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ADVANCED TREATMENT OF INDUSTRIALLY POLLUTED MUNICIPAL WASTES

Municipal wastewaters containing toxic pollutants may often require physicochemical methods of treatment in addition to or instead of the conventional biological process. Laboratory studies with the wastewaters previously treated biologically have shown, that the contact coagulation on upward rapid filter is suficient to decrease the COD and phosphorus concentrations to 75 g/m^3 and 1.3 g/m^3, respectively.

The method adopted was found effective also in removing the heavy metals with the exception of zinc. Further experiments of tertiary wastewaters treatment are continued in Hungary at the large experimental treatment plant at Balatonfured.

1. INTRODUCTION

According to the rules of Hungarian Water Authorities a pretreatment of industrial wastes is demanded. Due to disregarding these instructions municipal wastewaters heavilly polluted by industrial and trade effluents are often inaccessible to treatment by the conventional biological, activated sludge method to a degree making them acceptable for discharge into a recipient. The inhibiting toxic substances may hinder the biochemical degradation of the organic constituents, the foam of resistant synthetic detergents develop a barrier even to the oxygen uptake needed for the process.

Consequent from the foregoing, occasionally (in the presence of inhibiting substances) instead of biological treatment, the application of physicochemical treatment methods may become necessary.

A further advantage of the physicochemical methods is the reduction of algal nutrients in the effluent, making it suitable to discharge into lakes or reservoirs. A great reduction is also achieved in various trace pollutants, such as detergents referred to above, phenols, oils and fats, as well as diverse heavy metal compounds. The latter assume primary significance where the effluent is disposed of by irrigation.

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According to the results of laboratory experiments conducted with continuous tertiary treatment of effluent from the Biological Sewage Treatment Plant of South-Pest — by the addition of chemicals the COD concentration could be reduced to below the 75 g/cm³ value specified, while the phosphorus content of phosphates to below the 1.3 g/m³ value required for lakes. The phenol content in the biologically treated effluent remained unaffected by clarification and filtration, but the slight residue could be removed completely on activated carbon columns. Clarification and filtration proved similary little effective in oil and detergent removal, but activated carbon adsorption was observed to be particularly effective in removing the detergents [2].

In pilot-plant experiments with upward flow filtration we have studied the effect of a single final treatment structure on the quality of the effluent from the South-Pest sewage plant. At 4 m/h filtration velocity and feeding aluminium sulphate at the rate of 30 g/m³, the dissolved organic content of the filtrate was found to be acceptable, while phosphates were removed sufficiently to make the effluent acceptable for discharge into a lake [3].

The upward flow filter can thus be applied successfully for the final treatment of effluents from the biological stage, provided that the efficiency of biological treatment is not deteriorated as a whole by toxic substances.

2. EXPERIMENTS WITH THE PILOT-PLANT MODEL OF TERTIARY TREATMENT

2.1. FOLLOWING BIOLOGICAL TREATMENT

Experiments have been conducted for years by VITUKI at the experimental pilot biological sewage treatment plant located along the North-Pest Sewage Pumping Plant. A considerable part of the wastewater is of industrial origin (pharmaceutical, shipyard, tannery, metal processing and textile works) and contains a variety of heavy metal compounds, so that the effluent from the biological stage is still heavily polluted. Tertiary treatment has been attempted on the pilot plant set up here (fig.). The pipe network of the plant has been designed to bypass the biological stage if required, permitting the raw sewage to be treated directly on the pilot installation.

The organic content of the effluent from the biological stage ranged from 190 to 314 g/m³ in terms of COD. Since the final filtration experiments at the South-Pest plant have resulted in a COD removal not exceeding 36.5 per cent even in the optimal mode of operation, chemical flocculation in a flow-trough tank of 1 m² area has been adopted ahead of filtration. The filter was the upward-flow unit with a 2 m sand layer and of 0.5 m² area in the South-Pest experiments. The bulk of the clarifier and filter effluent was collected in a tank, the filtrate collected being used for backwashing, while the smaller part was admitted to an 0.04 m² activated-carbon column filled to a height of 2 m with granular Aquapur FD of Hungarian manufacture. The retention time in the column was about 40 minutes.

