifying step are beings which usually live in nature but which, under the conditions offered by waste waters are favoured to multiply abundantly, to the detriment of that which can not live here (which, even reach this environment, will disappear almost immediately). The organisms, either as living individuals or as rezistance forms (cysts, spores, eggs etc), could find here a living environment favourable to their development : a temperature of about 15-20^{0}C, a pH close to neutral, an environment in motion which contains small amounts of dissolved oxygen, but which are enough for their metabolic activities [7], [8].

In function of the requirements for dissolved oxygen, there are two types of biological steps: in one of them the degradation processes of colloidal or dissolved organic substances develop on aerobic way, and other, in which these processes develop so intensely (or slowly) so that the degradation of organic pollutants is preferred to develop on anaerobic way [9]. Microbial biomasses produced within biological step of purifying units are then concentrated in secondary decanters. From here, they are transported to sludge drying spaces and, finally, used as organic fertilizer on agricultural soils (only they do not contain heavy metals or hard biodegradable pesticides).

Coming again to the bacteria which develop within the biological step of purification, it may be observed that initially these are spread in the mass of wastewater or, at th most they may agglutinate on thin organic or mineral particles. In biological installations their metabolic processes are triggered by favorable conditions controlled by man - occurrence of free oxygen, water movement, temperature suitable to the processes type (aerobic or anaerobic) and they grow exponentially. Under the action of electrostatic forces between them, an agglutination process of free bacteria. This way appear some “flocs” of bacteria and microscopic fungi, that may reach even 1 cm diameter; as effect of water turbulence, they are fragmented, determining an acceleration of general processes of flocculation. These bacterial flocs (activated sludge flocs) are growing, become more heavy, and so they become easier extractable from water after it is transferred to secondary decanters through mechanical processes. It takes place a transformation of colloidal, dissolved of thin particulate organic substances towards heavy bacterial mass, easy to be extracted from wastewater through the simple process of gravitational decantation in secondary decanters.

In the biological step of purification it takes place the spontaneous installation of a biocoenose specialized for the degradation of organic substances, composed predominantly from degrading organisms, organisms which feed on the first and from predators of all these – primary consumers. Specifically for these biocoenoses is the net predominance of degraders which, because their large volume, are consumed only in small ratio by bacterivores and by second order of predators. Within these biocoenoses the role of primary producers is fulfilled by degrading bacteria. Therefore, the true primary producers play no role. Here do not occur photosynthesizing organisms. All the trophic chains developed in these biocoenoses start from the degradators. Photosynthesizing organisms, as cyanobacteria or green algae can not live here, because transparency of wastewaters is quasi null, and the water is in continuous motion so, even such organisms reach here, they will be deprived of solar light.

These trophic chains are short, so that matter circulation flows quikly, unidirectionally.

In present, the humans know the biological processes, the biocoenoses which are formed in these waters and are able to optimize the environmental conditions specific to development of certain microbial associations useful to rapid purifying processes: wastewater discharge, optimal microbial loading in installation, evacuation of the surplus of produced bacterial biomass, the intensity of aeration, in order to maintain a certain, optimal, oxygen concentration in water mass of biological step (neither a supraoxygenation, nor a suboxygenation – this last resulting in the apparition of anaerobic processes), a neutral or slightly basic pH, a continuous motion of wastewaters, an optimal reaction time for the intended purification level etc.

Function of the amount of dissolved oxygen required by biological purification processes, there are distinguished two types of biological steps of purification: aerobic biological step, and anaerobic biological step.

1.Biological purification step based on aerobic processes is represented by several types of installations where are developed aerobic bacteria, namely: aerotanks, biofiltres, oxidation ponds/lagoons, basins for aquatic plants growing.

Aerotanks are basins containing wastewaters in which development of bacterial biomass takes place in water mass (Fig.3)[4].

Here, bacteria belonging to different types (coccoid, bacilli, spirills, bacterial filaments etc), together with free hyphae of fungi develop and slowly join one to another, so, after a while there are only very few free bacteria in water mass, most of bacteria and fungi being included in "activated sludge flocs", flocs which are easy sedimentable, but they, growing too much, under the action of water currents and of air bubbles, are continuously fragmented, and the fragments grow unceasingly (Fig.4)[3].

