EXPERIMENTAL INVESTIGATION OF PLASTIC TRICKLING FILTER MEDIA

By

D. Dulovics

Section of Water Supply and Canalization, Institute of Water Management and Hydraulic Engineering, Technical University, Budapest

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1. Introduction

Trickling-filter sewage purification is one of the oldest methods of artificial biological waste-water treatment. Its specific advantages still justify its use, in spite of the rapid development and extension of the activated sludge process. The biological trickling filter as a biochemical reactor is not yet utilized at full capacity. Its construction and operation are expected to undergo further development [1].

The trickling filter operation, of common knowledge, has been treated in several Hungarian and foreign publications. Essentials of the processes as, for example, making allowance for the actual influence of temperature, hydraulic and organic loads and intensity variation, character of biochemical processes inside the trickling filter, the mass of microorganisms, transport and adsorption of oxygen and nutrients as well as the time of contact between organic matters in solution and in suspension and the biological film have not yet been cleared [2].

Factors affecting the trickling-filter sewage treatment processes similarly to the activated sludge process, are:

— nature of sewage to be degraded (quantity, quality),
— rate and evenness of hydraulic load (return sludge percentage, sewage distribution),
— degradation oxygen supply (available and consumed),
— quantity and quality of microorganisms (biological film) performing degradation,
— temperature conditions (of sewage and atmosphere),
— operational conditions (filter change, elastic change of load, function in the treatment process) [3, 4].

As seen from the high number of factors, simulation of the process of trickling-filter sewage treatment by exact mathematical models would be rather difficult, therefore approximation has been attempted by picking out one or other main influencing factor and by simplifying or neglecting the effects of the others.

2. Overall reaction-kinetic description of the trickling-filter sewage treatment

Simulation of the processes in trickling-filter sewage treatment has been dealt with in great many publications. In shortage of space, rather than a literature survey, only the three fundamental groups of the models will be given below.

Simulations may be either by:

a) residence-time models;

b) first-order reaction-kinetic models; or

c) models simultaneously allowing for mass transfer and biological processes.

a) *Residence-time models*

Degradation is a timely process, the residence time being crucial for the process efficiency. In these models piston-flow is assumed and the detention times are averaged.

The general relationship of degradation is:

$$\frac{S_e}{S_o} = e^{-kt_S}$$

where:

S_e, S_o — BOD_5 concentration in effluent and inflow sewage, respectively;
k — coefficient of proportionality;
t_S — mean residence time.

The function of the residence time will be detailed later.

Taking the longitudinal mixing, the coefficient of axial dispersion, the height of the trickling filter and the film thickness into account, the formula above becomes:

$$\frac{S_e}{S_o} = e^{-\left\{\frac{V_F}{2\delta A_a D_a} - \left[\left(\frac{V_F}{2A_a D_a}\right)^2 + \frac{k'}{\delta D_a}\right]^{1/2} \cdot H\right\}}$$

where, beside the symbols quoted above,

V_F — hydraulic surface loading;
δ — film thickness;
D_a — coefficient of axial scatter;
k' — coefficient of proportionality;
A_a — active film surface.

b) *The first-order reaction-kinetic models are described in general form by the following equation:*

$$\frac{S_e}{S_o} = e^{-K_a \frac{A_a \cdot H}{V_F}}$$

where, beside the notations already known,

K_a — pseudo-first-order reaction-kinetic constant of microbiological reactions in liquid and film phases where diffusion is the limiting factor.

c) *Models taking both mass transfer and biological processes into account are in general form:*

$$S_e = S_r + (S_o - S_r)e^{\frac{-K_m \cdot H}{V_F}}$$

where, beside the notations above:

S_r — concentration of the non-degradable substratum;
K_m — total mass transfer coefficient:

$$\frac{1}{K_m} = \frac{1}{K_L \cdot F} + \frac{\alpha}{K \cdot X}$$

K_L — mass transfer coefficient (function of Reynolds number *Re*, Schmidt number *Sc*, and concentration S_o);
F — specific surface of trickling filter;
K — first-order reaction-kinetic constant;
α — specific adsorption coefficient;
X — concentration of dissolved oxygen.

From the above it is evident that in the operation of the trickling filter as a biochemical reactor, the hydraulic characteristics are of high significance. The flow velocities and flow quality definitely determine the mass transfer (nutrient and dissolved O_2 supply, removal of metabolic products, rinsing of the biologic film, etc.). The residence time is also important for the timely course of biochemical reactions.

Introduction of the plastic trickling filters stressed the significance of hydraulic characteristics although noteworthy efforts have also previously been made to increase the efficiency of trickling filters [6, 7, 8, 9, 10].

1970 to 1978, research was made on application possibilities of plastic trickling filters in Hungary and on their hydraulic characteristics [3, 4, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21].

3. Investigation of the hydraulic system of trickling filters

Above, the hydraulic characteristics of the trickling filters and their influence on the sewage purification efficiency have been pointed out.

From the hydraulic point of view, the trickling filter consists of three structural components:

— distributor,

— media of the trickling filter,

— collector and outlet system.

The development and nature of the water film are determined by the hydraulic surface load and by the structures of the distributor and media of the trickling filter.

The distributor performs the primary distribution, while the secondary distribution depends on the charge type.

In the case of plastic trickling filters, particular care should be spent on the evenness of primary distribution. Experiments involved the development and testing of two medium types: lamellar, two-way corrugated (BO) and tubular (BMB).

Interpretation of secondary distribution is represented in Fig. 1 for the cases of tuff, lamellar (BO) and tubular (BMB) media.

In the case of traditional trickling filters utilizing mineral media, secondary distribution absolutely contributed to the water distribution. The void system in rock media is ramified so that the water percolating downwards can spread, equalizing unevennesses of the primary distribution.

In media of regular structure, however, no or little of such a secondary distribution can be reckoned with. Namely, the voids of lamellar and tubular media are laterally not connected, therefore the water on the surface passes along a fixed guideway without a possibility of equalization.

