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MUNICIPAL WASTEWATER TREATMENT BY MEANS OF AQUACULTURES

Development of some alternative methods of wastewater treatment such as autoregulation processes of natural ecosystems represents nowadays some attempt to prospective utilization a such resources of nature.

Natural wastewater treatment includes, e.g. gradual infiltration, biodegradation, stabilization, soil filtration, root drainage on wetlands, etc.

Natural processes, mostly as tertiary steps, are costless and improve the environmental quality. They are appropriate for smaller municipalities. The wastewater has to be without any xenobiotics and basic pollutants are expected to be removed in mechanical as well as biological wastewater treatment system.

The classical, biological wastewater treatment (using activated sludge) besides its advantages has also some drawbacks. Among them high requirements of area, slow down in the rate of biodegradation as a result of low temperatures are worth mentioning; moreover, high concentrations of nitrogen compounds in wastewater make the economy of the process inefficient. Difficulties arising from the fact that the content of xenobiotics in environment is rather high should not be neglected either because of the need of activated sludge cultivation and adaptation as well as production of N_2O which increases the atmospheric ozone depletion.

The mentioned facts as well as the recession in world economics lead to the necessity of application of some alternative methods in wastewater treatment, e.g. autoregulation processes of natural ecosystems [1]. In the future, we will be able to modify some ecosystems and thus to cause them to work in such a way as to supplement the existing conventional methods of wastewater treatment.

Taking account of the environmental quality improvement, these possibilities are considered as future-oriented. They increase the ecosystem productivity and may revive damaged areas. Some ecosystems are created by man, e.g. fields, forests, etc. They are able to clean the wastewater by means of natural filtration or gradual

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infiltration into a soil [2]. More intense possibilities are, for example, hydroponic cultures which serve not only as reservoirs of pretreated wastewater, but they are integral part of wastewater treatment system as well. The characteristic feature of the methods outlined is their low investment cost; however, they require appropriate climatic conditions – mainly subtropic up to tropic – as well as large areas.

In small municipalities, special attention is paid to aquacultures, e.g. water hyacinths (*Eichhornia crassipes*) which is most commonly found in tropical climate [3]. In central Europe, *Typha latifolia* and *Lemna trisulca* are usable first of all in natural wetlands, fisheries and water trenches. The dynamics of substrate removal in their natural ecosystems has not been described satisfactorily. Scientists have supposed that not only aquatic plants remove an inorganic substrate, but also the contribution of fauna to this process is substantial.

It is known that larvae of insects and some species of fish are regularly caught by birds which causes removal of phosphorus. When swamps dry up in the sun, the hyacinths either are harvested and used with benefit as green forage for cattle and poultry or are composted together with drained slush. Due to activity of 2000 species of bacteria, some tens of thousands of species representing fungi as well as large amount of plants, the ecosystem polluted to some extent is able to return slowly to the equilibrium on wetlands, sludgy areas with special vegetation (e.g., reed) which mechanically pretreat wastewater. Such a costless wastewater treatment facility works on the basis of root drainage. The reed fulfills two functions: first of all its long blades enrich the soil with oxygen which is necessary for microorganism respiration. On the other hand, the leaving as well as the dying away rootlets due to their structure on the wetland bottom contribute to the mellowing of the soil which at the same time increases horizontal water infiltration. The time required for the creation of a suitable aquatic vegetation with satisfactory ability to degrade waste compounds can be as long as 3 years.

In the southern coast of the Atlantic Ocean, there are wetlands and ponds overgrown with huge trees such as *Taxodium distichum* var. *nutans* and *Nyssa sylvatica* var. *biflora* which improve some hydraulic properties of the environment and create ideal conditions for tertiary wastewater treatment. North of Gainesville (Florida), the wastewater has been tertiary treated by means of *Cypress domes* vegetation with very promising results. During such a selfpurification process the plants representing the *Lemnaceae* family and the *Spirodela* species began to grow extraordinarily fast under and above the water level. This vigorous growth inhibited the reaeration of water and successively anoxic conditions were created [4].

The cultivation of aquatic hyacinths was planned also at some lagoons in Třeboň, southern part of Moravia, as well as in the region of Ostrava (former Czechoslovakia). The tests showed that in our climatic conditions, the plants representing the *Lemnaceae* family are more prosperous, and their productivity is comparable with that of aquatic hyacinths [5]. These plants are characterized by weak root systems and air channels in their leaves which enables them to float on the surface of water. Such a natural wastewater treatment system works as tertiary one after the mechanical and the biological treatment. This system of wastewater treatment is isolated from the bottom by impermeable layer. Aquatic flora is harvested 5–7 times per year.