Fig. 3. – An aerotank in function

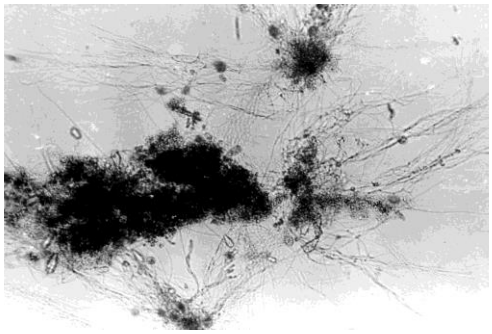

Fig. 4 – Image of a floc of activated sludge

The mass of sludge flocs is in continuous contact with the nutritive environment where they live, but also with the dissolved oxygen. The man creates perfect conditions for the increase of bacterial mass on the basis of organic substances from wastewaters [4], [5].

Primary consumers of bacteria and fungi are microscopic animals – predominantly protozoa, as ciliates, zooflagellates and amoebas. With the protozoa there are several microscopic worms, as nemathods and rotifers (Fig.5).

An other characteristic of the biocoenose is that it is effectively bactericidal for pathogemic germs reaching here. Hence, it takes place the disappearance of quasi-all pathogenic germs which, if try to develop, have not their specific support for developing .. and die.

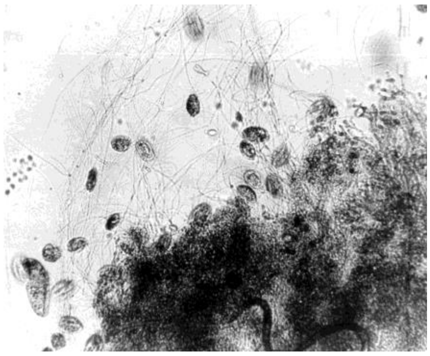

Fig. 5. – Images of organisms which live in aerotanks

The predators of these primary consumers are predators ciliates, several worms and … that's all. In aerotanks no other predator animals were met.

When the amount of activated sludge increases over the maximal admissible limits for provide an intense purification process, when appear processes of mineralization of bacterial biomass, excess sludge is removed from the aerotank and sent to secondary settlement tanks, and further away to an installation which thichens the sludge, then compressed and dried, or is sent to mud beds where, after the

Fig.6 .– "Earth" produced from activated sludge after their composting

gravitational removing of water excess, is transformed in compost for fertilizing of agricultural cultures (Fig.6).

On that sludge beds is possible to install flies larvae which eat bacterial masses, therefore they being consumert of I and II order of this sludge. They hinder transition to anaerobic degradative processes. This sludge, when dried, is composed 99 % of bacterial biomass resulted from putrescible organic substances from wastewaters, which could not be extracted from here in other manner.

Biofilters are installations for biological purification created by man, which imitate the natural process of covering solid surfaces from running waters with a film of organisms which take off water their food and dissolved oxygen (Fig.7) [6], [7], [9], [11].

Fig. 7. – Image of a small-sized biofilter

A biofilter consists in a vat, open at upper part, which is filled with volcanic spongy rock, broken stones or pieces of volcanic tuff; here is introduced wastewater previously passed through mechanic step. This is spread through a spraying system, which disperses it on the surface of rock surface. This water flows down ftom the top through the mass of solid material, as a thin film, under which, on the stuffing material develops a bacterial biomass. It grows longer where wastewaters are more loaded with organic substances (meaning the surface of the biofilter) and is thinner where water organic loading is more reduced (meaning the bottom of the biofilter). Through the bottom of the filter air is brewing, so the wastewater is permanently saturated with dissolved oxygen, and the processes are going on the aerobic way [11].