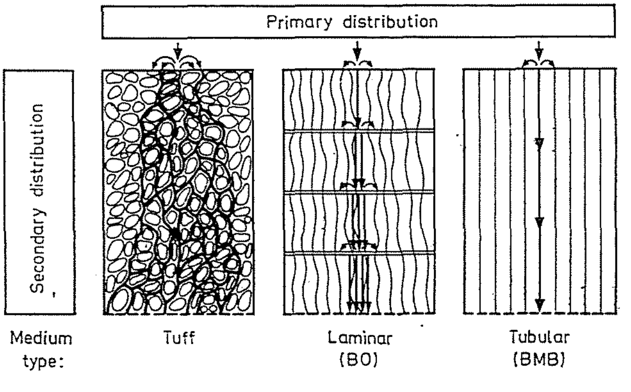


Fig. 1. Interpretation of secondary distribution

A secondary distribution could take place also by the splashing up of the water falling on the trickling filter. Rock charges have few and relatively small surface voids, therefore this way of the secondary distribution may be significant. On the contrary, plastic charges have large surface voids compared to the plastic plate thickness, hardly contributing to the further diminution of the drops.

3.1 *Distribution of the sewage on the surface of the trickling filter*

Sewage dispersion on the trickling filter surface is realized by the sewage distributor that may be either

— stationary or
— mobile.

Both distributor types have specific hydraulic characteristics which should be known in order to assure a suitable distribution pattern, i.e., uniform load. This is of a particular significance for plastic trickling filters of increased hydraulic load and special medium structure, because efficient operation of the trickling filter depends on the uniform distribution, optimum conditions of passing through the medium and the appropriate residence time.

Because of the importance of distribution on trickling filters, laboratory, pilot and operating tests have been made.

In Fig. 2 the scatters due to a rotary sprinkling machine on laboratory, pilot model and operating trickling filters are presented *vs.* hydraulic surface charge.

Also the scatters point out the care needed in the design of the distributor to assure a uniform load. The effect of uneven distribution is rather conspicuous along the wall and near the distributing cylinder. During operation the holes of the distributing equipment should regularly be cleaned; process worth while to be automated.

3.2 *Percolation of the sewage through the trickling filter*

The sewage is fed by the distributors periodically onto a unit surface of the trickling filter. The features of the distribution, the periodicity and time intervals, the load amplitudes affect the flow of the sewage inside the trickling filter.

After the distribution of the sewage fed upon the medium it arrives on the biologic film adhering to the surface and passes over on it as a thinner or thicker water sheet depending on the hydraulic conditions.

In dependence on the distributor type and on the uniformity of distribution, the flow is either steady or tends to steady state.

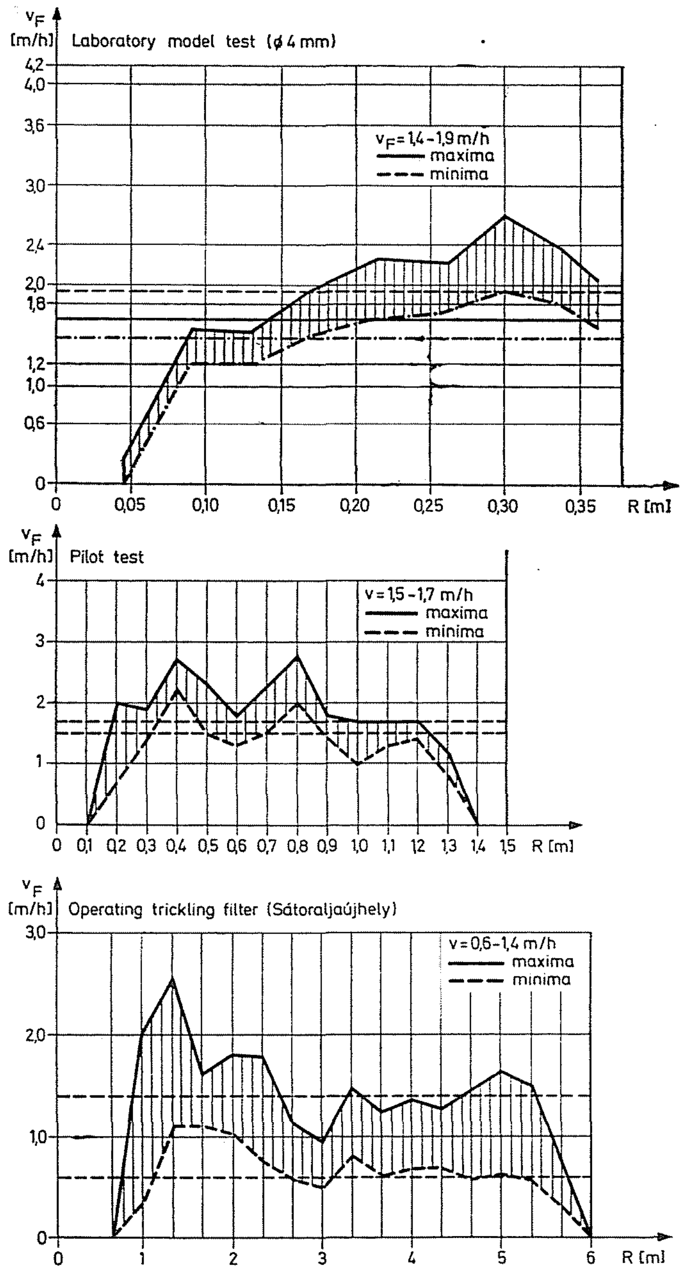


Fig. 2. Scatter of the radial distribution of hydraulic surface load

The intermittent unsteady water flow down the trickling filter has been observed to tend to steady state. This phenomenon is due to the flattening and intermingling of the *flood waves* resulting from the periodical feeding of the water.

The equalization depends on the surface properties (friction), on the physical behaviour of the liquid, on the feeding intervals and on the load amplitudes.

