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ASPECTS CONCERNING FIXED FILM BIOLOGICAL WASTEWATER TREATMENT

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ABSTRACT. The biological wastewater treatment is a very actual problem taking into account the necessity of aligning the Romanian laws to the European standards. As an interdisciplinary science the chemical engineering plays an important role in achieving this kind of wastewater treatment.

The fixed film treatment technology are extremely important in public health control and in environmental protection, being based on the natural mechanism of biological water cleaning.

The paper presents the state of the art in the field of biological treatment of municipal wastewater using the fixed film technique (biofilm).

The principal causes, water pollution sources and wastewater contaminants are shown; some analytical methods for the water pollution control are also presented.

The classification of methods for biological wastewater treatment is accompanied by the issue of the essential functional element of every such equipment, the biofilm issue.

After its definition and its approach as ecosystem, information concerning the biofilm composition, structure and formation mechanism are systemized.

Physical and mathematical models of the wastewater treatment process are systemized.

1. INTRODUCTION

The biological treatment of municipal wastewater is used as an economical possibility in order to remove the biodegradable organic pollutants and to obtain a water quality in accordance with international environmental standards.

Utilization of biological fixed-film processes (biofilm) presents the advantages of an enhanced biomass accumulation in biofilm systems by its attachment to a fixed medium, and of short liquid retention times that are possible without washout of the microbial population or loss of treatment efficiency.

The main equipment is a fixed film bioreactor containing a packing of plastic materials which offers a large surface for the growth of microbial film and can then be exposed to wastewater and oxygen, in order to effect organic substrate consumption by the biofilm.

The use of plastic packing in biofilters has become current practice, because of its large specific surface area and favorable voidage. The plastic media can be well ventilated and allow the operation of a biofilter with large hydraulic and organic loads. Random plastic modules, vertical (semi) corrugated bundles or cross-flow media are used.

The biofilter is a three-phase system characterized by extremely complex physical, chemical and biological processes. Because of its great complexity, it is difficult to elucidate experimentally the influence of different parameters and of their interactions on the performance of the process.

Simulation of processes that take place in a biofilter by using mathematical models illustrating as well as possible the biophysical reality allows exploring different biofilter operation strategies, in order to improve the bioprocess performance and to establish the optimal plant design methods.

The wastewater aerobic purifying processes occurs by elementary processes as transport of organic substrate and of oxygen through the wastewater film to the interface with the biofilm and biochemical reaction at the interface. The purifying process can be described by mass and momentum balance equations and by its biochemical kinetics, which are characteristic for living systems.

The paper presents shortly a conference concerning a review of fixed film biological wastewater treatment state of the art.

2. WASTEWATER CHARACTERISTICS AND EFFLUENT QUALITY PARAMETERS

In many arid and semi-arid countries water is becoming an increasingly scarce resource and planners are forced to consider any sources of water which might be used economically and effectively to promote further development.

Expansion of urban populations and increased coverage of domestic water supply and sewerage give rise to greater quantities of municipal wastewater.

Properly planned use of municipal wastewater alleviates surface water pollution problems and not only conserves valuable water. The nitrogen and phosphorus content of wastewater might reduce or eliminate the requirements for commercial fertilizers.

Municipal wastewater is mainly comprised of water (99.9%) together with relatively small concentrations of suspended and dissolved organic and inorganic solids. Among the organic substances present in sewage are carbohydrates, lignin, fats, soaps, synthetic detergents, proteins and their decomposition products, as well as various natural and synthetic organic chemicals from the process industries. Table 1 shows the levels of the major constituents of strong, medium and weak domestic wastewaters

Table 1:

MAJOR CONSTITUENTS OF TYPICAL DOMESTIC WASTEWATER

Constituent	**Concentration, [mg/l]**		
	Strong	**Medium**	**Weak**
Total solids	1200	700	350
Dissolved solids (TDS)	850	500	250
Suspended solids	350	200	100

Constituent	**Concentration, [mg/l]**		
	Strong	**Medium**	**Weak**
Nitrogen (as N)	85	40	20
Phosphorus (as P)	20	10	6
Chloride	100	50	30
Alkalinity (as $CaCO_3$)	200	100	50
Grease	150	100	50
BOD_5	300	200	100

Municipal wastewater also contains a variety of inorganic substances from domestic and industrial sources, including a number of potentially toxic elements such as arsenic, cadmium, chromium, copper, lead, mercury, zinc, etc.

Contaminants of greatest concern are the pathogenic micro- and macro-organisms.

Pathogenic viruses, bacteria, protozoa and helminthes may be present in raw municipal wastewater and will survive in the environment for long periods (Table 2).