Under the conditions created and controlled by man, in the biofilter a biocenosis is installed, predominantly bacterial and fungal, which is fixed on a solid substrate. It grows from this solid row substrate towards the water film, so, at a certain time, profound layers of this biofilm no longer have arobic life conditions and die. The biofilm breaks, external part is fragmented and taken by the water, sinking to the bottom of the biofilter through the spaces between pieces of solid substrate and leaves the biofiltre, being transferred to secondary decanters. At the breaking place of the biofilm reappear aerobic conditions, biological film is rapidly recovered, being, again, composed of aerobic microorganisms. Hence, it takes place a sort of auto elimination of bacterial masses.

The biocoenose of biological film in biofilters is made predominantly of different bacteria functional types and of fungi; on it are living different protozoa, bacteriofage worms and, also, a lot of dipteral larvae (flies) which eat bacterial masses. Their role is more important because they actively contributes to the detachment of the film from solid substrate. Within the water from the biofiltre live copepods (and all their developing stages). These crustaceans are final consumers of the trophic chains established here.

Sewage treatment lagoon are basins in which the water is kapt in motion through functioning of a pallet system (Fig.8) [7], [9].

Fig. 8. – Sewage treatment lagoon in Germany

So, bacterial masses are moved with water; other bacterial masses are fixed to the channel wall. Aeration is made at water surface, through the gaseous gas exchange between water and atmosphere. Temperature oscillations day-night and the seasonal ones are wider. Concurrently take place spme processes of aerobic and anaerobic degradation processes, the amounts of dissolved oxygen being lower compared to that determined in aerotanks or biofilters. Due to exposure to solar light in these oxidation ditches may appear cyanobacteria, even several photosynthetizing algae, which contribute to a small extent to water oxygenation.

In present creating these ponds is decreasing, because their purification efficiency is low, duration of the treatment process is longer and it is not successful when wastewater inflow has a high rate. They are still used in small rural communities, where their operation is ensured by 1-2 technicians.

In these ponds enters the already mechanically prepurified wastewater and, as much as the pond is being fed with water, at the outlet excess water is discharged to a secondary decanter, in order to eliminate the excess of bacterial mud produced in installation.The surveillance and control system of this type of installation is simpler, and purification achieved efficiency is under 75 %.

Sewage treatment basins which use aquatic or marsh plants represent a newer system, which is used for purification of several wastewater with relatively lower loads of biodegradable organic compounds (mostly for the treatment of urban wastewater or that coming from tourist resorts – especially during warm seasons) [12]. In these cases is used the capacity of several plants which have a very rich root system, to provide a support on which grow bacterial masses; these plants also have the capacity to uptake from wastewater nutrients and many simply organic compounds, which they use during photosynthetric process [1]. As a result, it is produced a very abundant vegetal biomass. The most used plants are Nile lettuce (*Pistia stratiotes*) or water hyacinth (*Eichhornia crassipes*) from floating macrophytes, or reed (*Phragmites*), rush (*Typha*) or bulrush (*Carex*) from marsh plants (Fig.9 and 10)[1][10].

During the vegetation season these plants have a very high capacity to uptake organic compounds and nutrients, leading to production of huge vegetable biomass, which may be used in animal feed, or to increase yield of composting sludges intended for fertilization of soils or, also, to obtain chlorophyll of industrial interest. The biocenoses installed on plant roots are dominated by bacteria too, but alongside them live a lot of other organisms: protists, algae, invertebrates (worms, gastropods, crustaceans, insect larvae, waterspiders) even some fish which consume this rich biomass produced by plants, bacteria and first consumers (when these floating plants were introduced into fish ponds, phytophagous fish consumed these plants, and their growth rhythm has doubled in the vegetation season).

e plants are dependent on seasonal dynamics, in Romania experienced have been made to create air conditioned installations that are functioning all year round (Figs.11 and 12); the results were remarkable. Now, unfortunately, the study of such installations is not continued.

Benefits of this purifying system are greater, because operation costs are largely recovered by using vegetable biomass in domestic animal feed as phytophagous fish feed; plant biomass production rate may reach 6 tons/hectare/day – value untouched by any fodder plant grown under natural conditions.