This is examplified by the observation that in the laboratory equipment, feeding by a comparatively fast revolving distributor, rapid flattening and mingling of flood waves and the equalizing effect of the collecting system cause the effluent water discharge to hardly change, practically to be considered as uniform.

Outcomes in similar processes conform with the above observations have been reported [22].

The sheet flow in a steeply sloping channel exhibits the following features.

In case of an undisturbed flow at the entrance and of a gradient steeper than critical, the flow will accelerate near the entrance. Then, the slope component of the gravity force ($G \cdot \sin Q$) exceeds the shear resistance T_e. With increasing velocity, however, the resistance increases faster than the moving force, reducing the flow depth and thus, the slope component of the gravity force. The difference between the two forces gradually diminishes, tends towards equilibrium ($T_e = G \cdot \sin Q$) and the slope of the energy line will be the same as that of the bed bottom, just as in steady flow. In the subsequent section of steady-state flow, — provided the physical properties of water are unchanged — change will occur only if the water discharge, the surface roughness, the flow section and the slope will change. The flow can only theoretically reach the steady state due to the inhomogeneous surface roughness, to the feed of water uneven in time, and to the changing slope conditions. These changes are, however, slight enough to be practically negligible at little error.

Observations of hydraulic processes in trickling filters show two distinct sections of water flow:

— section of varying pulsating sheet thickness;

— section of about constant sheet thickness.

These observations are conform with the above statements.

In the case of one of the charge types (tubular BMB) the boundary surface of the void system is inclined nearly, but never exactly, at 90° due to structural or fabricational imperfections. Inclination of the boundary surfaces of the second type (laminar BO) is significantly non-vertical. Thus, hydraulic simulation of the flow through the trickling filters investigated involves the flow phenomena described above.

The detailed analysis of these hydraulic processes is rendered more difficult partly by their complexity (surfaces of different designs and properties), partly by metrology difficulties, and partly by the inherent interactions of the trickling filter as a hydraulic system.

Also references [7, 8, 9, 23, 24] pick out some elements of the system such as flow conditions on the charge surface, bypassing distortions due to inherent interactions of the system.

3.3 *Trickling filter flow tests*

To overcome the difficulties outlined above, hydraulic characteristics of the trickling filters have been investigated in flow tests.

Flow tests permit to determine the residence time of the sewage inside the trickling filter, and the hydraulic characteristics of the charge, as the first step to the recognition of the processes inside the trickling filter.

The function of the residence time in the efficiency of degradation depends on the hydraulic and organic matter load in the sewage. In case of a low load, the change of the residence time little affects the efficiency of degradation. But in case of heavy loads, even a slight change significantly alters the degradation efficiency. In plastic trickling filters economically handling heavy loads, the residence time tends to decrease, that is why a great care is felt to be necessary to provide for the required residence time.

Experiments involved flow tests to determine the residence time.

For the theory of flow tests let us refer to [25, 26, 27, 28].

Our investigation method was the following:

The trickling filter was considered as a system, and applying some kind of "stimulus", the response function was recorded. The stimulus was to feed a marking dye, the response was the dye's appearance and evacuation from the trickling filter.

Feeding of the dyes is arbitrary in principle, but the measurements can only be evaluated if either

— feeding is instantaneous (unit pulse, Dirac-delta); or

— input follows a step function by abruptly increasing dye concentration and maintaining the feed at the same intensity (unit-step input function).

In the first case a *flow wave*, in the second case a *flow curve* is obtained.

The flow test results can be processed to various characteristic times such as appearence of the first signal t_e, time at the maximum t_m, 50 % evacuation of the dyer t_{50}, the time coordinate of the centroid of the area below the curve t_s, and appearance of the last signal t_u. From the above data t_m, t_{50}, t_s may be adopted as residence times. A single parameter is insufficient to conclude on the residence time [29]. From the interaction between the components of the trickling filter it follows that the flow depends also on the feeding defined by the distribution, as verified by [4] in accordance with other publications [30].

