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Influence of solids contained in septic tank effluent on lifespan of soil infiltration systems

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ABSTRACT

The aim of the study was to assess the clogging time according to several decisive parameters and conditions. Mathematical model describing solids' accumulation and decomposition in a soil filter as a function of time and, for example, total suspended solids (TSS) load in septic tank effluent (STE) was presented. The calculation procedure was based on the Kozeny–Carman equation. The experimental results of the hydraulic gradient were used to estimate the infiltration velocity. The empirical data of TSS concentrations in STE were taken from the literature and own study. The analyses of the factors affecting the time of clogging of the soil infiltration system (TSS concentration, biomass density, hydraulic load, clogging layer depth) were shown. Besides the decisive factors of clogging such as TSS concentration, water content and distribution of solids in the vertical cross-section of the filter were identified also as important factors. Due to the fact that the only controllable factor is the concentration of the suspension, one should strive to use highly efficient septic tanks or polishing systems in order to obtain the lowest possible concentrations of total suspended solids in the wastewater entering the soil drainage system.

Keywords: Clogging; Porosity; Septic tank effluent; Soil infiltration system; Total suspended solids

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1. Introduction

The treatment and disposal of STE is still one of the most popular and cost-effective possibilities in many European countries [1–4]. However, the disadvantage of this method is clogging danger and failure risk. Clogging or soil texture changes are common phenomena that occur in many filtration systems [5,6]. So the great challenge is to identify the crucial factors of this process with the aim to properly design and maintain such systems as long as possible – to extend the lifespan of these systems. One of the main factors of clogging is TSS concentration in STE. Despite the high theoretical efficiency of septic tanks (STs), there are some alarming reports suggesting that the TSS concentration in STE can be much higher than might be suspected. Among the reasons for low efficiency of STs, may be the tendency to use smaller chamber volumes of ST (nowadays the minimum recommended volume is 2.0 m^3, when several years ago it was 3.0 m^3) and insufficiently recognized processes that sludge accumulated in the septic tank undergoes. The volume of sludge accumulated in STs is sometimes not controlled (e.g., in Poland it is common). Nevertheless, septic tanks are still the most popular preliminary treatment device in on-site wastewater treatment plants and probably will be common in the near future.

Filtration of STE into the ground is one of the oldest methods of its treatment and disposal. It has many advantages, in particular high removal efficiency, disposal of

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treated wastewater into the groundwater (which is beneficial also because of the increase in local retention), very low energy requirement, and easy maintenance.

Unfortunately, this method of wastewater treatment also has weaknesses, including a gradual decrease in the permeability of the soil due to the accumulation of the matter within the pores of the soil. Accumulation is accompanied by decomposition, but typically it does not offset accumulation and therefore leads to a hydraulic conductivity decrease. Accumulation and decomposition, and consequently a decrease in water permeability, are primarily affected by properties of soil (porosity, size, homogeneity and shape of the grains, the content of certain substances and their impact on sorption properties of the soil such as calcium carbonate, humic acids and silicates) and characteristics of wastewater, in particular TSS load, TSS characteristics, suspended solids' biodegradability, size, uniformity and shape of TSS, temperature, pH, oxidation–reduction potential, biological treatment susceptibility, content of colloids and solutes, species composition, abundance and properties of microorganisms.

Some of these factors directly or indirectly affect the dynamics of the accumulation of matter in the pores of the soil, while other factors determine the decomposition of the accumulated matter. The most important factor is the accumulation of the suspended solids and its texture, while the main factors which determine the rate of decomposition (biodecomposition) are susceptibility of the suspension to decomposition, temperature, humidity and oxygen availability.

The improvement of the effectiveness of wastewater treatment can be achieved by applying appropriate construction of a septic tank. In terms of construction we can distinguish, among others, single or multi-chamber septic tanks and those fitted with an outflow filter or without one, or by appropriate design of the inlet and outlet construction. As was shown by studies from the last decades, the range of concentrations of TSS in septic tank effluents (STE) is very wide – from low concentrations - about several dozen mg/L [8-11] to very high values – over 100 mg/L [7,12,13]. Most research results indicate very high variability of STE (Table 1). Changeability in TSS concentration often reaches one order of magnitude.

