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Raziskave možnosti uporabe porozne keramike kot podstave ali filtrirne snovi pri čiščenju odpadnih vod

Using Porous Ceramics as a Substrate or Filter Media During the Cleaning of Sewage

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Naše preiskave so pokazale, da je lahko porozna keramika ustrezno nosilo biomase (podstava) pri bioloških čistilnih napravah. Lahko se uporablja tudi pri sistemu za vpihovanje zraka ter kot filtrirna snov v membranskem filtru v kombinaciji z biološko čistilno napravo. Posamezni rezultati preskusov so zelo spodbudni, zato smo prepričani, da imajo tovrstne snovi dobre možnosti za uporabo pri bioloških čistilnih napravah.

(Ključne besede: čiščenje odpadnih voda, naprave čistilne biološke, snovi filtrirne, keramika porozna)

Our research has shown that porous ceramics are good holders of biomass in biological water-treatment plants. They can also be used as an air-blowing system or as the filter media on a membrane filter in combination with a biological water-treatment plant. Individual tests have shown very positive results, and for this reason we are convinced such materials have good possibilities for more frequent use in biological water-treatment plants.

(Keywords: cleaning sewage, biological water-treatment plants, filter media, porous ceramics)

0 UVOD

Keramične podstave in filtrirne snovi se lahko vgrajujejo v čistilne naprave na različne načine, pri čemer imajo lahko zelo velik vpliv na učinek delovanja in s tem na oblikovanje same čistilne naprave. Pri tem lahko postopke biokemijskega čiščenja samo večajo, ali pa so glavno nosilo čiščenja. Vsi pojavi spodbujanja ali zaviranja biokemijskih postopkov razgradnje nečistoč še niso v celoti raziskani, dokazano pa je, da nekateri materiali omogočajo hitrejše postopke biokemijske razgradnje od drugih.

Postopke čiščenja, pri katerih sodelujejo keramične podstave in filtrirne snovi lahko razdelimo v naslednje skupine:
- biokemijska razgradnja nečistoč z bakterijsko združbo (keramične podstave so nosila biomase),
- fizikalno zadrževanje delcev s filtracijo (membranski filter),
- preostali postopki (adsorpcija, kemične reakcije, prenos informacij itn.).

0 INTRODUCTION

Ceramic substrates and filter media can be built into water-treatment plants in various ways, where they can have a great impact on the effect of the plant's activity and by that on the size of the water-treatment plant. In this way the procedures of biochemical cleaning are intensified or the ceramic substrates and the filter media become the main holders of cleaning. All the processes of stimulation or braking of the biochemical processes of the decomposition of impurities are still not explored well enough, although it has been proven that some materials enable quicker biochemical decomposition than others.

The processes of cleaning during which ceramic substrates and the filter media participate can be divided into the following groups:
- biochemical decomposition of impurities with the help of a bacterial community (ceramic substrates are holders of the biomass)
- physical holding of the particles with filtering (membrane filter)
- other processes (adsorption, chemical reactions, transfer of information, etc.)

Kadar se uporablja keramična snov kot filtrirna snov, katere glavna naloga je zadrževanje delcev (membranski filter), prevladujejo fizikalni postopki čiščenja. V takšnih primerih veljajo enačbe [3].

Za filtracijo velja naslednja enačba spreminjanja koncentracije (masna bilanca):

When one uses ceramic material as filter media, of which the main function is holding of the particles (the membrane filter), then the physical processes of cleaning prevail. In such instances the following equations can be applied [3].

For filtering the next equation for changing the concentration holds (mass balance):

$$\frac{\partial \sigma}{\partial t} + v_f \frac{\partial C}{\partial z} = 0 \qquad (1).$$

Enačba hitrosti filtracije pri čistilnih napravah:

The equation of filtration velocity is:

$$v_f = \frac{Q}{F} = -k_f \frac{d\psi}{ds} \qquad (2).$$

Kinetična enačba pa je:

The kinetic equations are:

$$\frac{\partial C}{\partial z} = \xi C \qquad (3)$$

$$\xi = F\ (dk\ \text{-1 do/to -3}\ ;\ ds\ \text{0 do/to 2}\ ;\ vf\ \text{0,3 do/to -1,56}\ ;\ \Pi^{0,5}\ \text{do/to}\ \Pi^{-2}\ ) \qquad (4)$$

$$\xi = a(\Pi - \sigma) \qquad (5)$$

$$\xi = b - c\frac{\sigma}{v_f.C} \qquad (6)$$

$$\xi = \xi_0 + e.\sigma - f\frac{\sigma}{\Pi - \sigma} \qquad (7).$$

Tu pomenijo:

v_f	filtracijska hitrost [m/s]
Q	pretok vode [m^3/s]
k_f	koeficient pretoka [m/s]
dψ/ds	potencialni padec
F	pretočni prerez [m^2]
s	pot pretoka [m]
σ	upornost filtra (zamašitev filtra)
C	koncentracija snovi, ki jo filtriramo [g/m^3]
z	debelina filtrirne snovi [m]
ξ	filtracijska stalnica
d_s	premer delca v suspenziji [m]
d_k	premer delcev v filtru (velikost odprtin) [m]
Π	poroznost filtrirne snovi
a, b, c	stalnice [-]
e, f	stalnici [-]
ξ_o	stalnica [-]