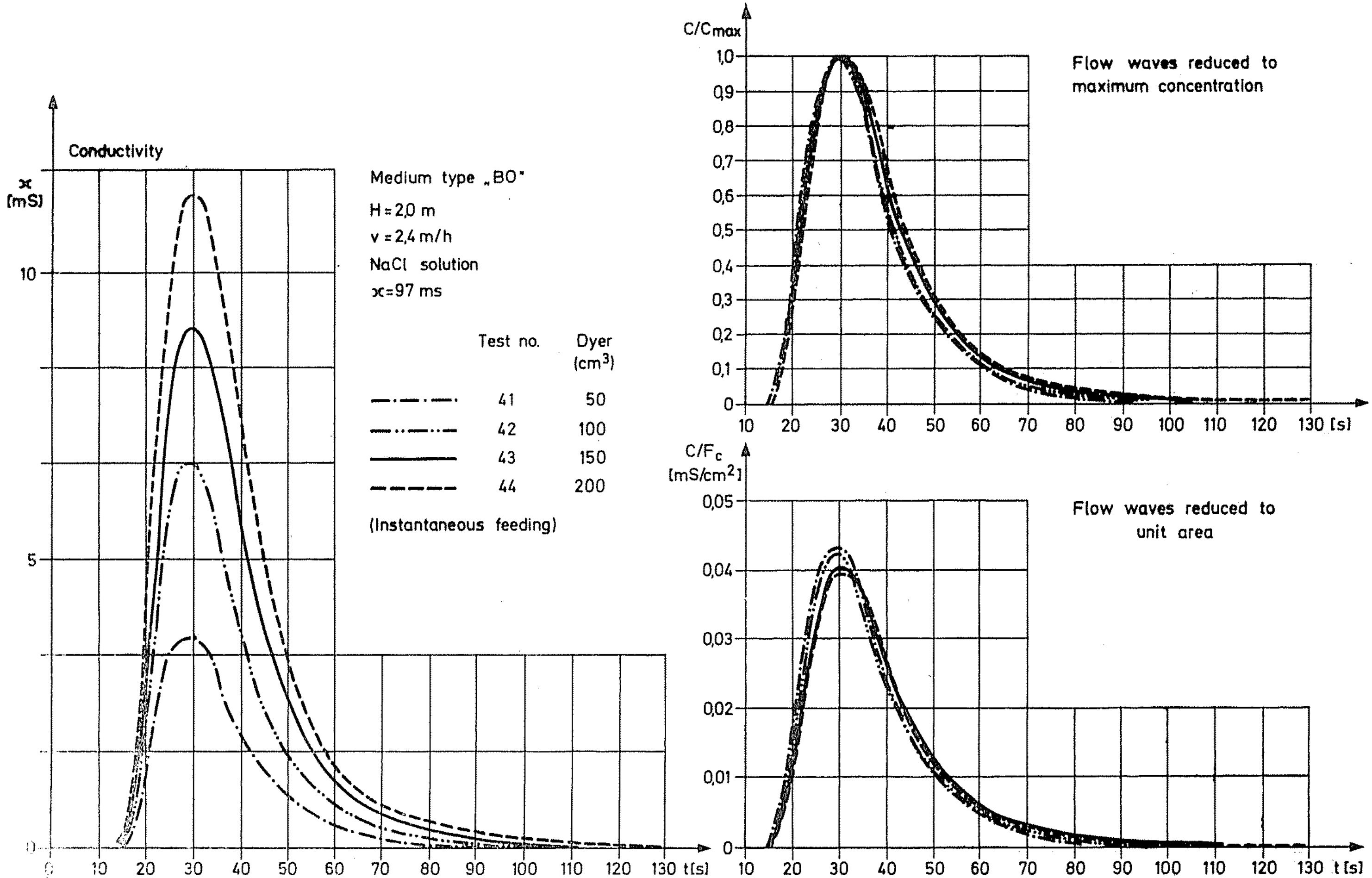


Fig. 3. Flow waves for different dyer dosages

This recognition is a restriction to the comparability; residence times in different charge types may only be compared under the same conditions (distribution, load, signalization, temperature, etc.).

In *laboratory measurements* on pure water, besides determination of the residence times it has also been investigated how reliable the flow wave measurements are, how the form of the flow wave is influenced by the dyer quantity and dosage time, and what is the relationship between the flow wave and the flow curve.

The effect of the dyer quantity on the form of the flow wave is seen in Figs 3, 7 and 8.

The varying dyer dosage does not change the form of the flow curve. Only the flow wave reduced to unit area exhibits flattening in direct proportion with the dyer quantity.

The flow waves and the residence times determined therefrom are seen in Fig. 4 as a function of the hydraulic load.

Fig. 5 represents the effect of the feeding time upon the flow wave form.

In the laboratory measurements, besides the flow waves also flow curves could be recorded by saturating the flow system with dyers.