Discrepancies in the above-mentioned results (Table 1) can be explained by the remarks of Jowett and Lay [14] and Jowett himself [15] indicating the importance of an opening in the partition wall. In the studies of Jowett and Lay [14] a single-chamber septic tank proved to be much better in removing contaminants than a two-chamber tank with an opening in the partition made of elbow (100 mm). However, the single-chamber septic tank was slightly worse than the two-chamber tank with a wide orifice in the partition wall. A sufficiently wide orifice in the partition wall calms the stream between chambers and prevents turbulence that transports untreated wastewater to the outlet.

Żytyński [16] noted, for the septic tank consisting of two chambers of volume 2 m^3 each, connected in series, without an outlet filter, the concentration of TSS at the outlet in the range 55–290 mg/L, with an average of 146 ± 45 mg/L (five measurements). However, after replacing it with a one-chamber ST of volume 2 m^3 with an outlet filter filled with a volcanic lava rock (the average concentration of the total suspended solid at the outflow was significantly reduced by 43 ± 3 mg/L (194 measurements, range: 0–239 mg/L). The study of Crites and Tchobanoglous [17] also showed a positive effect of the use of a outlet filter on the outflow. The average concentration of TSS in the effluent from the septic tank without an outflow filter was 80 mg/L (40–140 mg/L), and in the effluent from the septic tank with an outflow filter it was 30 mg/L (20–55 mg/L). In both cases, the average TSS concentration in raw wastewater was 503 mg/L.

Table 1
Concentration of total suspended solids at the outflow of the septic tanks

Reference	Averages ± standard deviations (mg/L)	Number of measurements
Spychała and Łucyk [7]	167 ± 20	20
Spychała et al. [8]	46 ± 11	24
Pawlak [9]	43 ± 3	194
Lowe et al. [10]	69 ± 4	61
Lowe et al. [11]	79 ± 6	88
Richards et al. [12]	116 ± 30	N. k.
	69 ± 29	N. k.
Vo et al. [13]	108 ± 53	N. k.

N. k. = not known.

Nowadays single- or double-chamber (for three to five users) septic tanks are most commonly used in on-site wastewater treatment plants. Seabloom et al. [18] indicated a negative effect of dividing the ST into two chambers. However, the results from another study [18] showed similar TSS removal efficiencies of single- and double-chamber septic tanks.

Besides the ST construction improvement, there are some attempts to modify both – the septic tank [19] and the soil infiltration system (SIS) [20,21], or to use new materials as filtering media [22] which is a reasonable trend. However, the conventional type of SIS will probably still be designed and applied due to its simple construction and low cost. Nevertheless, the knowledge related to clogging time will always be useful, independently of system construction, when soil is used as a wastewater receiver. A lot of model research is being done, for example, related to design of infiltration trenches [23].

A very important factor for clogging layer (top filter layer) permeability is the water content of clogging matter, because it directly affects the real (effective) pore void decrease. The values of this parameter vary to a large extent (Table 2).

The aim of the study was to assess the clogging time according to several decisive parameters and conditions: TSS concentration and biodegradability, biomass density, hydraulic load and clogging layer depth.

2. Methods

Due to the complexity of the phenomena of accumulation and decomposition, it is difficult to develop a mathematical model describing them in detail as a whole. Existing

Table 2
Biofilm (biomass) density according to literature sources

Reference	Biofilm density (mg/cm^3)
Lemmer et al. [25]	14
Wäsche et al. [24]	10–30
Lazarova and Manem [26]	25–105
Zhang and Bishop [27]	16.4–93.7
Zhang and Bishop [28]	39.1
Own study	50.9

models usually describe only some aspects of this process, such as the thickness of the layer with the highest content of organic matter accumulated in the soil [29]. The velocity of infiltration of wastewater into the clogging (top) layer depends on the hydraulic load, the level of the wastewater stagnating on the filter surface and the suction pressure of the unsaturated zone, located under a saturated clogging layer [30]. The lifetime of an SIS depends on the cumulative load of organic matter [31], the hydraulic conductivity related to the content of solids accumulated in the soil [32], the long-term acceptance rate [33] and the biomass content in the soil [34].