It was found necessary to operate the clarifier at loading rates ranging from 3.5 to 4 m³/h, otherwise sludge skimming was unsatisfactory. The filter, on the other hand, yielded

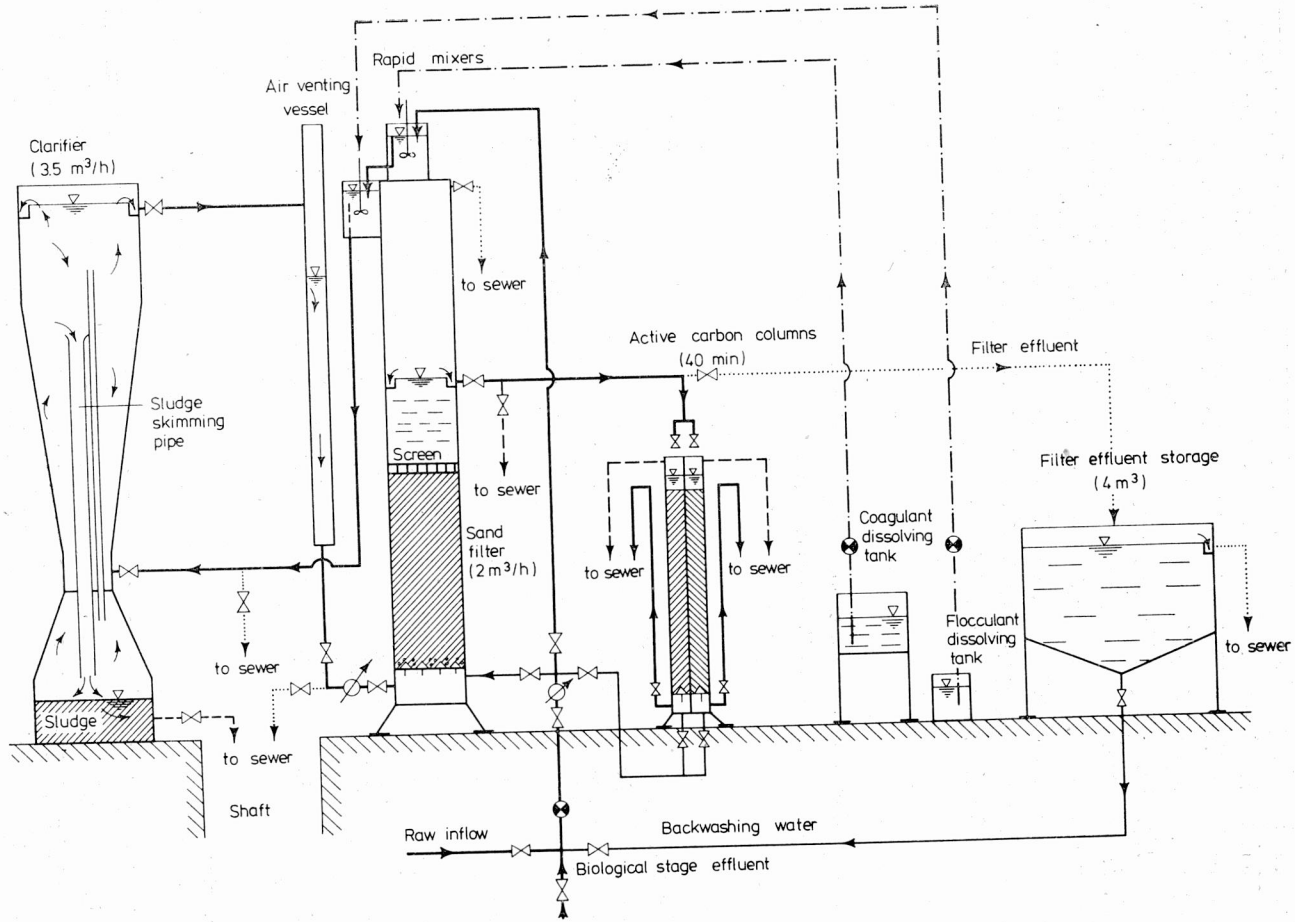

Fig. Pilot plant model of tertiary wastewater treatment

—— wastewater, —— backwashing water, — — — supernatant, —·—·— coagulant, ... other

Rys. 1. Stacja pilotowa trzystopniowego oczyszczania ścieków

—— ścieki, —— woda do powtórnego oczyszczania, — — — supernatant, —·—·— koagulant, ... inne

optimal results at a loading rate 2 m^3/h. The excess clarifier effluent was therefore discharged to waste.