Pri precejalniku ima podstava glavno vlogo zagotovitve ustrezne površine, na kateri se razvije bakterijska združba. V postopke fizikalnega in kemijskega čiščenje se podstava vključuje v glavnem le posredno. Glavni postopki čiščenja potekajo med odpadno vodo in bakterijsko združbo. Pri rastlinski čistilni napravi s pritrjenim rastlinjem gre v bistvu

Meanings of the symbols:

v_f	velocity of filtering [m/s]
Q	flow rate of water [m^3/s]
k_f	hydraulic conductivity (flow coefficient) [m/s]
dψ/ds	potential drop
F	flow cros-section [m^2]
s	flow path [m]
σ	resistance of the filter
C	concentration of the filtrated material [g/m^3]
z	thickness of the filter media [m]
ξ	filtration constant
d_s	diameter of the particle in suspension [m]
d_k	diameter of the particles in the filter (size of openings) [m]
Π	porosity of the filter media
a b, c	constants [-]
e, f	constants [-]
ξ_o	constant [-]

At the filter the main function of the substrate is to ensure a suitable surface on which the bacterial community develops. In the processes of physical and chemical cleaning the substrate is only indirectly incorporated. The main processes of cleaning occur in the next relation: wastewater - bacterial community. A wetland water-treatment plant with a fixed wetland is, in essence, prav tako za precejalnik, saj prevladujoči postopki čiščenja potekajo med pritrjeno bakterijsko združbo na podstavi in odpadno vodo (Börner T.). V rastlinski čistilni napravi je namreč več ko 90% bakterijske združbe pritrjene na podstavi. Rastline so v glavnim namenjene za dovod kisika do bakterijske združbe ter porabljajo nastalo biomaso za svojo rast.

Postopke čiščenja, ki potekajo na precejalniku, lahko obravnavamo tudi kot podaljšano vzdolžno disperzijo, pri čemer na ni pomembno, kakšni postopki v čistilni napravi potekajo, temveč le učinki čiščenja [5]:

also a filter, because the dominant processes of cleaning are performed in the next relation: fixed bacterial culture on substrate - sewage (Börner, 1992). In a wetland water-treatment plant more than 90% of the bacterial communities are fixed on the substrate. The vegetation serves as an oxygen supplier for the bacterial community and it uses the formed biomass for its own growth.

The processes of cleaning that occur on the filter may be viewed as a prolonged longitudinal dispersion, where only the cleaning effects, not the processes occurring in the water-treatment plant, are important [5]:

$$D\frac{\partial^2 C}{\partial x^2} - V\frac{\partial C}{\partial x} = \frac{\partial C}{\partial t} \qquad (8).$$

Rešitev zgornje enačbe pri spremljanju koncentracije katerekoli snovi v precejalniku ali rastlinski čistilni napravi pri začetnih pogojih t = 0, C(0,t) = C_o, se glasi:

The solution of the above equation during the monitoring of the concentration of any material in a filter or in a wetland water-treatment plant for the initial conditions t = 0, C(0,t) = Co is the following:

$$C(x,t) = \frac{1}{2}C_0 e^{t\gamma}\left\{e^{\frac{x(V-\xi)}{2D}} \cdot erfc \cdot \left(\frac{x-\xi.t}{2\sqrt{Dt}}\right) + e^{\frac{x(V+\xi)}{2D}} \cdot erfc\left(\frac{x+\xi.t}{2\sqrt{Dt}}\right)\right\} \qquad (9)$$

$$\xi = \sqrt{V^2 + 4D\gamma} \qquad (10)$$

$$erfc\ y = 1 - erf\ y = 1 - \phi.(y) = 1 - \frac{2}{\sqrt{\pi}}.\int_0^y e^{-Z^2} dz \qquad (11).$$

Tu pomenijo:

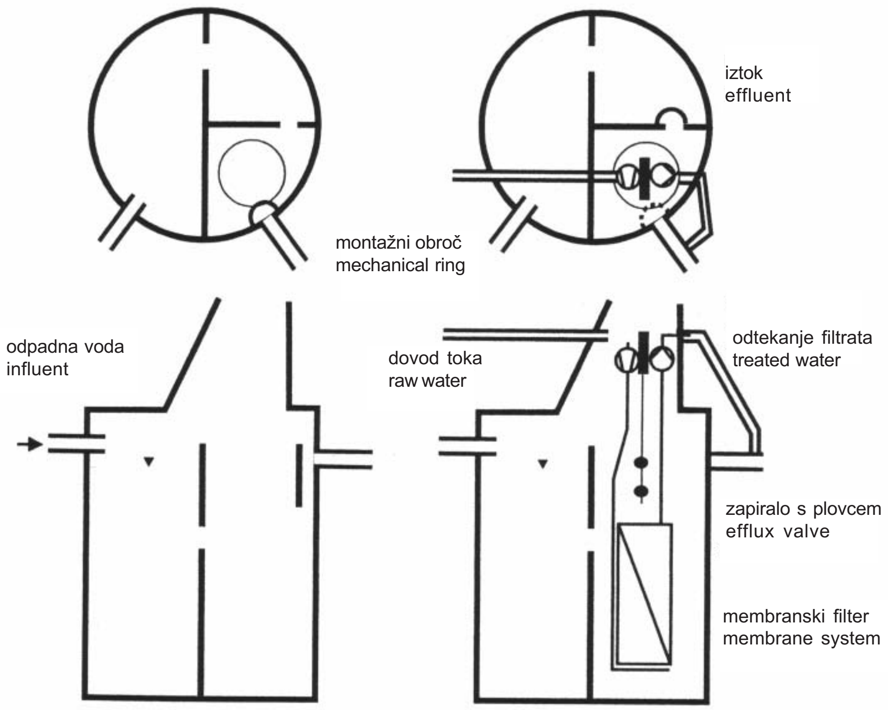
D	vzdolžni disperzijski koeficient [m²/s]
C	koncentracija raztopine v tekočini [g/m³]
V	povprečna hitrost toka [m/s]
X	koordinata vzporedna s tokom tekočine [x]
t	čas [s]
ξ	filtracijska stalnica

Meanings of the symbols:

D	longitudinal dispersion coefficient [m²/s]
C	solution concentration in the liquid [g/m³]
V	mean flow velocity [m/s]
X	coordinate parallel to the liquid current [m]
t	time [s]
ξ	filtration constant

Porozna keramika se lahko uporablja kot nosilo biomase (podstava) ali pa kot membranska filtrirna snov. V zadnjem času se uporabljajo membranski filtri v kombinaciji z biološkimi čistilnimi napravami. Kot filtrirna snov v teh membranskih filtrih se uporabljajo najpogosteje polimerne in kompozitne membrane, porozna keramika, porozno steklo, porozne kovine pa redkeje. Razlog za to je verjetno v slabšem poznavanju tehnologije izdelave drugih membranskih naprav. Najbolj razvite so tehnologije izdelave polimernih in kompozitnih membran, zato so takšne naprave postale lahko dostopne in razmeroma poceni. Mnenja smo, da je mogoče iz porozne keramike izdelati tudi ustrezne membranske filtrirne naprave, ki se lahko vgrajujejo v membranske filtre in niso bistveno slabši od polimernih. Pri nekaterih značilnostih imajo lahko tudi določene prednosti, ki jih je mogoče koristno izrabiti.

Porous ceramics can be used as a holder of biomass (substrate) or as membrane filter media. Lately, the membrane filters have been used in combination with biological water-treatment plants. As the filter media in these membrane polymeric filters and composite membranes are often used, while porous ceramics, porous glass and porous metals are used only rarely. The main reason for that is probably the somewhat poorer knowledge of the technology of making of other membrane modules. The most developed is the technology of making polymeric and composite membranes, which is nowadays accessible and relatively cheap. Our opinion is that from a porous ceramics membrane filter modules can also be made. They can then be built into the membrane filters, and are as effective as the polymeric ones. In the case of some characteristics they can also have important advantages that can be usefully employed.



Sl. 1. *Primer male čistilne naprave brez membranskega filtra in z vgrajenim membranskim filtrom [2]*
Fig. 1. *Example of a small-sized water-treatment plant without a membrane filter and with a built-in membrane filter [2]*

Primer vgradnje membranskega filtra v majhno komunalno čistilno napravo je prikazan na sliki 1. Avtor Gründer B. [2] ne navaja vrste membran, ki so vgrajene v filtru, ker to ni pomembno. Pomembno je, da takšna membranska naprava ustrezno deluje.