According to several papers one hectare of aquatic hyacinths under appropriate climatic conditions can eliminate from the water during a day up to 44 kg of nitrogen and a large amount of other nutrients which in the case of one wastewater treatment plant represents the capacity of 5000 equivalent inhabitants. Because of the mentioned root treatment facilities allowing us to reach a decrease in BOD as seroius as 75–95%, they are used first of all for municipalities of several hundreds inhabitants. According to some authors facultative lagoons with aquatic "weed" exhibit higher purification degree than some deeper stabilization ponds with aquatic algae. The function of aquatic vegetation at the bottom of lagoons can be compared to the function of gravel filter; moreover, the plants additionally enrich the environment with new colonies of aerobic, heterotrophic bacteria. The cost of the above natural facilities is uncomparably lower than that of conventional wastewater treatment plant and it can be totally covered by the production of biogas (by anaerobic decay of harvested aquatic vegetation). Nitrogen reduction in this system occurs probably through inorganic nitrogen uptake [6].

In biological accumulation basins (which serve as stabilizers and the place of final stage of wastewater treatment), the following processes take place:

1. Aerobic oxidation of hydrocarbons to biomass, CO_2, and H_2O (qualiative parameters of the aerobic process in stabilization basins are illustrated in the table):

$$6(CH_2O)_x + 5O_2 = (CH_2O)_x + 5CO_2 + 5H_2O + \text{energy}.$$

growth of microorganisms

Table

Qualitative parameters of the aerobic process in stabilization basins

Index	Aerobic oxidation min	Aerobic oxidation optimum	Aerobic oxidation max
Population of microorganisms in 1 cm^2	10^8	10^{10}	10^{12}
Nutrients		hydrocarbons, protein, grease	
Oxygen (mg/dm^3)	1	10	30
Time (days)	5	–	10
Temperature (°C)	15	25	40
pH	6.5	8	10
Alkalinity (mg/dm^3)	–	200	–
Typical reaction		fotosynthesis	
Competitive reaction		sedimentation, methane fermentation	
Toxic compounds		heavy metals	
Energy source		nutrients	
E (redox) in mV	+ 0.2	+ 0.5	–

2. Because of oxygen deficiency the transformation of hydrocarbons to biomass and to organic acids occurs:

$$5(CH_2O)_x = \underset{\text{growth of microorganisms}}{(CH_2O)_x} + 2\,CH_3COOH + \text{energy} \ \langle\text{anaerobic degradation}\rangle .$$

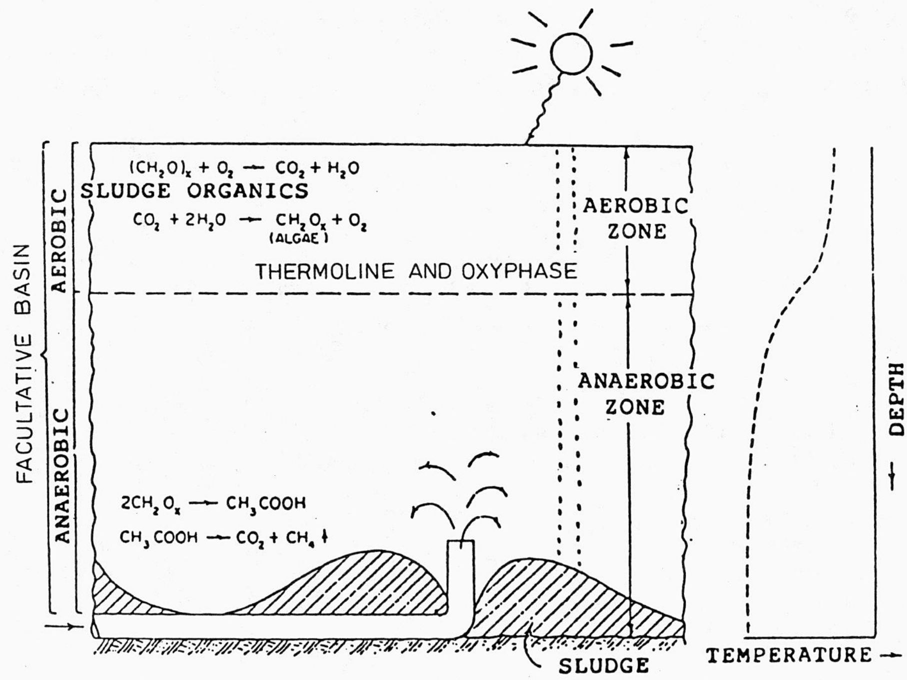
3. Organic acids can be degraded to methane and carbon dioxide and at the same time the reproduction of methanogenous bacteria takes place (methane fermentation):

$$2.5\,CH_3COOH = \underset{\text{growth of microorganisms}}{(CH_2O)_x} + 2\,CH_4 + 2\,CO_2 + \text{energy} \ \langle\text{anaerobic fermentation}\rangle .$$

4. In the presence of sun light, aquatic vegetation produces organic matter and oxygen (the energy of light is transformed into organic compounds):

$$(CH_2O)_x + CO_2 + \text{sun} + \text{vegetation} = 2(CH_2O)_x + O_2 + H_2O .$$

The figure illustrates the scheme of the biological process outlined. The temperature stratification in the biological basin during the whole year is representated by the thermoline identical with anaerobic–aerobic zone border. The existence of aerobic bacteria is dependent on the presence of vegetation which produces oxygen and vice



Functional scheme of stabilization basin versa the vegetation is dependent on the presence of bacteria since they produce CO_2 and NH_3. Under the thermoline, the decay and the methane fermentation process are going on. These processes require organic acids as substrate.