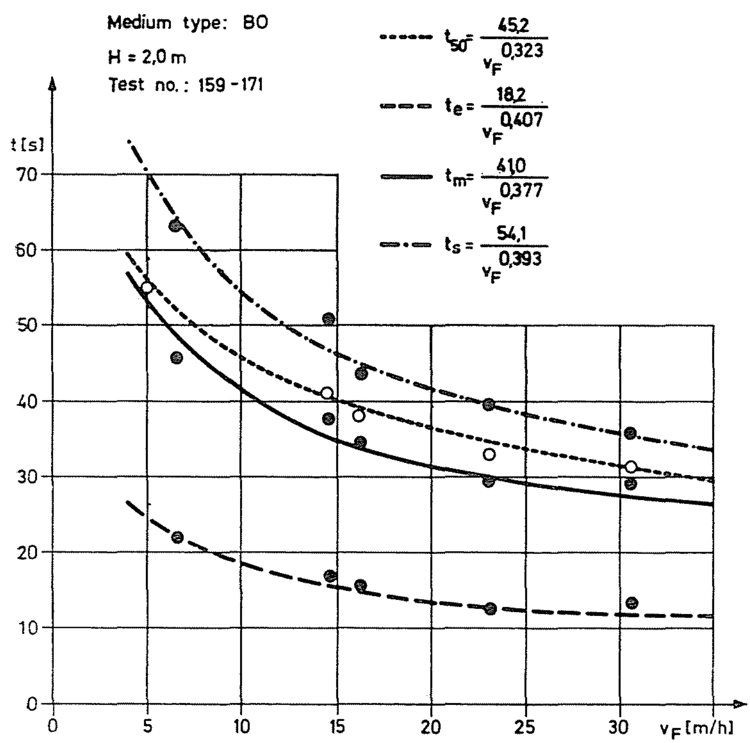


Fig. 4. Flow wave characteristics *vs.* hydraulic surface load

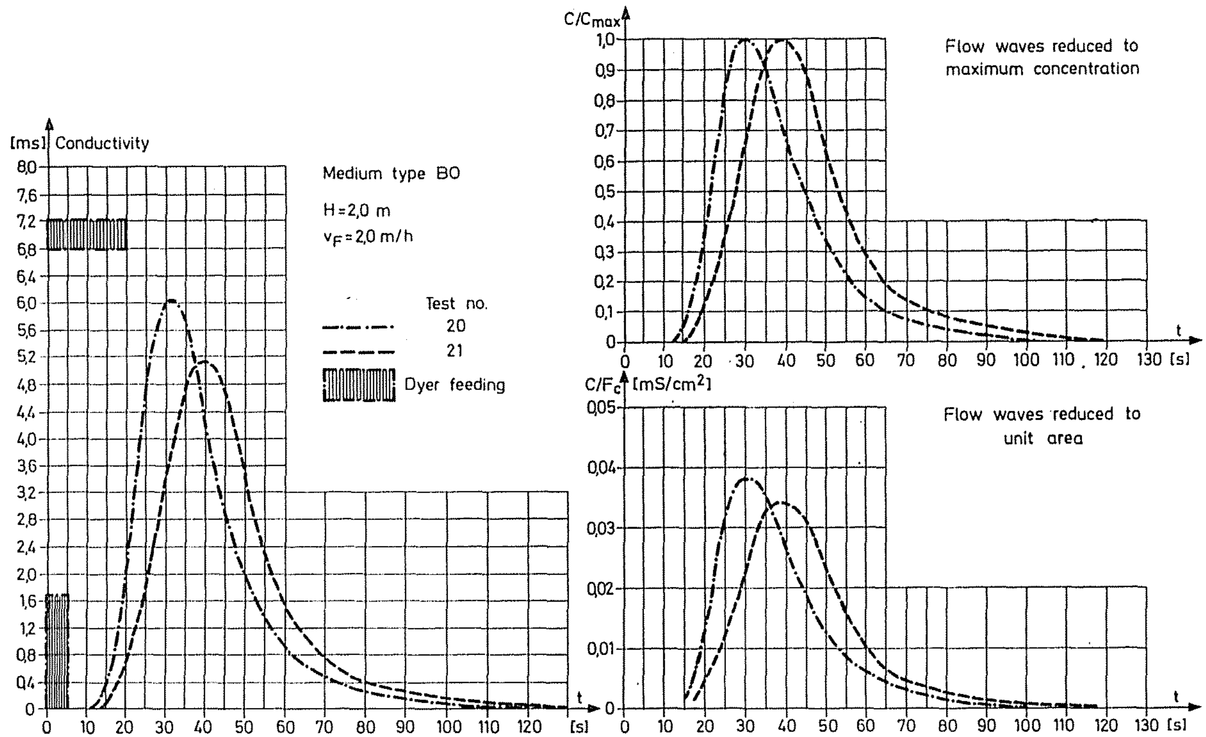


Fig. 5. **Effect of the dyer feeding time on the flow wave shape**

The ideal flow wave corresponds to the density function, and the flow curve to the distribution function of the residence time.

There is another method, the so-called *balance method* for determining the residence time [31].

Also our laboratory measurements involved such investigations.

Summarizing the laboratory experiments, Fig. 6 is a comparison between residence times determined from the flow wave centroids, from the flow curve and by the balance method as a function of the hydraulic surface load. In connection with the figure it can be stated that for dyer pulse feeding times short enough, the residence times measured and calculated from the flow curve are in a fair agreement. The balance method yields much lower residence times.

Further laboratory tests concerned the effect of the biological film upon the residence time, simulating the film by a gelatine layer [32]. Test results, in agreement with those obtained abroad [8], confirmed the braking function of the film.

Pilot tests have been carried out at the pumping station of Budapest—Angyalföld [4]. Besides the laminar BO and tubular BMB plastic media, also a traditional medium tuff has been investigated.

The filler media investigated were placed in a cylindrical trickling filter divided radially into three parts providing for identical conditions for their comparative investigation.

For the determination of the residence time the same methods have been applied as for the laboratory measurements above. Fig. 7 shows the flow waves for different charges under hydraulic surface loads $v_F = 2.27$ m/h and $v_F = 1.7$ m/h.

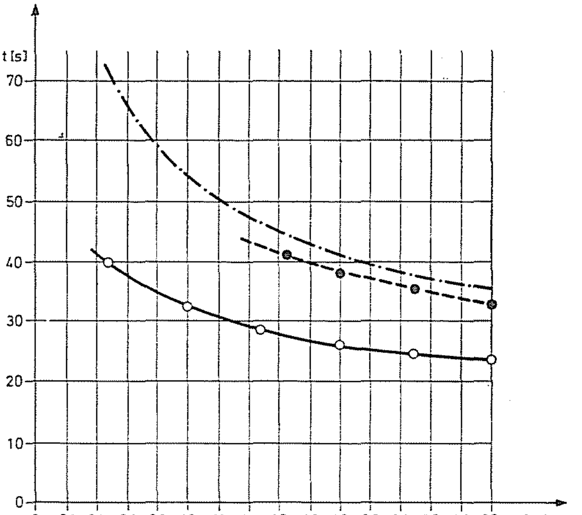


Fig. 6. Residence time *vs.* hydraulic surface load determined by different methods

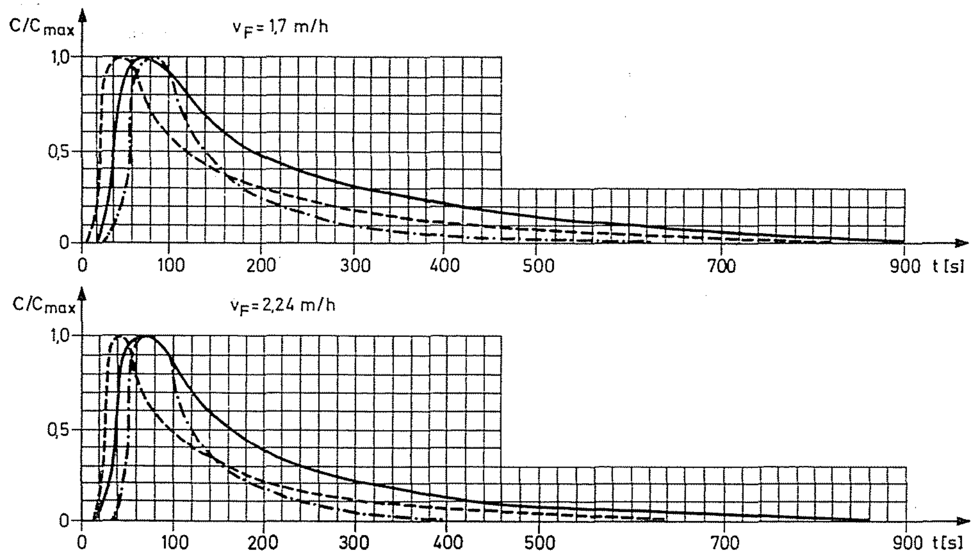


Fig. 7. Flow waves for different media

The comparison of simultaneous measurement results shows the order of flow wave of running up and of peaking to be: BMB-BO-tuff.