Initially the bauxite product trademarked FLOXIT [4] and patented by VITUKI was only added to the clarifier as coagulant at rates between 100 and 300 mg/dm^3. The COD concentration in the clarified and sand filtered water was in no case higher than 70 mg/dm^3, while the suspended solids concentration in the clarified and sand filtered water was in no case higher than 70 mg/dm^3, while the suspended solids concentration was below 20 mg/dm^3. The water thus treated contained no more than 1.2 mg phosphorus per dm^3. Active carbon treatment has improved further the quality of the effluent, although this was superfluous in the present case. Clarification and filtration alone were enough to guarantee an effluent meeting the specified standards and the phosphorus content was also low enough for discharge into recipient lakes.

Table 1

Tertiary treatment of effluent from the biological stage at North-Pest on the experimental pilot plant
Trzystopniowe oczyszczanie ścieków z północnego Pesztu w eksperymentalnej stacji pilotowej po uprzednim oczyszczaniu biologicznym

Coagulant* feed (mg/dm^3)	Flocculant** feed (mg/dm^3)	Suspended solids (mg/dm^3)		COD (mg/dm^3)			Dissolved P (mg/dm^3)	
		Biol. effluent	Clard and filtd.	Biol. effluent	Clard and filtd.	Act. carbon effluent	Biol. effluent	Clard and filtd.
300	0	42	14	260	62	46	1.8	0.7
250	0	36	6	247	47	30	0.8	0.1
200	0	129	18	314	53.5	30.5	2.6	1.1
150	0	58	12	195	53.5	23	1.1	0.2
100	0	54	20	217	58.5	30.5	1.7	1.2
100	1.5	74	16	190	39	12	1.2	0.8
50	1.5	74	24	200	45	14	0	0
25	1.5	84	20	240	64	18	0.7	0.2

* Floxit

** Polietilenium

The reduction attainable in the feed rate of the coagulant by adding also a flocculant (Polietilen-imin manufactured in the USSR) was studied subsequently in a few experiments. When adding 1.5 mg PEI per dm^3 an effuent meeting the specifications was obtained by feeding the bauxite coagulant at the rate of 25 mg/dm^3 only. The use of small volumes of the coagulant resulted in smaller sludge volumes, indicating the advisability of using the flocculant, although clarification and filtration were still necessary (table 1).

2.2. PHYSICOCHEMICAL TREATMENT OF RAW SEWAGE

The pilot plant model was then used to study the physicochemical treatment of raw sewage without the biological stage.

During the period of experiments the COD of the raw sewage fluctuated from 484 to 762 mg/dm³. At constant hydraulic loading the feed rate of the bauxite coagulant was varied between 100 and 300 mg/dm³. At feed rates higher than 150 mg/dm³ the COD of the effluent after clarification and filtration was invariably lower than 174 mg/dm³, and thus always of a quality superior to that of the biological stage effluent in earlier experiments. Nevertheless, for attaining the limit value specified, namely 75 mg COD per dm³, further active carbon treatment with at least 40 min. retention time was found essential.

For reducing the sludge volume even more, an additional series of experiments was started with the simultaneous application of the bauxite coagulant and the flocculant Praestol manufactured in the GFR. The hydraulic loading was left unchanged, the feed rates of the basic flocculant and the coagulant varied from 100 to 200 and 1 to 4 mg/dm³, respectively. According to the experimental results the feed rate of Praestol had to be increased up to 4 mg/dm³ in order to obtain the desired effluent quality at 100 mg/dm³ feed rate of the bauxite coagulant. However, the costs of chemicals were greatly increased thereby (table 2).