The general form of the equation describing the accumulation and degradation of pollutants (TSS) in soil (sand) can be expressed in the following form:

$$\frac{\partial X}{\partial t} = -q\frac{\partial C_{\mathrm{TSS}}}{\partial L} + k \times X \tag{1}$$

where X - content of accumulated TSS in volume unit of soil after time, mg/cm^3; t - time, d; q - hydraulic loading of the filer surface, cm/d; C_{TSS} - concentration of TSS in STE on the depth L, mg/cm^3; L - distance of STE migration in filter depth, cm; k - rate of TSS biodegradability, 1/d.

The value of the distribution of the TSS accumulated in the soil can be calculated using empirical equations [37] in the following forms:

$$k = k'_{\max}\left(E\Theta_{\mathrm{wt}} + F\right) \tag{2}$$

$$k'_{\max} = k_{\max}\left(CC_1 - D\right) \tag{3}$$

$$k_{\max} = e^{A/T+B} \tag{4}$$

After implementation of Eqs. (3) and (4) into Eq. (2) [33]:

$$k = e^{\left(A/T+B\right)\left(CC_1-D\right)\left(E\Theta_{\mathrm{wt}}+F\right)} \tag{5}$$

where k - rate of TSS biodegradability, 1/d; $k_{\max}$ - rate of biodegradability slowly degradable fraction at optimal conditions equal to 0,01 1/d (at 30°C); $k'_{\max}$ - rate of biodegradability easy degradable fraction at optimal water content of the soil, 1/d; E - constant, $E = 9$ for <0.1 or $E = -2.14$ for >0.2 or $E = 1.0$ for the rest of values; Θ_{wt} - water content of the soil; F - constant, $F = 0$ for <0.1 or $F = 1.43$ for >0.2 or $F = 0.8$ for the rest of values; C_1 - fraction of total organic carbon, which did not undergo decomposition; C, D - constants (Table 3); A - constant, $A = -6.022$; T - soil temperature, K; B - constant, $B = 12.96$.

Eq. (6) can be used to determine the mass of solids in the soil (TSS delivered with an STE) after a certain period of time, depending on their initial concentration X_p, according to the equation of the first order reaction kinetics:

$$X_t = X_p e^{-kt} \tag{6}$$

where X_t - content of (suspended) solids after time, g/m^2 of soil; X_p - initial content of (suspended) solids, g/m^{2}of soil; k - constant of decomposition velocity, 1/d; t - time of decomposition, d.

The loss of solids content after a certain period of time in relation to the initial content can be described in the form of Eq. (7). To describe the phenomenon of formation (accumulation and decomposition) of the total suspended solids over time, during the daily dosage the accumulated weight of the soil can be represented as a sum of terms in a geometric quotient in the form of Eq. (7):

$$X_t = X_d + X_d e^{-k} + X_d e^{-2k} + \ldots X_d e^{-kt} \tag{7}$$

Or in the other form:

$$X_t = X_d \frac{1-e^{-\mathrm{k}t}}{e^{k}-1} \tag{8}$$

where X_t - cumulative dose of TSS, g/m^2; X_d - daily dose of TSS, g/(m^2 d); t - whole time of dosage, d.

Assuming independent decay of several fractions of TSS, the process can be described in the form of Eq. (9):

$$X_{\mathrm{tot}} = \sum_{i=1}^{n} X_{t-i} = \sum_{i=1}^{n}\left[X_{\mathrm{d}i}\frac{1-e^{-k_i t}}{e^{k_i - 1}}\right] \tag{9}$$

where X_{tot} - total accumulated mass of several fractions of TSS, g/m^2; X_{t-i}- cumulative dose of TSS for particular fraction of TSS, g/m^2; X_{d-i} - daily dose for particular fraction of TSS, g/(m^2 d); n - number of fractions; i - summation index.

The next step is calculation of the filtration coefficient of a porous medium using the equation elaborated by Kozeny and modified by Carman [36]

$$K = \left(\frac{\rho g}{\mu}\right)\left(\frac{\varepsilon^3}{1-\varepsilon^2}\right)^2\left(\frac{d_m^2}{180}\right) \tag{10}$$

where K - filtration coefficient, m/s; ρ - water density, kg/m^3; g - earth acceleration, m/s^2; μ - dynamic viscosity of liquid, Pa·s; ε – porosity; d_m - effective diameter of soil (sand), m.