The sloping leg, referring to the evacuation, shows the BO to be the slowest to evacuate, followed by the BMB and the tuff.

The relatively rapid evacuation of the tuff was partly due to the development of clogging, hydraulic short-circuit (break-through) in the hydraulic surface load range mentioned.

The relationship between the hydraulic surface load and residence time for these two media is demonstrated in Fig. 8, showing the effect of the medium

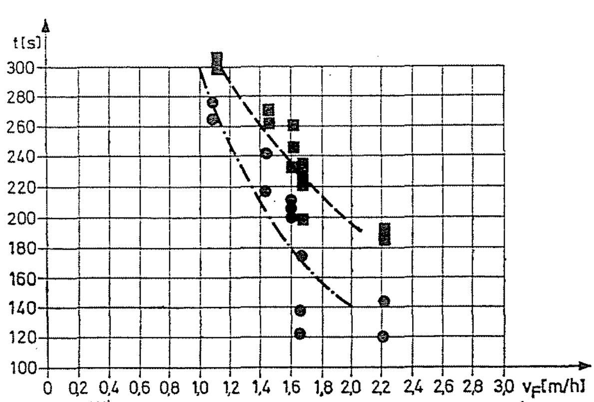


Fig. 8. Hydraulic surface load *vs.* residence time

Table 1

Overall results of

	15. 1.—28. 1. 1976			23. 4.—4. 6. 1976			7. 6.—29. 8. 1976		
	max.	avg.	min.	max.	avg.	min.	max.	avg.	min.
Fed on trickling filter (g/m^3)	710	441.3	200	760	549.2	330	1200	662.4	430
Tubular (BMB) effluent (g/m^3)	460	251.4	155	600	280	120	470	361.2	200
Lamellar (BO) effluent (g/m^3)	560	271.0	110	520	272.5	110	480	362.4	220
Tuff effluent (g/m^3)	540	380.0	260	560	289.6	150	480	386.5	180
Decomposition efficiency η_2 %	62	38.0	20	66	49.3	30	66	43.4	31
Decomposition efficiency η_3 %	77	44.2	10	67	50.4	33	64	44.0	29
Decomposition efficiency η_4 %	41	29.7	13	66	47.8	28	65	39.7	29
Surface hydr. load V_f (m/h)		1.42			1 21			1.89	
Hydr. load/vol. T_b (m^3/m^3d)		11.33			9.68			15.10	
Biol. load/vol. T_b (kg/m^3d)		5.00			5.27			10.00	

Table 2

Overall results of

	5. 1.—28. 1. 1976			28. 4.—4. 6. 1976			7. 6.—29. 7. 1976		
	max.	avg.	min.	max.	avg.	min.	max.	avg.	min.
Fed on trickling filter (g/m^3)	360	222.8	110	340	267.5	155	330	284.2	200
Tubular (BMB) effluent (g/m^3)	300	130.0	41	190	137.9	57	240	189.2	135
Lamellar (BO) effluent (g/m^3)	295	152.0	52	190	138.5	46	255	219.2	125
Tuff effluent (g/m^3)	320	240.0	140	220	160.5	78	260	194.7	125
Decomposition efficiency η_2 %	79	44.7	9	63	49.4	34	48	33.4	22
Decomposition efficiency η_3 %	66	41.3	10	70	49.5	40	48	32.2	23
Decomposition efficiency η_4 %	35	22.0	3	51	42.0	21	53	31.1	16
Surface hydr. load V_f (m/h)		1.42			1.21			1.89	
Hydr. load/vol. T_b (m^3/m^3d)		11.33			9.68			15.10	
Biol. load/vol. T_b (kg/m^3d)		2.50			2.59			4.29	
Sewage temperature °C		5—8.5			14.5—18			16—18.5	

KOD investigations 1976

	30. 7.—10. 10. 1976			25. 10.—11. 11. 1976			5. 1.—10. 11. 1976		
	max.	avg.	min.	max.	avg.	min.	max.	avg.	min.
Fed on trickling filter (g/m^3)	720	557.0	380	1100	672	460	1200	591.8	200
Tubular (BMB) effluent (g/m^3)	500	341.8	190	500	338	80	600	323.9	80
Lamellar (BO) effluent (g/m^3)	580	362.5	190	520	359	115	580	335.3	110
Tuff effluent (g/m^3)	—	—	—	—	—	—	560	346.0	150
Decomposition efficiency η_2 %	54	39.6	17	87	48	22	87	43.7	17
Decomposition efficiency η_3 %	55	36.6	7	75	47	28	77	43.9	7
Decomposition efficiency η_4 %	—	—	—	—	—	—	47.8	41.8	13
Surface hydr. load V_f (m/h)		1.63			1.81		1.89	1.62	1.21
Hydr. load/vol. T_b (m^3/m^{3}d)		13.00			14.45		15.10	12.95	9.68
Biol. load/vol. T_b (kg/m^{3}d)		7.24			9.7		10.10	7.76	5.00

BOD_5 investigations 1976

	30. 7.—10. 10. 1976			25. 10.—11. 11. 1976			5. 1.—10. 11. 1976		
	max.	avg.	min.	max.	avg.	min.	max.	avg.	min.
Fed on trickling filter (g/m^3)	380	321.7	180	350	306	190	380	287.9	110
Tubular (BMB) effluent (g/m^3)	300	211.7	90	250	187	80	300	177.5	41
Lamellar (BO) effluent (g/m^3)	315	210.7	115	255	198	105	315	188.9	46
Tuff effluent (g/m^3)	—	—	—	—	—	—	320	185.5	78
Decomposition efficiency η_2 %	68	36.3	12	76	40	18	79.0	40.0	9
Decomposition efficiency η_3 %	56	35.8	17	70	35	22	70.0	38.2	10
Decomposition efficiency η_4 %	—	—	—	—	—	—	53	34.7	3
Surface hydr. load V_f (m/h)		1.63			1.81		1.89	1.59	1.21
Hydr. load/vol. T_b (m^3/m^{3}d)		13.00			14.45		15.10	12.71	9.68
Biol. load/vol. T_b (kg/m^{3}d)		4.18			4.42		4.42	3.59	2.50
Sewage temperature °C		15.5–18.2			14.3–17.6				

structure on the residence time. In the range of the lower surface loads, the residence times of the two media do not differ significantly, but the difference grows increasing with the surface load. In spite of its significantly larger specific surface, the tubular charge BMB consisting of nearly vertical surfaces is more sensitive to the increase of the hydraulic surface load.