Table 2:

POSSIBLE LEVELS OF PATHOGENS IN WASTEWATER

Type of pathogen		**Survival times, [days]** (Figures in brackets show the usual survival time)		
		Faeces and sludge	**Fresh water and sewage**	**Soil**
Viruses:	*Enteroviruses*	<100 (<20)	<120 (<50)	<100 (<20)
Bacteria:	*Escherichia coli*	<90 (<50)	<60 (<30)	<70 (<20)
	Salmonella spp.	<60 (<30)	<60 (<30)	<70 (<20)
	Shigella spp.	<30 (<10)	<30 (<10)	-
	Vibrio cholerae	<30 (<5)	<30 (<10)	<20 (<10)
Protozoa:	*Entamoeba histolytica*	<30 (<15)	<30 (<15)	<20 (<10)
Helminthes:	*Ascaris Lumbricoides*	Months*	Months*	Months*
*eggs	Hookworms: *Anglostoma duedenale*; *Necator americanus*	Months*	Months*	Months*
	Schistosoma mansoni	Months*	Months*	Months*
	Taenia saginata	Months*	Months*	Months*
	Trichuris trichiura	Months*	Months*	Months*

3. WASTEWATER TREATMENT SYSTEMS

The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. The design of wastewater treatment plants is usually based on the need to reduce organic and suspended solids loads to limit pollution of the environment

Conventional wastewater treatment consists of a combination of physical, chemical, and biological processes and operations to remove solids, organic matter and, sometimes, nutrients from wastewater. General terms used to describe different degrees of treatment, in order of increasing treatment level, are preliminary, primary, secondary, and tertiary and/or advanced wastewater treatment. Disinfection to remove pathogens follows sometimes the last treatment step.

The step involving the use of biological systems follows after preliminary and primary treatment, where removal of coarse solids and other large materials often found in raw wastewater and of settleable organic and inorganic solids by sedimentation was performed, is the secondary treatment.

The ***secondary treatment*** objective of is the further treatment of the effluent from primary treatment, to remove the residual organics and suspended solids. In most cases, secondary treatment follows primary treatment and involves the removal of *biodegradable* dissolved and colloidal organic matter using *aerobic biological treatment processes*. Aerobic biological treatment is performed in the presence of oxygen by aerobic microorganisms (principally bacteria) that metabolize the organic matter in the wastewater, thereby producing more microorganisms and inorganic end-products (principally CO_2, NH_3, and H_2O). The microorganisms must be separated from the treated wastewater by sedimentation to produce clarified secondary effluent. The biological solids removed during secondary sedimentation, called secondary or biological sludge, are normally combined with primary sludge for sludge processing.

Common high-rate biological processes, characterized by relatively small reactor volumes and high concentrations of microorganisms, include the activated sludge processes, trickling filters or biofilters, oxidation ditches, and rotating biological contactors (RBC). A combination of two of these processes in series (e.g., biofilter followed by activated sludge) is sometimes used to treat municipal wastewater containing a high concentration of organic material from industrial sources.

In the *activated sludge process*, the dispersed-growth reactor is an aeration tank or basin containing a suspension of the wastewater and microorganisms, the mixed liquor. The contents of the aeration tank are mixed vigorously by aeration devices, which also supply oxygen to the biological suspension. Hydraulic retention time in the aeration tanks usually ranges from 3 to 8 hours but can be higher with high BOD_5 wastewaters. Following the aeration step, the microorganisms are separated from the liquid by sedimentation and the clarified liquid is secondary effluent. A portion of the biological sludge is recycled to the aeration basin to maintain a high mixed-liquor suspended solids (MLSS) level. The remainder is removed from the process and sent to sludge processing to maintain a relatively constant concentration of microorganisms in the system. Several variations of the basic activated sludge process, such as extended aeration and oxidation ditches, are in common use, but the principles are similar.

A *trickling filter* or *biofilter* consists of a basin or tower filled with support media such as stones, plastic shapes, or wooden slats. Wastewater is applied intermittently, or sometimes continuously, over the media. Microorganisms become attached to the media and form a *biological layer* or *fixed film*. Organic matter in the wastewater diffuses into the film, where it is metabolized. Oxygen is normally supplied to the film by the natural flow of air either up or down through the media, depending on the relative temperatures of the wastewater and ambient air. Blowers can also supply forced air but this is rarely necessary. The thickness of the biofilm increases as new organisms grow. Periodically, portions of the film 'slough off the media. The sloughed material is separated from the liquid in a secondary clarifier and discharged to sludge processing. Clarified liquid from the secondary clarifier is the secondary effluent and a portion is often recycled to the biofilter to improve hydraulic distribution of the wastewater over the filter.

Rotating biological contactors (RBCs) are *fixed-film* reactors similar to biofilters in that organisms are attached to support media. In the case of the RBC, the support media are slowly rotating discs that are partially submerged in flowing wastewater in the reactor. Oxygen is supplied to the attached biofilm from the air when the film is out of the water and from the liquid when submerged, since oxygen is transferred to the wastewater by surface turbulence created by the discs' rotation. Sloughed pieces of biofilm are removed in the same manner described for biofilters.