Carrier [37] suggested the use of effective diameter calculation for grain size in KC formula. The effective diameter d_m can be calculated using Eq. (11):

$$d_m = \frac{1}{\sum\left(\frac{f_i}{D_{\mathrm{ave}\,i}}\right)} \tag{11}$$

Table 3
Values of constants C and D for easy and slowly degradable sludge (solids) fractions [35]

Solids source	Easy biodegradable fraction		Slowly biodegradable fraction	
	C	D	C	D
Industrial wastewater suspended solid or sludge	83	53	40	23
Communal wastewater suspended solid or sludge	125	95	80	59

where f_i - fraction of particles between two sieve size; larger and smaller; $D_{\text{ave } i}$ - average particle size between two sieve size; larger and smaller, cm; and $D_{\text{ave } i}$ is calculated from Eq. (12)

$$D_{\text{ave } i} = D_l^{0,5} \times D_s^{0,5} \tag{12}$$

where D_l - larger sieve size, cm; D_s - smaller sieve size, cm.

The mixture of fine and medium sand (Fig. 1) was assumed for simulation.

The clogging layer hydraulic resistance (when an unsaturated zone exists under the clogging layer) can be calculated using Eq. (13) given by Bouma [30]:

$$I = \frac{h_c + h_w + S}{h_k} \tag{13}$$

where I - hydraulic gradient; h_c - clogging layer depth, m; h_w - average depth of wastewater above the clogging layer surface during wastewater dose infiltration, m; S - capillary suction of unsaturated zone, m.

The value of capillary suction of the unsaturated zone below the clogging layer was determined empirically by Spychała and Błażejewski [38] using tensiometer installed at the minimum level of the saturated layer (clogging layer, depth of 2.0 cm) and it was equal to 0.30 m; the temperature in the research well, where the fine sand columns were installed (located in the field conditions below ground level) was in range: 15°C–30°C,

Knowing the filtration coefficient and hydraulic gradient values, the infiltration velocity into the clogging layer can be calculated:

$$V_i = K_c \times I \tag{14}$$

where V_i - infiltration velocity, cm/d; K_c - clogging layer filtration coefficient, cm/d; I - hydraulic gradient.

The value of capillary suction of the unsaturated zone below the clogging layer was determined empirically by Spychała and Błażejewski [38] and it was 0.30 m. The calculated clogging layer hydraulic resistance was equal to 4.45.

The hydraulic load equaled 1.6 cm/d was assumed for fine sand and STE BOD_5 content of 150 mg/L [39] and was comparable with the EU recommendation [40] of 1.5–3.0 cm/d, but the upper limit is a relatively high value compared with field terms in Poland (domination of sandy clays and loamy sands).