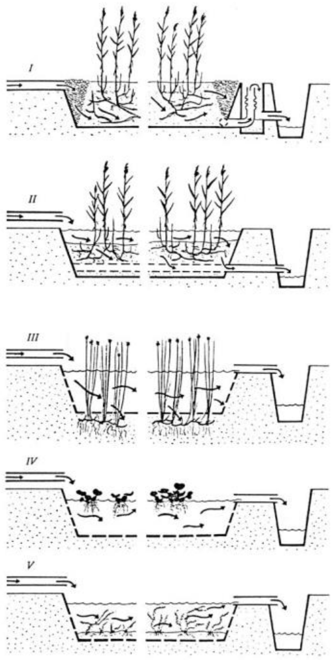

Fig. 9. - Types of sewage treatment plants with macrophytes. I and II - Purification using palustrian macrophytes with and without fine suspension retaining filter, III – Purification reed, IV - Purification with floating macrophytes, V - Purification with submerged macrophytes (after Brix & Schierup, 1989)

Fig. 10. – Setting tank, full covered with floating plants

Fig. 11. - Climatized plant for floating plants in Pitesti

Fig.12. - Chanels with water hyacinth inside the installation of Pitesti

The ecosystems formed within biological step of aerobic purification of treatment units are spontaneously, naturally established. However they can be routed in order to function with maximum efficiency, to counteract shocks determined by concentrated wastewaters, to prevent destruction of bacterial biomass in case of discharge of toxic substances, to cope with pollutant fluctuations in wastewater. This way people can steer purification processes, in order to attaint purification parameters required for the conservation of water resources from respective hydrological basin.

2.Biological purification step based on anaerobic processes (reducing)

In the case of wastewaters with very high organic substances load, the action to maintain them under decaying conditions on aerobic way is sometimes difficult. Also, in the same situation is the degradation of organic sludges produced in biological purification step of purification unit. This situation led to the development of special purification technologies based on realizing of anaerobic degradations, i.e. on the use of anaerobic decomposition of wastewaters.This type of installation is named methantanks, because the process results finally in methane production (Fig.13).

Fig.13. - Methantanks at the Bucharest purifying station

Methantanks are installations in which is stored sludges taken from secondary decanters, but also some wastewaters very highly loaded with organic substances; these are seeded with anaerobic bacteria. These decompose organic substances slower, in longer periods of time (up to 30 days), under stenothermic conditions (temperatures between 37 – 40^0 C), and using mechanical devices for slow agitation of organic material submitted to decomposing. Only mixed cultures of anaerobic bacteria develop in aerotanks.

Resulted material consists in fermented mud, water poor in organic substances (which, after a prealable aeration may be discharced on sludge drying beds in vicinity) and methane (which may be used for warming sludge masses during the functioning of methantanks, for heating different spaces or for moving the engines which are powered by methane).

The advantages of this system of anaerobic purification is the possibility to purify of some wastewaters which can not be properly treated otherwise, reduction of solid materials incompletely purified (of the sludges whose storage on drying beds would take a lot), production of methane, final composting of biological sludges used in agriculture etc.

Biological purification systems always have to be preceded by a good mechanical purification, neutralizing the pH of the waters; also, must be avoided the shocks provoked by toxic pollutants which drain suddenly in high concentrations and amounts.

Coming back to the ecotechnologies used in biological step of wastewaters purification, it should mentioned that these were created for purpose to accelerate water self-purification processes, in order to offer both to nature, but also to mankind, increased possibilities for water re-use, for keeping surface water quality. These ecotechnologies are in present enough controlled, for obtaining higher purification efficiencies, in time periods as small as possible at lower costs. For this purpose the expertise of specialists is used and, also, a wide range of automation systems of operating and control processes.

Biological purification is a field in which handling of several technologies is in an advanced position, somewhat similar to biotechnologies for producing antibiotics or some special organic compounds.

Conclusions

In the case of ecotechnologies used now in biological purification of wastewaters may be established :

- overseeing how the treatment process takes place, on each type of wastewater;
- establishing the best type of biological purification for each kind of wastewater;
- rapid priming of the biological step of purification;
- preventing dysfunctions caused by possible shocks produced by heavy organic loads;
- rebalancing the normal purification processes in case of malfunctions in operation of purification installations (power failures, interruption of aeration etc);
- taking measures to maintain an effective treatment at levels above the threshold of 95 %;