4. Analysis of chemical and biological characteristics

Pilot tests for the comparative evaluation of different plastic medium types have been completed, besides of hydraulic measurements, with chemical and biological analyses.*

The pilot tests — as against laboratory experiments — necessarily are imprinted by restrictions of the actual circumstances, such as the quality of the inflow sewage, restrictions arising from the design and operation of the pilot plant, etc. [4].

4.1 *Degradation in terms of chemical parameters*

The quality of a process of degradation is primarily characterized by its efficiency. The quality of the sewage purification is evaluated by the degree of removal of the different pollutants (BOD_5, KOD, suspended matter, nitrogenous compounds, etc.).

The pilot tests — made to compare the media BMB, BO and the traditional tuff — aimed at determining the degradation capacity and operational characteristics of the media. The measured chemical characteristics have been compiled in Tables 1, 2 and 3.

The chemical analyses pointed out that the sewage containing much of industrial contamination is difficult to biologically degrade, as seen also from the results in terms of degradation efficiency (in general, $\eta_{KOD} > \eta_{BOD_5}$).

Comparison of degradation efficiencies of the two medium types showed little difference, in spite of the rather different specific surfaces ($F_{BMB} = 138$ m^2/m^3 and $F_{BO} = 80.5$ m^2/m^3). This is explained by the different charge structures confirmed also by the residence times reported under 3.3.

In the experiments the tuff tests served as reference in comparing the plastic charges subjected to the same loads. Consequently, the tuff medium got soon clogged despite of its large-size grains ($d = 10$ to 20 cm).

Chemical test results have been compared with those published on laboratory or pilot tests on communal sewages [33, 34, 35, 36, 37]. The comparison

* The chemical and biological parameters have been determined at the laboratory of the Institute of Water Management and Hydraulic Engineering of the Technical University, Budapest.

Table 3

Nitrogen balance investigations

Sampling time (1976)	NH_4^+ [g/m³]				NO_2^- [g/m³]				NO_3^- [g/m³]			
	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.	3.	4.
22.6	34.6	31.2	30.3	31.8	1.2	0.08	0.05	0.05	5.2	0	0	0
25.6	51.2	50.2	34.2	35.4	1.4	0.05	0.07	0.06	3.5	0	0	0
5.7	32.4	30.8	31.2	30.0	1.2	0.06	0.04	0.05	3.7	0	0	0
14.7	34.7	30.3	29.8	33.1	0.8	0.07	0.06	0.04	3.5	0	0	0
21.7	33.8	29.3	29.7	30.2	0.9	0.06	0.05	0.05	5.1	0	0	0
30.7	34.1	28.9	30.0	32.6	1.4	0.07	0.06	0.06	6.3	0	0	0
4.8	34.4	32.9	30.0	32.9	0.9	0.05	0.06	0.05	3.4	0	0	0
13.8	44.3	41.5	40.2	38.2	1.3	0.06	0.05	0.06	3.7	0	0	0
7.9	32.3	30.2	28.9	—	1.2	0.06	0.05	—	4.7	0	0	0
17.9	31.1	31.2	30.3	—	0.8	0.05	0.05	—	1.8	0	0	0
5.10	43.5	40.3	38.7	—	1.3	0.05	0.06	—	4.2	0	0	0
11.10	32.8	28.7	30.5	—	1.2	0.06	0.06	—	3.8	0	0	0
25.10	34.0	29.2	32.4	—	1.1	0.06	0.06	—	4.7	0	0	0

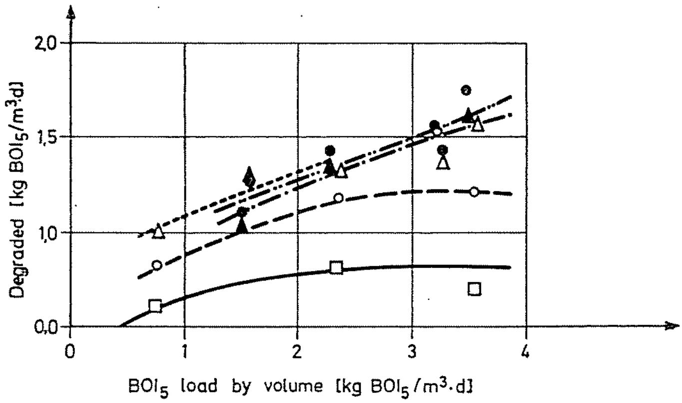
Sampling from:
1. Sewage fed on trickling filter
2. Tubular (BMB) effluent
3. Lamellar (BO) effluent
4. Tuff effluent.

showed the efficiencies of the tested medium types to be up to expectations. Degradation efficiencies for identical volume loads BOD_5 and for identical hydraulic volume loads η_{BOD_5} and η_{BOD}, resp., have been plotted in Fig. 9.

4.2 *Degradation in terms of biological parameters*

Parallel to chemical analyses, also biological control analyses have been carried out [38].

Pilot tests involved also biological rating of the raw sewage. The arriving sewage showed a polysaprobic nature in every analysis which meant that it had only bacterial content and sporadically some *polytoma uvella*, colourless flagellates. (This and the lack of oxygen in the raw water as well as a 34 to 51 g/m³ NH_4^+-ion concentration hint to the strong putrescence of the sewage.) Most cases of saprobiological qualifications showed an α-mezosaprobical character (in the case of trickling filters with traditional media, the character of the effluent sewage is, in general, $p\alpha$) proving the superiority of plastic media. Table 4 presents the results of a short autumnal biological analysis.