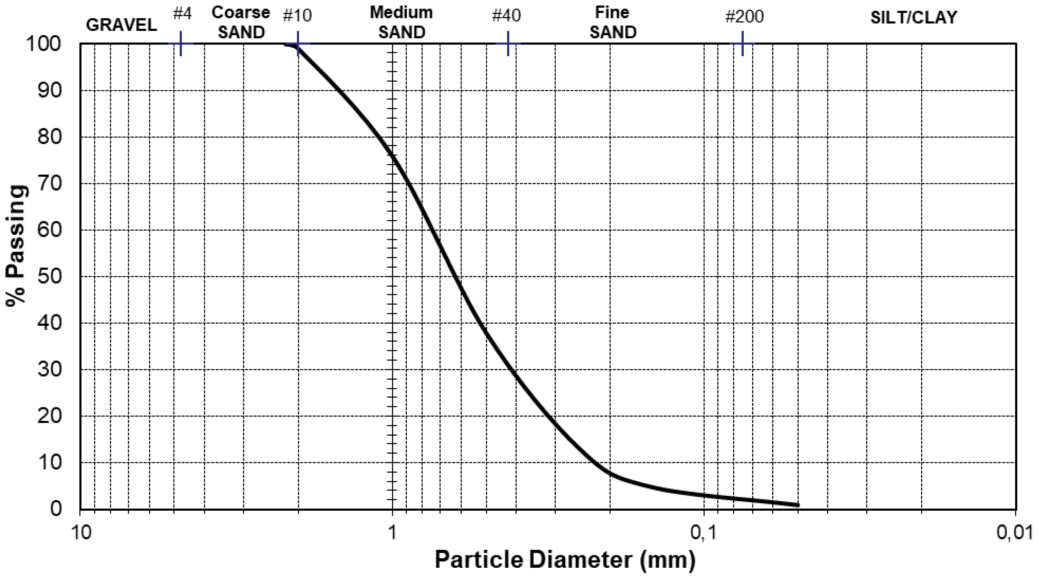

Fig. 1. Grain size distribution.

The infiltration velocity value should be compared with the hydraulic load. A value of the infiltration velocity lower than the hydraulic loading rate is an evident symptom of advanced clogging and a failure of the system, resulting in wastewater stagnation on the filter surface.

3. Results

Three exemplary values have been assumed for the simulation: 25, 50 and 75 mg/L. According to EN 1085 [41] for raw domestic wastewater 200 L/(PE·d) unit outflow and 70 g/(PE·d) TSS unit load should be assumed, what gives the TSS concentration equal to 350 mg/L. Assumed for simulation value of TSS equal to 25 mg/L corresponds to 93% ST removal efficiency. Similar values are reported by several authors as minimum values for STE [9,12]. That's why in authors opinion, 25 mg/L TSS concentration can be assumed for very high efficient STs (even equipped with different kinds of outflow polishing filters). The 50 mg/L value has been chosen as representative for the range most common in the literature [10–12]. The third value (75 mg/L) has been chosen as representative (in authors subjective opinion) for the high TSS concentration in STE, characterized by relatively low efficiency (about 80%). Although this value is much lower than maximum values reported in the literature, in authors opinion, the values about 100 mg/L and higher should be treated as obtained rather by failure or not properly (too high amount of sludge) maintained ST (efficiency about 70% or lower).

Using Eqs. (1)–(9), the independent decay of several fractions of TSS was calculated. Each fraction (excluding non-degradable) can be characterized by a specific decomposition rate (Fig. 2).

The empirically indicated values of TSS concentrations in STE have been used. From the wide range (Table 1), three values have been taken to represent average, minimum and maximum values for this simulation. Assuming a particular TSS concentration in STE it is possible to calculate the total mass accumulated in the SIS in time. Not all matter transported with the STE is accumulated in the filter; therefore the accumulated matter was reduced by the rate of TSS removal efficiency presented by the filter. The TSS removal efficiency (74%) was assumed as indicated during studies carried on the same type of soil [42].

Based on the Spychała and Błażejewski [38] study, it was assumed that 22% was accumulated in the top two cm of filter depth (clogging layer).

The real porosity of the clogging layer after the time of operation at given values of variables (TSS concentration, clogging layer thickness and water content: 0.02) was calculated.

Regarding the organic matter vertical distribution in the sand filter and its content in the clogging layer, the value of capillary suction under the clogging layer was measured. The value of initial porosity was assumed to be 0.375 [43]. The final effective (after time) porosity was calculated as the difference between initial porosity and biomass volume.

The filtration coefficient of a porous medium was calculated using the equation developed by Kozeny (1927) and modified by Carman (1957) [36] (Eq. (10)).

As the next step, the hydraulic load was taken into consideration. The hydraulic load equal to 1.6 cm/d was assumed following US EPA recommendations [39].

Simulations showed that the estimated time of clogging can vary within a very wide range (Fig. 3). For fine sand, TSS concentration of 25 mg/L, recommended hydraulic load (1.6 cm/d) and average dry mass content in biomass equal to 0.02, this time is about 29 years. The clogging time is much shorter – about 11 years – for the same values as mentioned above but for TSS concentration equal to 50 mg/L. However, such concentration is still relatively low compared with values observed in the field studies. For the TSS concentration in STE, equal to 75 mg/L (close to the medium value from the field data range), this simulation showed that clogging can occur after 5 or 6 years only.