Porozne keramične snovi (podstave, filtrirne snovi) lahko izdelamo na več načinov, odvisno od lastnosti, ki jih pričakujemo. Pri sintranju keramične snovi lahko dosežemo popolno zlitje delcev, ali pa ostane del strukture še odprt. Pri izdelavi grobih keramičnih membran se lahko v keramično maso vmeša gorljiv organski material, ki omogoča nastanek razmeroma velike odprte površine. Kot najbolj grobi dodatek za dosego odprtosti strukture se lahko uporablja zelo drobna žagovina, še drobnejše pore pa omogoča dodatek škroba. Najdrobnejšo strukturo keramičnih membran dosežemo s slojem aluminijevega hidroksida.

V keramične snovi in steklo je mogoče vgrajevati tudi različne informacije, ki lahko spodbujajo postopke biokemijske razgradnje. Opravili smo nekaj tovrstnih preizkusov in ugotovili določene pozitivne učinke. Rezultati preiskav še tečejo, zato jih ne navajamo. Pri tem gre v veliki

An example of the implantation of a membrane filter in a small communal water-treatment plant is shown in Figure 1. The author of this figure (Gründer, 2000) does not state the type of membranes that are being used because it is not important. What is important is that such a membrane module works properly.

Porous ceramic materials (substrate, filter media) can be made in various ways. This depends on the characteristics we want them to have. During the sintering of ceramic material we can either achieve the perfect fusion of particles or a part of structure remains opened. When creating rough ceramic membranes we can add combustible organic materials, which enables the creation of a large open surface. As the roughest additive for achieving the openness of the structure one can use very refined sawdust, whereas more refined pores can be achieved by adding starch. We can achieve the most refined ceramic-membrane structure with the help of a layer of aluminium hydroxide.

In ceramic materials and glasses it is possible to build-in "information", which can stimulate the processes of biochemical decomposition. We have conducted several such experiments that show some positive effects. The results of our research are currently being investigated in a more thorough manner, and meri tudi za postopke, ki še niso v celoti znanstveno razjasnjeni.

that is why we do not mention them in this paper. Most of the processes are still not scientifically cleared up.

1 SNOVI IN METODE

Pri pilotnih preizkusih izdelave keramičnih membran smo se zadovoljili s simetrično strukturo, zato je postopek izdelave obsegal le tri faze: priprava keramične mase, oblikovanje profila in sintranje. Izbrali smo dve različni keramični snovi: FSZ/F–Fuchssche Tongruben GmbH & Co. KG in S 3–Keramika Liboje

Snov FSZ/F je deklarirana kot snov z razmeroma majhno poroznostjo, medtem ko ima S – snov 2 do 3 krat večjo poroznost. Za ugotavljanje filtracijske zmožnosti porozne keramike smo merili: zmožnost vpijanja vode, prepustnost zraka, prepustnost vode ter zmožnost zadrževanja delcev TiO_2 z znano porazdelitvijo delcev.

Preizkuse uporabe različnih podstav smo izvajali na poskusni čistilni napravi, izdelani iz poliakrilnega stekla, ki je podana na sliki 2. V prekate smo dajali podstave (rečni prod, zeolit, keramika, steklo, šota, vermikulit itn.) in odpadno vodo spuščali prek naprave na različne načine.

V velikih prekatih P1, P2 in P3 smo imeli rečni prod, v prekate 1, 2, 3 in 4 pa smo dodajali posebne podstave. Pred dodajanjem posebnih podstav smo spuščali prek čistilne naprave samo greznično odpadno vodo, da se je na pesku kot podstavi oblikovala ustrezna bakterijska združba. Nato smo dodajali posebne podstave. Dejavnost mikrobne biomase smo merili z metodo spremembe INT (jodo-nitro-tetrazonijevega klorida) v formazan. V epruvete smo dodali okoli 20 g peska ali druge podstave z bakterijskim filmom, dodali 5 ml 0,85% NaCl, 0,5 ml 0,5% Na – acetata in 0,2 ml