Table 2

Experimental treatment by physicochemical method of North-Pest raw wastewater on the pilot plant
Eksperymentalne oczyszczanie surowych ścieków z północnego Pesztu w stacji pilotowej metodami fizyko-chemicznymi

Coagulant* feed (mg/dm³)	Flocculant** feed (mg/dm³)	Suspended solids (mg/dm³)		(COD mg/dm³)					Dissolved P (mg/dm³)	
						Act. carbon filtered				
		Raw	Clard and filtd.	Raw	Clard and filtd.	10 min.	20 min.	40 min.	Raw	Clard and filtd.
300	0	157	39	534	174	114	87.1	45.5	3.45	1.15
250	0	218	40	656	128	116	83.9	43.9	3.0	2.2
200	0	389	38.5	517	171	155	123	61.5	3.0	1.75
200	1	218	14	603	151	139	127	71.4	3.1	2.4
200	2	176	52	567	127	143	95.2	47.6	2.7	0.9
150	0	210	54	530	145	132	125	72.2	4.6	1.4
150	1	196	36	698	159	127	91.3	71.4	1.8	0.7
150	2	132	20	762	87.3	87.3	63.5	19.8	0.9	0
100	0	244	32	484	200	188	141	100	2.75	0.5
100	4	130	33	560	249	187	121	70	2.78	0.07

* Floxit
** Praestol

2.3. REMOVAL OF HEAVY METALS

Of the heavy metals present in the effluents from the heavy-metals processing industry, the concentrations of mercury and zinc in the wastewater studied were higher than the tolerable value and little affected by biological treatment.

Experiments have revealed clarification and filtration to be sufficient for reducing the mercury content in the effluent from the biological stage to below the threshold value of 2 $\mu g/dm^3$, however the case of physicochemical treatment without the biological stage resulted mostly similarly (tables 3 and 4).

Table 3

Mercury removal from North-Pest biological stage effluent by tertiary treatment

Usuwanie rtęci przez trzystopniowe oczyszczanie ścieków północnego Pesztu po oczyszczaniu biologicznym

Coagulant* feed (mg/dm^3)	Flocculant** feed (mg/dm^3)	Mercury concentration ($\mu g/dm^3$)		
		in biological effluent	clarifier effluent	filter effluent
250	0	8.2	2.0	<1
150	0	37.0	1.4	<1
25	1.5	21.0	2.4	<1

* Floxit

** Polietilenimin

Table 4

Mercury removal from North-Pest raw wastewater by physicochemical treatment

Usuwanie rtęci z surowych ścieków z północnego Pesztu z zastosowaniem oczyszczania fizykochemicznego

Coagulant* (mg/dm^3)	Flocculant** (mg/dm^3)	Mercury concentration ($\mu g/dm^3$)		
		raw	clarifier effluent	filter effluent
250	0	5.8	5.4	4.0
200	0	19	9.75	<1
100	0	6.4	<1	<1

* Floxit

** Praestol

Unfortunately final treatment following the biological stage has also failed in reducing effectively the zinc content. Publications in the foreign professional literature have reported, however, that lime as the coagulant in zinc removal was much more effective than aluminium sulphate, the latter closely resembling the bauxite product used in these experiments.

The chromium content in the raw wastewater has attained on no occasion the threshold value of 10 mg/dm^3. In these experiments clarification and filtration were invariably found effective in reducing the chromium concentration when the raw wastewater was treated by physicochemical methods (tables 5 and 6).