4. Discussion

The decay of several fractions of TSS was calculated (Eqs. (1)–(9)). It is worth noting that the temperature and humidity have a significant impact on the decomposition rate of the slow-degradable fraction of TSS, for example, during the winter season [35]. However, not all studies support such a high dependence of the rate of the process (the

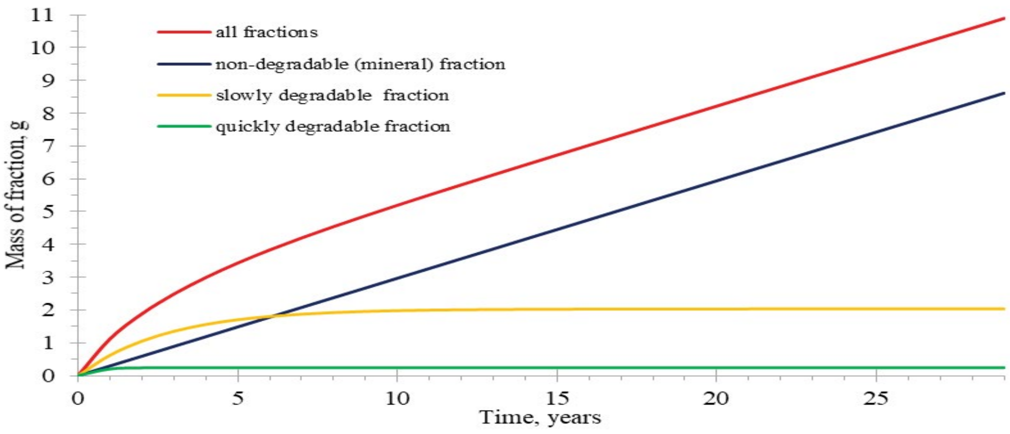

Fig. 2. Solid fractions' cumulative content in soil (sand) dependent on time of supply (for 25 mg/L TSS in STE).