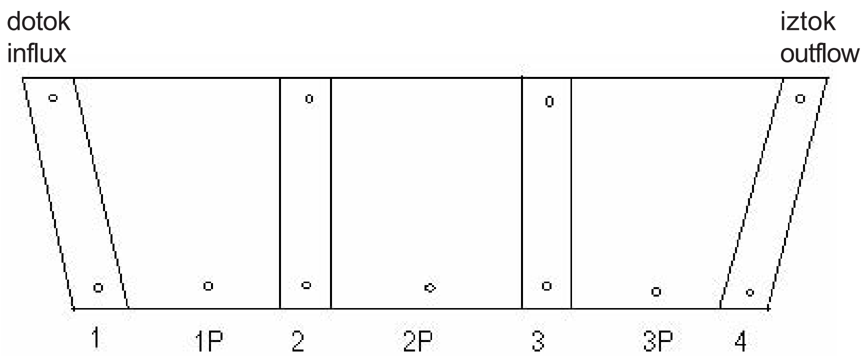
1 MATERIALS AND METHODS

The ceramic membranes used in the pilot experiments were made with only a symmetrical structure, and that is why the manufacturing procedure included only three phases: preparing the ceramic mass, forming of the profile, and sintering. Two different ceramic masses were chosen: FSZ/F- Fuchssche Tongruben GmbH & Co. KG and S 3 - Ceramics Liboje.

The mass FSZ/F is declared as the one with the relatively low porosity, while the porosity of the S3 mass is two to three times greater. To establish the filtration ability of the porous ceramics we measured the following: ability to absorb water, permeability to air, permeability to water, and the ability of to hold TiO_2 particles with a known distribution.

The use of different substrates was carried out on a pilot water-treatment plant made from Plexiglas, which is shown in Figure 2. We placed the substrates in ventricles (river gravel, zeolite, ceramics, glass, peat, Vermikulit, etc.) and dropped sewage over the device in different ways.

River gravel was placed in the large chambers P1, P2 and P3, and in chambers 1, 2, 3 and 4 special substrates were added. Before adding the special substrates we dropped only plain sewage over the water-treatment plant to enable the bacterial community to form on the substrate (sand). Next, special substrates were added. The activity of the microbial biomass was measured with the INT conversion method (iodo-nytro-tetrasonium chloride to formazan). In the test tube we added approximately 20 g of sand or other substrate with a bacterial film and added 5 ml of 0.85% NaCl, 0.5 ml of 0.5% Na - acetate and 0.2 ml of 0.25%



Sl. 2. *Skica poskusne čistilne naprave*
Fig. 2. *Pilot-plant scheme*

0,25% INT. Vzorce smo inkubirali pri sobni temperaturi in po 24 urah izločili formazan s 3 ali 5 ml izobutanola. Količino nastalega formazana smo določili spektrafotometrično pri valovni dolžini 490 nm. Izračun smo izvedli po naslednjem obrazcu:

INT. The samples were incubated at room temperature and after 24th hours we extracted formazan with the help of 3 or 5 ml of iso-butanol. The amount of formed formazan was established with the spectrophotometric method at a 490-nm wavelength. The calculations were carried out with the following equation:

$$\text{dejavnost mikrobnega ETS/activity microbs ETS } (\mu l\ O_2 S^{-1} h^{-1}) = \frac{Abs^{490nm}.V_r}{S.t.1,42.V_t} \quad (12).$$

Tu pomenijo:

Abs$^{490\ nm}$ absorpcija izobutanolne frakcije [-],

V_r končna prostornina reakcijske zmesi (5,7 ali 11,4) [ml],

S velikost vzorca (podstave) [g],

t čas inkubacije (24 ur) [h],

1,42 faktor premene količine formazana v prostornino kisika [-].

Meanings of the symbols:

Abs$^{490\ nm}$ absorption of isobutanol fraction [-],

V_r final volume of the reaction mixture (5.7 or 11.4) [ml],

S size of sample (substrate) [g],

t time of incubation (24 hours) [h],

1.42 conversion factor (amount of formazan to the volume of oxygen) [-].

2 EKSPERIMENTALNI DEL

2.1 Izdelava keramičnih filtrirnih snovi

Iz izbranih keramičnih mas z deležem vlage 19% (FSZ/F– Fuchssche Tongruben GmbH & Co. KG in S 3– Keramika Liboje) smo izdelali ploščati filtrirni snovi s postopkom struženja. Po sušenju smo sintrali izdelka v električni peči pri različnih temperaturah. S sintranjem se zagotovi ustrezna mehanska trdnost ter delno zmanjša poroznost. Najprej smo izmerili velikost in porazdelitev delcev v keramičnih snoveh. Ta porazdelitev je zelo pomembna, saj po sintranju zagotavljajo poroznost prav prazni prostori med delci. S temperaturo in časom sintranja se prazni prostori postopno zmanjšujejo in v končni fazi pride do popolnega zlitja. Na sliki 3 sta prikazani porazdelitveni krivulji za obe uporabljeni keramični snovi. Velikost in porazdelitev delcev pri obeh keramičnih snoveh sta približno enaka. Zato je bila tudi velikost odprtin med delci v obeh primerih približno enaka. Ker sta bila tudi čas in temperatura sintranja za obe gradivi enaki, je bila poroznost odvisna le od vrste snovi.