Stabilization basins, being deeper biological lagoons, smell bad because the concentrated wastewater is discharged there. The wastewater treatment in such a case is accomplished anaerobically. The wastewater after the anaerobic decay may be discharged for the final aerobic treatment to upgraded through-flow basins of assimilation pond type [7].

For tertiary wastewater treatment also several types of soil filtration are applied. As a rule, after sedimentation the wastewater is used for watering and infiltration of grassy surfaces covered with, e.g. *Glyceria aquatica, Phalaris arundinacea*, etc. occurring usually at clay–sandy and silty soils. In result of fast infiltration of wastewaters in the region with errosive sandy relief covered by conifers, it is possible to achieve, using appropriate hydraulic parameters, satisfactory results [8].

CONCLUSIONS

In our geographical region, utilization of the aquacultures in wastewater treatment is limited to some specific cases. The wastewater has to be mechanically and biologically pretreated. The natural technology described is used in the cases when the wastewater quality is not satisfactory for waterway, eventually when the water has to be used for some other purposes. The application of natural wastewater treatment is also limited by area and relief requirements. If we take into account the optimization of the surrounding environment, such an ecosystem has several benefits. The methods of wastewater treatment with the use of plants exhibit considerably high efficiency in degradation of nitrogen compounds. In the case when the wastewater does not contain toxic compunds, it is possible to obtain valuable forage or a specific fertilizer. The technology described brings substantial benefits: it removes the smell as well as algae. The compact surface layer of vegetation reduces the escape of gases produced in anaerobic zone and simultaneously absorbs sun light and thus inhibits the photosynthesis in the body of water and therefore production of algae. At the bottom of the basin, sludge management is recommended to be carried out per about 20 years, but it is questionable if it would be satisfactory.

LITERATURE

[1] ŽÁKOVÁ Z. et al., *Vegetační spůsoby čištění vody a možnosti jejich aplikace*, Sbor. přednášek, ČSVTS, Brno 1987.

[2] KICKUTH R., *Abwasserreinigung in Mosaikmatrizen aus anaerob. und aerob. Teilbezirken, Vortrag vor der Österreich*, Arbeitsgruppe Chem. Apparatewesen und Verfahrenstechnik am 24.10.1980 in Graz.

[3] MARTIN P., WANIELISTA P.E., ECKENFELDER W.W., *Advances in Water and Waste Water Treatment*, Hyacinths, 1978.

[4] DIERBERG, FORREST E., BREZONIK P.L., *Tertiary treatment of municipal waste water by Cypress domes*, WR, 1983, Vol. 17, 9, pp. 1027–1040.
[5] LAŠTŮVKA L., *Vodní hyacint*, Věda a život, 5, p. 336.
[6] RAO S.V.R., *A review of the technological feasibility of aquacultures for municipal waste water treatment*, Int. Journ. of Environm. Studies, 1986, Vol. 27, pp. 219–223.
[7] SEIDEL K., HAPPEL H., GRAUE G., *Beiträge zur Gewässergesundung*, 2. erweiterte Auflage 1978.
[8] SUNDBLAD K., LOWGREN M., WITTGREN H.B., *Wastewater Treatment or Resource Management*, Vatten, 1988, 44, pp. 320–324.

KULTURY WODNE W OCZYSZCZANIU ŚCIEKÓW

Rozwój pewnych alternatywnych metod oczyszczania ścieków, takich jak procesy samoregulacyjne naturalnych ekosystemów, stanowi obecnie pewną przyszłościową próbę wykorzystania bogatych zasobów naturalnych.

Naturalne procesy oczyszczania ścieków obejmują przykładowo stopniową infiltrację, biodegradację, stabilizację, filtrację w glebie, drenaż na moczarach itp.

Naturalne procesy, stosowane przeważnie jako trzeci stopień oczyszczania, są mniej kosztowne i przyczyniają się do zmniejszenia zanieczyszczenia środowiska naturalnego. Są one odpowiednie w przypadku małych aglomeracji miejskich. Oczyszczane ścieki nie powinny zawierać żadnych substancji ksenobiotycznych. Oczekuje się, iż podstawowe zanieczyszczenia będą usunięte na drodze mechanicznego i biologicznego oczyszczania.

ВОДНЫЕ КУЛЬТУРЫ В ОЧИСТКЕ СТОЧНЫХ ВОД

Развитие некоторых альтернативных методов очистки сточных вод, таких как саморегуляционные процессы натуральных экосистем, составляет в настоящее время некоторый опыт использования в будущем богатых натуральных ресурсов.

Натуральные процессы очистки сточных вод охватывают примерно постепенную инфильтрацию, биодеградацию, стабилизацию, фильтрацию в почве, дренаж на болотах итп.

Натуральные процессы, применяемые прежде всего как третья степень очистки, являются более дешевыми и причиняются к понижению загрязнения натуральной среды. Они являются соответствующими в случае малых городских агломераций. Очищаемые сточные воды не должны содержать никаких ксенобиотических веществ. Ожидается, что основные загрязнения будут удаляться путем механической и биологической очистки.