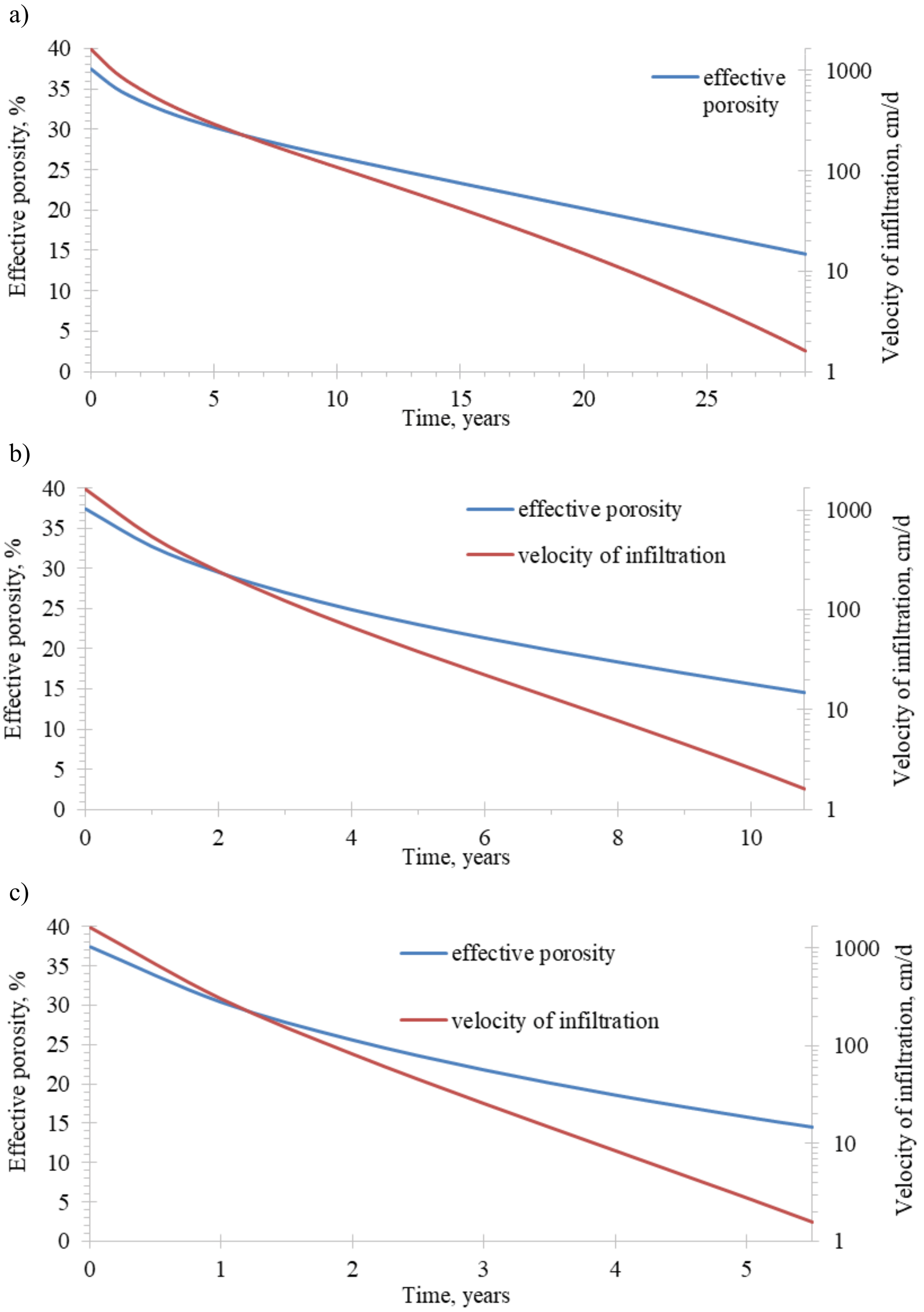

Fig. 3. Predicted clogging time: (a) simulation for 25 mg/L TSS in STE; (b) simulation for 50 mg/L TSS in STE; (c) simulation for 75 mg/L TSS in STE.

rate of decomposition) on the temperature. For example, Thomas and Bendixen [44] found no effect of temperature on the rate of degradation of organic carbon in wastewater pretreated in the septic tank, fed into the soil. Other authors reported that the rapid growth of biomass can cause a strong decrease in hydraulic conductivity [45]. These authors indicated influence of variable substrate dosing and oxygen accessibility on growth rate and biomass decomposition.

The smallest percentage of the wastewater dosage is an irreducible fraction (mineral), but due to the lack of decay (k = 0) the accumulation is greatest and is linear (Fig. 2). Other fractions were degradable (organic). The cumulative weight of these fractions after a certain period of time tends to a constant value (the increment becomes smaller). The lower the value of the distribution constant, the longer the time after which this stabilization occurs; in this case for k = 0.005 1/d this time is approximately 1 year, and for k = 0.001 1/d it is about 10–12 years.

The TSS removal efficiency of soil infiltration layer (30.0 cm of thickness), equaled to 74%, and the rate of organic matter accumulation in clogging layer (22%) was assumed based on the Spychała and Błażejewski [38] research, because that studies were carried out in comparable conditions on the same type of soil (43.7 ± 5.1 mg/L of TSS in STE and 6.5 ± 1.7 mg/L of TSS in treated wastewater, $n = 31$). In that study, 39 mg of organic matter was accumulated in the first two centimeters of depth (180 mg of total dry organic mass was observed in the whole depth of the filter equal to 30 cm).

The distribution of solids in the filter vertical profile depends on several factors (soil grain size and uniformity, compaction, hydraulic loading, dose volume, time of dosage and many others), but for comparable conditions similar distributions in a fine sand can be found in the literature, both for modeled data [46] and empirical research [47]. A study carried out by Miller at al. [47], for an experiment lasting 158 d and hydraulic loading of wastewater (BOD_5 equal to 15 g O_2/m^3 on average) equal to 122 cm/d, the solids content in the first 1 cm of depth was about 25%–30% of the total mass of the whole vertical profile.

A very important factor for clogging layer permeability is the water content of clogging matter (biomass), because it directly affects the real (effective) pore void decrease. TSS density was assumed to equal 20 mg/cm^3 (0.02), being comparable with biomass density (the clogging matter due to presence of microorganisms and extracellular substances). This parameter is largely differentiated by one order of magnitude – according to literature data (Table 3) between 10 and 105 mg/cm^3, because it is depended on numerous and various factors and conditions, that is: live organisms content, physical conditions, hydraulic conditions, stressing factors and many other factors affecting biofilm (biomass) properties.