S slike 4 je razvidno, da je prepustnost zraka zelo odvisna od temperature sintranja ter vrste keramične snovi. Pri keramični snovi FSZ/F je pri temperaturi 1000 °C že prišlo do tako majhne prepustnosti zraka, da z razpoložljivo metodo ni bila več merljiva.

Tudi vpojnost vode je odvisna od temperature sintranja in vrste snovi. Keramična

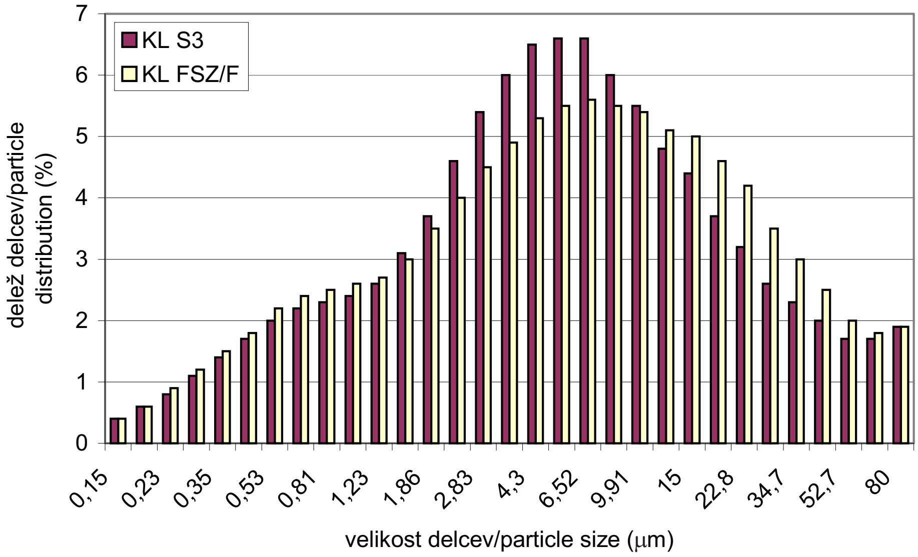
2 EXPERIMENTAL

2.1 Making the ceramic filter media

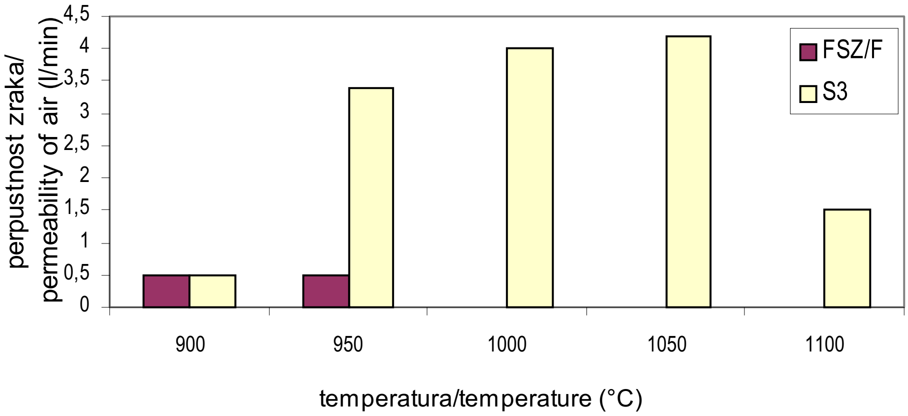
From selected ceramic masses with a 19% moisture content (FSZ/F- Fuchssche Tongruben GmbH & Co. KG and S3- Ceramics Liboje) we created flat filter media using lathe-tooling methods. After the products were dried they were sintered in electric furnaces at different temperatures. The sintering ensures a suitable mechanical strength and partly reduces the porosity. First we measured the size and distribution of particles in the ceramic masses. This distribution is very important because after sintering the empty places between the particles ensure the porosity. The exposure time and the sintering temperature slowly reduce the size of the empty places until it comes to a perfect fusion. Figure 3 shows the distribution curve for both the ceramic masses used. The size and the distribution of the particles in both the ceramic masses are approximately equal. Therefore, the size of the openings between the particles in both cases was approximately equal. Because the exposure time and the sintering temperature were the same for both materials, we can conclude that the porosity depends only on the type of material.

From Figure 4 it can be seen that the permeability of the air is very dependent on the temperature of the sintering and on the ceramic mass type. In the case of the FSZ/F ceramic mass the permeability of the air at 1000°C was so small that we were not able to measure it.