Table 5

Chromium removal from North-Pest biological stage effluent by tertiary treatment

Usuwanie chromu z biologicznie oczyszczonych ścieków z północnego Pesztu przez trzystopniowe oczyszczanie

Coagulant* feed (mg/dm^3)	Flocculant** feed (mg/dm^3)	Chromium concentration (mg/dm^3)		
		in biological effluent	clarifier effluent	filter effluent
150	0	3.37	0.62	<0.12
100	0	0.50	0.25	<0.12
50	1.5	1.25	0.25	<0.12
25	1.5	7.75	1.40	<0.12

* Floxit

** Poietilenimin

Table 6

Chromium removal from North-Pest raw wastewater by physicochemical treatment

Usuwanie chromu z surowych ścieków z północnego Pesztu z zastosowaniem oczyszczania fizykochemicznego

Coagulant* feed (mg/dm^3)	Flocculant** feed (mg/dm^3)	Chromium concentration (mg/dm^3)		
		raw	clarifier effluent	filter effluent
300	0	2.00	1.70	0.25
250	0	3.75	2.12	0.25
200	0	4.32	3.50	0.12
200	2	3.00	0.50	0.12
150	0	1.62	1.60	0.12
150	1	1.70	0.12	0.12

* Floxit

** Praestol

The raw wastewater contained below 325 μg lead/dm³ generally, far below the threshold value of 10 000 μg. By means of final treatment even this could be reduced in the majority of cases to below the limit value of 100 μg/dm³, specified as the limit concentration for drinking water*.

The cadmium content in the raw wastewater was even less and did not approach the 10 μg/dm³ limit allowed for drinking water. The removal efficiency of clarification and filtration ranged from 60 to 75 percent.

3. SUMMARY AND CONCLUSIONS

Wastewaters containing toxic pollutants may often require physicochemical methods of treatment in addition to the conventional biological process. In this way even the specifications concerning the phosphorus and nitrogen components of effluents to be discharged into lakes or reservoirs can be satisfied, where the customary biological methods are ineffective.

The final treatment methods referred to collectively as tertiary treatment are rather expensive, prompting a closer scrutiny into the unit processes that are absolutely essential for attaining the effluent quality standards specified. Evidently these will depend primarily on the quality of the raw wastewater, but are influenced also to some extent by requirements at the recipient.

Earlier studies with the effluent from the biological stage at the South-Pest Sewage Treatment Plant have shown final treatment on a single upward flow (rapid coagulation) filter with chemical feed to be sufficient for meeting the specifications as regards both the 75 g/m³ COD limit and the dissolved phosphate concentration admissible for discharge into lakes. On the other hand, the wastewater containing considerable amounts of toxic substance at the North-Pest Sewage Pumping Station has already called for more sophisticated methods. For this reason experiments have been conducted with tertiary treatment on a pilot plant receiving the effluent from the biological stage (fig. 1). Clarification and filtration after the addition of chemicals to this effluent were found to meet completely the specifications as regards both organic content and dissolved phosphate concentration in effluents to be discharged into lakes (table 1).

The poor efficiency of the biological stage observed here has prompted attempts at testing the model of the tertiary treatment stage with raw sewage by-passed around the biological stage. In this case activated carbon treatment with a retention time of 40 minutes proved absolutely necessary for the effluent clarified and filtered.

The method adopted was found effective also in removing the heavy metal pollutants with the exception of zinc for the removal of which lime coagulation is primarily suited.

The complex evaluation of experimental data is not accomplished yet. In the course of this a more detailed information on physicochemical and chemical phenomena in the

* WHO Internat. 1971.

experimental technology is desirable. Further experiments are scheduled at the large experimental treatment plant to be completed this year (1977) at Balatonfüred and including a full tertiary treatment stage as well. The results attained there will serve as the basis for the decision whether or not the physicochemical methods of nitrogen removal are warranted along with biological treatment in Hungary.

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WYSOKOEFEKTYWNE METODY OCZYSZCZANIA ŚCIEKÓW MIEJSKICH ZANIECZYSZCZONYCH PRZEZ PRZEMYSŁ

Ścieki miejskie zawierające zanieczyszczenia toksyczne wymagają często zastosowania do ich oczyszczania metod fizyczno-chemicznych, stosowanych po procesie biologicznym lub zamiast niego. Badania laboratoryjne nad koagulacją kontaktową na filtrach pospiesznych o przepływie z dołu do góry wykazały obniżenie ChZT do 75 g/m^3, a stężenie fosforanów do 1.3 g/m^3 w odniesieniu do ścieków oczyszczonych uprzednio biologicznie.