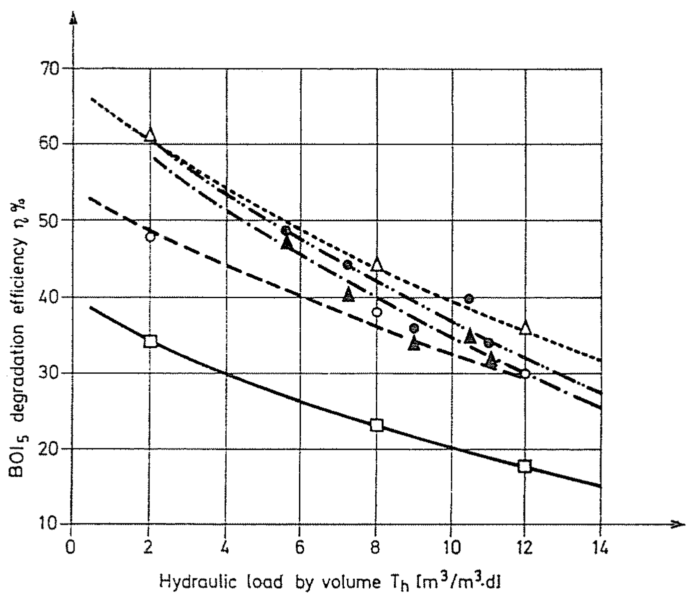


Fig. 9. Comparison of proper and Stevenage's [37] test results: — — △ — — — Surfpac crincleclose (F_f = 187 m²/m³); — — — ○ — — — Cloisonyle (F_f = 220 m²/m³); — — — □ — — — Flocor (F_f = 85 m²/m³); ● tubular BMB (F_f = 138 m²/m³); × lamellar BO (F_f = 80.5 m²/m³)

The biological analyses showed the number of freely floating microbes in the effluent to strongly fluctuate, though being higher than in trickling filters containing traditional media.

In case of an adequate operation, the biocoenosis between the film on the plastic trickling filter and the effluent water is similar to that in the activated sludge system.

Table 4

Biologic test results of media types BMB and BO [4]

Sampling time (1976)	Medium type Tubular (BMB)		Lamellar (BO)	
	T_k %	Rating	T_k %	Rating
23.10	51.8	α	45.4	α
24.10	79.3	$\alpha\beta$	32.3	$p\alpha$
28.10	35.9	$p\alpha$	48.4	α
29.10	36.8	$p\alpha$	39.9	α
1.11	39.6	α	46.4	α
3.11	50.2	α	38.4	α
4.11	43.2	α	43.3	α
5.11	52.5	α	60.6	α
8.11	46.9	α	38.6	α
9.11	66.3	$\alpha\beta$	68.6	$\alpha\beta$
10.11	81.0	$\alpha\beta$	73.6	$\alpha\beta$
11.11	50.0	α	45.0	α
19.11	74.5	$\alpha\beta$	70.5	$\alpha\beta$

5. Conclusion and evaluation

At the Institute of Water Management and Hydraulic Engineering, Technical University, Budapest, research work concerned the development of plastic trickling filters, involving flow, chemical and biological analyses on BMB and BO type media.

Our investigations into the flow processes started from the approximate hydraulic system of the trickling filter, involving the sewage distribution, the flow through the medium, and the factors affecting the flow.

Investigations confirmed the importance of the distribution for the residence time and for the processes within the trickling filter. At the same time, the distributor and the structure of the trickling filter medium appeared to be co-determinant for the development of the water film and both should be treated together as an integral unit.

The residence time also depends on the distributor type, on the distribution periodicity and on the load amplitude.

The evenness or unevenness of the surface load may be characterized by the scatter. In turn, the surface load directly influences the residence time. In case of plastic media, impossibility of a secondary distribution stresses the primary distribution.

This is why uniform distribution is of importance for increasing the efficiency of the trickling filter.

Experimental evidence showed flow theory methods to suit determination of residence times.

In evaluating the results it should be noted, however, that different equipment designs and sizes as well as distributors prevent a comparison of residence times else than under restricted conditions. The same is true for the comparison of published measurement results.

No linear relationship has been found between the residence time and the height of the trickling filter. The relationship between surface load residence time and trickling filter height shows that the lower the trickling filter, the more the increase of surface load reduces the residence time. In case of higher trickling filters, this effect is less pronounced, making them less sensitive to surface load changes.

Although analysis of the hydraulic processes was the main point of the research, the biological trickling filter was thought of as a biochemical reactor simultaneously accommodating biochemical and physical processes, both intervening in the trickling filter operation efficiency.

For the sake of a complex estimation, investigation of the plastic media involved also complementary chemical and biological tests.

Chemical and biological investigations showed BMB and BO medium types to be utilizable in compliance with their structural properties: for primary filter equipment.

Degradation efficiencies of both medium types equal, or in certain cases surpass those published for charge types utilized under similar circumstances.

Operation tests of pilot plants showed trickling filters with BMB and BO media

— to be exempt from clogging;
— to permit load changes in wide ranges;
— to support load fluctuations;
— to be simple to operate.

Summary

Multiannual research has been made on plastic trickling filters, on the reaction kinetics of sewage purification with trickling filters and on the effect of flow on biochemical processes within the trickling filter. Description is given of the hydraulic system of the trickling filter, distribution of the sewage, the distributor, the percolation through the medium, and the factors affecting the flow conditions. The analysis is focussed on the residence time. Structures of the distributor and the medium are co-determinant for the quality of the water film flowing through the medium. The residence time depends on the distribution features: periodicity, period length and load amplitude. In certain conditions, the flow theory methods may be applied to determine the residence time. The chemical and biological research results proved degradation values of the developed BMB and BO media to equal those of foreign make.

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Dr. Dezső DULOVICS, H-1521, Budapest

* In Hungarian