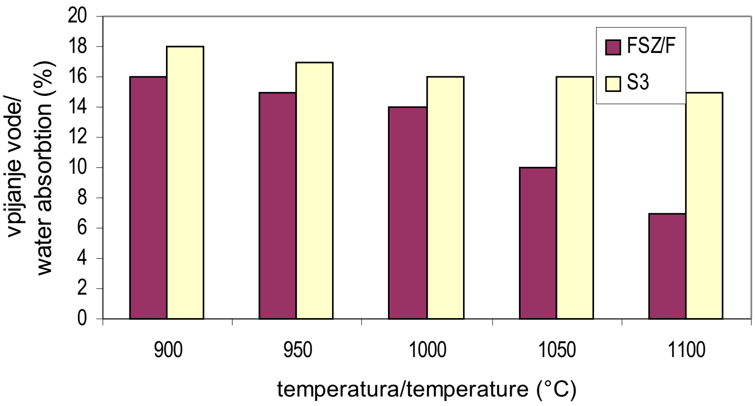
The water absorbency is also dependent on the sintering temperature and on the type of mate-



Sl. 3. *Porazdelitvene krivulje delcev v keramičnih snoveh FSZ/F in S 3*
Fig. 3. *Particle distribution curve for ceramic masses FSZ/F and S3*



Sl. 4. *Odvisnost prepustnosti zraka od temperature sintranja*
Fig. 4. *Permeability of air versus the sintering temperature*



Sl. 5. *Odvisnost prepustnosti zraka od temperature sintranja (l/min), ΔP = 400 Pa*
Fig. 5. *Permeability of air versus the sintering temperature (l/min), ΔP = 400 Pa*

snov S3 je imela pri 900 °C nekoliko večjo vpojnost vode kakor FSZ/F. S povečanjem temperature sintranja do 1100 °C pa se ji je vpojnost vode le nekoliko zmanjšala, medtem ko se je pri snovi FSZ/F zmanjšala za več ko 60 odstotkov.

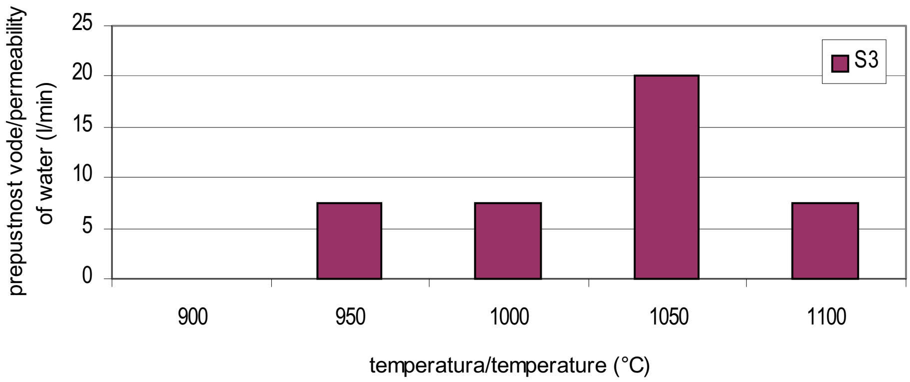
Pri napravi, izdelani iz keramične snovi S, ki se je pokazala kot primernejša, smo izmerili tudi odvisnost prepustnosti vode od temperature sintranja. S slike 6 je razvidno, da je bila dosežena največja prepustnost vode pri temperaturi sintranja 1050 °C.

Pri porozni keramiki, ki je bila izdelana iz keramične snovi S 3 in sintrana pri 1050 °C, smo merili tudi zmožnost zadrževanja delcev iz vodne suspenzije delcev Ti O_2 s porazdelitvijo, ki smo jo predhodno izmerili in je podana na sliki 7. Ker v filtratu nismo

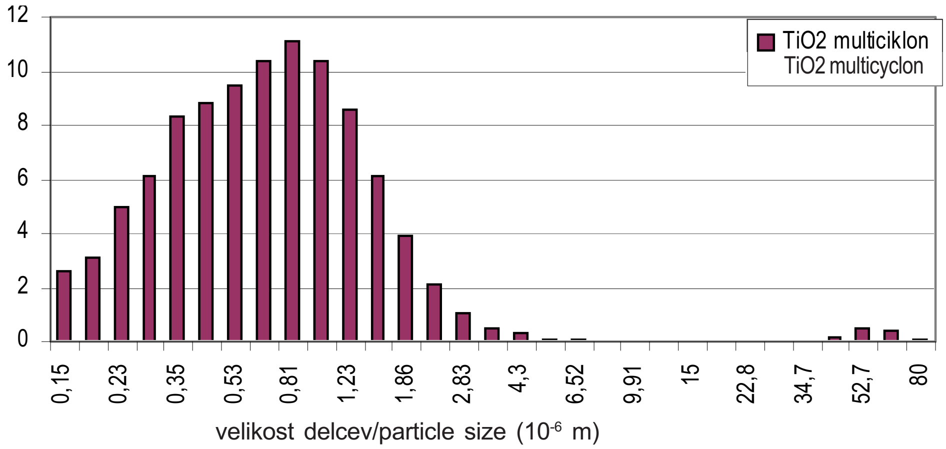
rial. At 900°C the S3 ceramic mass had a slightly larger water absorbency than the FSZ/F. By increasing the sintering temperature to 1100°C the water absorbency of the S3 reduced slightly, while for the FSZ/F it fell by more than 60%.