Ścieki zawierające substancje toksyczne pochodzące ze stacji pomp północnego Pesztu były przebadane na wybudowanej tam stacji pilotowej. Zastosowane procesy konwencjonalnej koagulacji z sedymentacją oraz filtracja po uprzednim biologicznym oczyszczaniu ścieków całkowicie spełniały wymagania norm w zakresie stężenia ChZT i fosforanów ustalone dla ścieków odprowadzonych do jezior (tabela 1). Badany wariantowo układ oczyszczania fizyczno-chemicznego ścieków surowych wymagał dodatkowo zastosowania procesu adsorpcji na węglu aktywnym o czasie kontaktu 40 min.

Zastosowane metody były także efektywne przy usuwaniu metali z wyjątkiem cynku.

Dalsze badania nad trzecim stopniem oczyszczania ścieków są kontynuowane w WRL w dużej oczyszczalni pilotowej w Balatonfüred.

HOCHEFFEKTIVE ABWASSER-REINIGUNGSMETHODEN BEI ANWESENHEIT VON VERUNREINIGUNGEN INDUSTRIELLER HERKUNFT

Kommunalabwässer, die toxische Stoffe beinhalten, bedürfen einer physikalischen und chemischen Behandlung nach der biologischen Reinigung oder anstatt deren.

Laborversuche zur Kontaktfällung von biologisch vorgereinigten Abwässern auf Kiesfiltern, ergaben beim Durchfluß von unten nach oben eine CSB-Restkonzentration bis zu 75 g/m^3 und eine Phosphat-Konzentration bis zu 1,3 g/m^3.

Als Test-Abwässer (mit toxischen Inhaltsstoffen) dienten solche der Pumpstation Pest-Nord, die daselbst im Pilotmaßstab untersucht wurden. Konventionelle chemische Fällung mit anschliessender Sedimentetion und Filtration — die nach biologischer Vorreinigung erfolgten — entsprachen voll den

Grenzbedingungen betr. CSB- und Phosphatkonzentrationen für Abwässer, welche in Seen abgeleitet werden sollen (vergl. Tabelle 1). Bei einer Alternativlösung mit physikalisch-chemischen Reinigung der rohen Abwässer, mußte eine Sorptionsanlage mit Aktivkohle, die eine Kontaktzeit von 40 min gewährleistete, nachgeschaltet werden.

In beiden Fällen wurden aus dem Abwasser Schwermetalle weitgehend entzogen; Zinck bildete eine Ausnahme.

Die Untersuchungen betr. der dritten Reinigungsstufe werden nunmehr auf einer Pilotanlage in Balatonfüred fortgesetzt.

ВЫСОКОЭФФЕКТИВНЫЕ МЕТОДЫ ОЧИСТКИ ГОРОДСКИХ СТОЧНЫХ ВОД, ЗАГРЯЗНЕННЫХ ПРОМЫШЛЕННОСТЬЮ

Городские сточные воды, содержащие токсичные загрязнения, часто требуют применения для их очистки физико-химических методов, применяемых после биологического процесса или вместо него. Лабораторные исследования по контактной коагуляции на скорых фильтрах с течентем снизу вверх показали снижение ХПК до 75 г/м^3, а концентрацию фосфатов до 1,3 г/м^3, по отношению к предварительно биологически очищенным сточным водам.

Сточные воды, содержащие токсичные вещества, происходящие от насосной станции северного Пешта, были исследованы на построенной там опытной станции. Применённые процессы традиционной коагуляции с седиментацией, а также фильтрация после предварительной биологической очистки сточных вод полностью удовлетворяли требованиям к нормам по концентрации ХПК и фосфатов, установленным для сточных вод, отводимых в озёра (таблица 1). Вариантно исследуемая система физико-химической очистки сырых сточных вод требовала добавочного применения процесса адсорбции на активированном угле с временем контакта 40 мин.

Применённые методы были также эффективными в отношении удаления металлов, за исключением цинка.

В ВНР продолжают проводить дальнейшие исследования по третьей степени очистки сточных вод на большой опытной станции в Балатонфуред.