The filtration coefficient for given final effective (after time) porosity was calculated using the equation developed by Kozeny (1927) and modified by Carman (1957) [36] (Eq. (10)). This coefficient should be defined especially for the clogging layer, which is saturated (especially when the wastewater ponds on the surface) and has a decisive impact on the whole filter permeability, because of the much smaller value than the permeability coefficient of deeper layers. Under the clogging layer, the soil is often unsaturated, which makes the permeability coefficient calculations more complicated.

The highest, assumed in this study, TSS concentration of 75 mg/L resulting in clogging time of almost 6 years was relatively low compared to values observed in the field studies (Table 1) – much higher than 100 mg/L in many cases.

The presented calculated scenarios showed that TSS concentration in STE frequently occurring in the field conditions can cause relatively fast clogging and failure of the system – after 2–3 years. It corresponds to some reports, for example, from some Polish communities equipped with on-site wastewater treatment plants equipped with ST. There are reports in the last years that it is not rare in Polish communities having systems with ST and SIS for there to be failure of several from several dozen objects after 1–3 years of lifespan.

The values of clogging time (lifespan) of SIS in this study were simulated assuming that the volume of microorganisms is negligibly low, but there exist some reports suggesting that it can play a more significant role in soil filter pores [46]. Taking into account this factor, the calculated values of clogging time would be even shorter.

5. Conclusions

Based on this study, the following conclusions can be drawn:

- For the TSS concentration in STE, equal to 75 mg/L (close to the medium value from the field data range), this simulation showed that clogging can occur after 5 or 6 years only.
- Due to the fact that the only controllable factor, besides hydraulic load, is the concentration of TSS, one should strive for the use of highly efficient septic tanks or tertiary treatment units in order to obtain the lowest possible concentrations of TSS in the STE introduced into the SIS.
- Beside the growth and decay rate, very important factors are biomass water content (volume) and maximum biomass concentration. Further studies related to live biomass concentration in porous media and its water content during STE filtration are needed.
- Clogging layer depth is often not exactly detected, but it has a crucial role in mathematical model formulating. Therefore further investigations on this topic are warranted.

Symbols

A — Constant
B — Constant
C — Constants
C_{TSS} — Concentration of TSS in STE on the depth L, mg/cm^3
C_1 — Fraction of total organic carbon, which did not undergo decomposition
D — Constants
$D_{ave\,i}$ — Average particle size between two sieve size; larger and smaller, cm
D_l — Larger sieve size, cm
d_m — Effective diameter of soil (sand), m
D_s — Smaller sieve size, cm
E — Constant
F — Constant
f_i — Fraction of particles between two sieve size; larger and smaller
g — Earth acceleration, m/s^2
h_c — Clogging layer depth, m
h_w — Average depth of wastewater above the clogging layer surface during wastewater dose infiltration, m
i — Summation index
I — Hydraulic gradient
k — Rate of biodegradability, 1/d
K — Filtration coefficient, m/s
K_c — Clogging layer filtration coefficient, cm/d
k_{max} — Constant of slowly degradable fraction at optimal conditions equal to 0,01 1/d (at 30°C)
k'_{max} — Constant of easy degradable fraction at optimal water content of the soil, 1/d
L — Distance of STE migration in filter depth, cm

n — Number of fractions
q — Hydraulic loading of the filter surface, cm/d
S — Capillary suction of unsaturated zone, m
t — Time, d
T — Soil temperature, K
V_i — Infiltration velocity, cm/d,
X — Content of accumulated TSS in volume unit of soil after time, mg/cm^3
X_d — Daily dose of TSS, g/(m^2 d)
$X_{d\text{-}i}$ — Daily dose for particular fraction of TSS, g/(m^2 d)
X_p — Initial content of (suspended) solids, mg/L of soil
X_t — Content of TSS, g/m^2
X_{tot} — Total accumulated mass of several fractions of TSS, g/m^2
$X_{t\text{-}i}$ — Cumulative dose of TSS for particular fraction of TSS, g/m^2
μ — Dynamic viscosity of liquid, Pa s
ε — Porosity
Θ_{wt} — Water content of the soil
ρ — Water density, kg/m^3

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