Biofilms present a range of unique opportunities for application in environmental tech-nologies for cleanup and containment of hazardous wastes. They may be found on essentially any environmental surface in which sufficient moisture is present. Their development is most rapid in flowing systems where adequate nutrients are available.

Biological treatment systems rely on the metabolic versatility of mixed microbial populations for their efficiency.

Biofilms are composed of populations or communities of microorganisms adhering to environmental surfaces. These microorganisms are usually encased in an extracellular polysaccharide (glycocalyx) that they themselves synthesize.

The formation of a biofilm follows a course the nature of which can be predicted and recorded (figure 1).

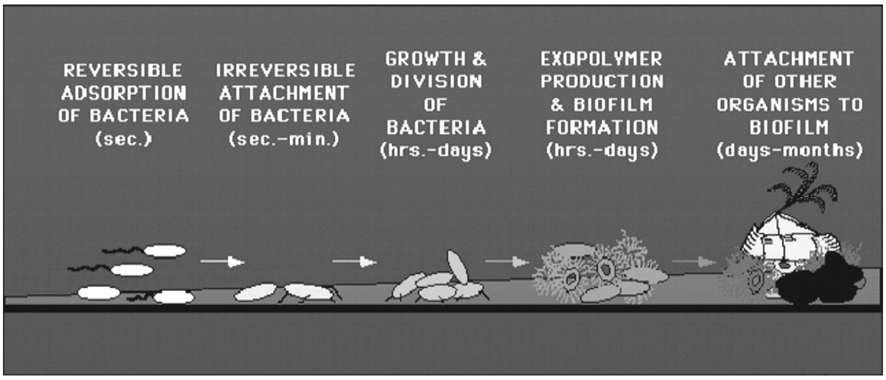

Figure 1: Biofilm formation

4. MODELING OF FIXED FILM BIOLOGICAL

A physical model of the biological fixed film wastewater treatment process is shown in figure 2.

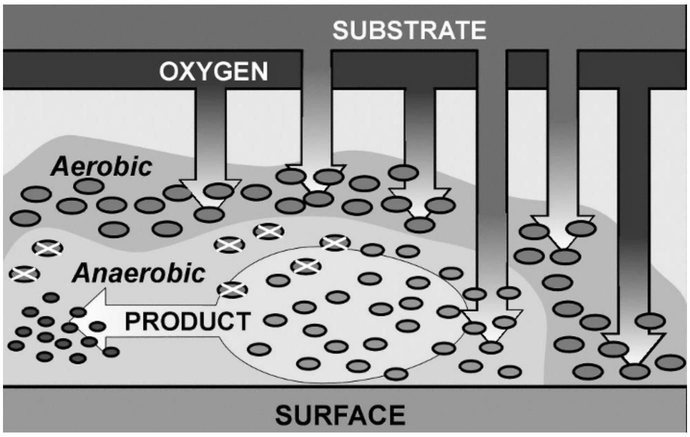

Figure 2: Physical model of fixed film wastewater treatment process

The wastewater aerobic purifying processes occurs by elementary processes as transport of organic substrate and of oxygen through the wastewater film to the interface with the biofilm and biochemical reaction at the interface. The purifying process can be described by mass and momentum balance equations and by its biochemical kinetics, which are characteristic for living systems.

Three kind of mathematical models are used:

- an “old generation” of mathematical models, represented by empirical (NRC, Ten States, British Manual, etc) and semiempirical models. Semiempirical models assume biofilters are pseudohomogeneous systems, with a flat organic contaminant concentration profile through the cross section of the biofilter. The mass conservation of organic substrate in a differential volume of a biofilter, where the rate determining stage of process is taken to be the first-order biochemical reaction occurring at the biofilm-wastewater interface is used for obtaining this kind of model.
- an “intermediate generation” of mathematical models considers the biofilter as a heterogeneous system and appears from the need to quantify substrate utilization rate and biofilm growth rate.
- the “new generation” of mathematical models was initiated by B.E.Logan, who takes into account both substrate/oxygen diffusional transport through the wastewater film and the first-order biochemical reaction occurring at the biofilm - wastewater interface.

5. CONCLUSION

The paper shows that the fixed film treatment technology is important in public health control and in environmental protection, being based on the natural mechanism of biological water cleaning.

The biological treatment of municipal wastewater is used as an economical possibility in order to remove the biodegradable organic pollutants and to obtain a water quality in accordance with international environmental standards.

The step involving the use of biological systems follows after preliminary and primary treatment, where removal of coarse solids and other large materials often found in raw wastewater and of settleable organic and inorganic solids by sedimentation was performed, is the secondary treatment.

The paper shows some physical and mathematical models of the wastewater treatment process, based on three kind of mathematical models, in order to demonstrate the efficiency of the biological treatment of municipal wastewater.

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