In the case of the module made from ceramic mass S3, which proved to be more suitable, the dependence of the water permeability on the sintering temperature was also measured. From Figure 6 it is clear that the greatest permeability of water was achieved for a sintering temperature of 1050°C.

In the case of the porous ceramic that was made from ceramic mass S3 and sintered at 1050°C we also measured the ability to hold particles of TiO_2 particle water suspension with a distribution that was preliminarily measured and is shown in Figure 7. Because we could not establish the presence of the TiO_2



Sl. 6. *Odvisnost prepustnosti vode od temperature sintranja (l/min), ΔP = 100 Pa*
Fig. 6. *Permeability of water versus the sintering temperature (l/min), ΔP = 100 Pa*



Sl. 7. *Porazdelitvena krivulja delcev TiO_2, ki smo jih uporabili za testiranje porozne keramike*
Fig. 7. *Distribution curve of TiO_2 particles that were used for testing the porous ceramics*

opazili delcev Ti O_2, smo mnenja, da so pore manjše od velikosti najdrobnejših delcev.

Pri primerjavi našega vzorca porozne keramike z drugimi filtrirnimi snovmi se vidi velika razlika med PTFE in keramičnimi membranami. Membrana PTFE je znana kot filter z najbolj odprto strukturo. Pri membrani, ki je podana v preglednici, je 93-odstotna odprtost strukture. Keramične membrane imajo bistveno bolj zaprto strukturo. Tega parametra nismo merili, temveč smo merili prepustnost zraka in vode. Z dodajanjem škroba ali kakšnih drugih gorljivih snovi pa lahko povečamo poroznost. Pri tem moramo upoštevati, da z dodatki povečamo tudi velikost por, kar pa negativno vpliva na zmožnost zadrževanja delcev. Zato je najboljša rešitev izdelava asimetrične strukture porozne keramike. Tanek dejavni sloj ima zelo majhne pore, debelejši nosilni sloj pa večje pore, ki ne pomenijo velikega upora pri filtraciji.

Pri primerjavi našega vzorca porozne keramike z drugimi filtrirnimi snovmi lahko ugotovimo, da smo izdelali razmeroma dobro keramično filtrirno snov. Morda bi lahko z njo zadrževali celo bakterije, saj je njihova velikost večja od 0,2 µm.

Naša keramična filtrirna snov je imela veliko večjo prepustnost vode od tržnega izdelka. Pri tem pa ni bila bistvena razlika v velikosti por. Pri našem vzorcu smo ugotovili, da je filter zadržal tudi vse delce velikosti 0,15 µm. Meritev zadrževanja delcev velikosti 0,13 µm pa žal nismo mogli izvesti.

2.2 Testiranje porozne keramike kot podstave v bioloških čistilnih napravah

Začetne preizkuse smo izvajali na poskusni čistilni napravi, izdelani iz poliakrilnega stekla z izmerami, ki so podane na sliki 2 po opisani metodi. Rezultati so podani na slikah 8 do 12.

particles in the filtrate we concluded that the pores were smaller than the most refined particles.

A comparison of our sample of porous ceramic with other filter media shows a great difference between the PTFE and the ceramic membranes. The PTFE membrane is known as the filter with the most open structure. In the case of the membrane in the table there is a 93% openness of the structure. The ceramic membranes have much more closed structures. These parameters were not measured, but the permeability of the air and the water were. By adding starch or another combustible material an increased porosity could be achieved. But we must consider that by using additives the pore size increases, which has a negative effect on the ability to hold the particles. That is why the best solution is to make porous ceramics with an asymmetric structure. The thin active layer has very small pores and the fatter carrier layer has bigger pores, which consequently results in a smaller resistance during filtering.

From a comparison of our porous ceramic samples with other filter media we can establish that we created a relatively well-functioning ceramic filter media. Perhaps it could even filter bacteria, because their size is greater than 0.2 µm.

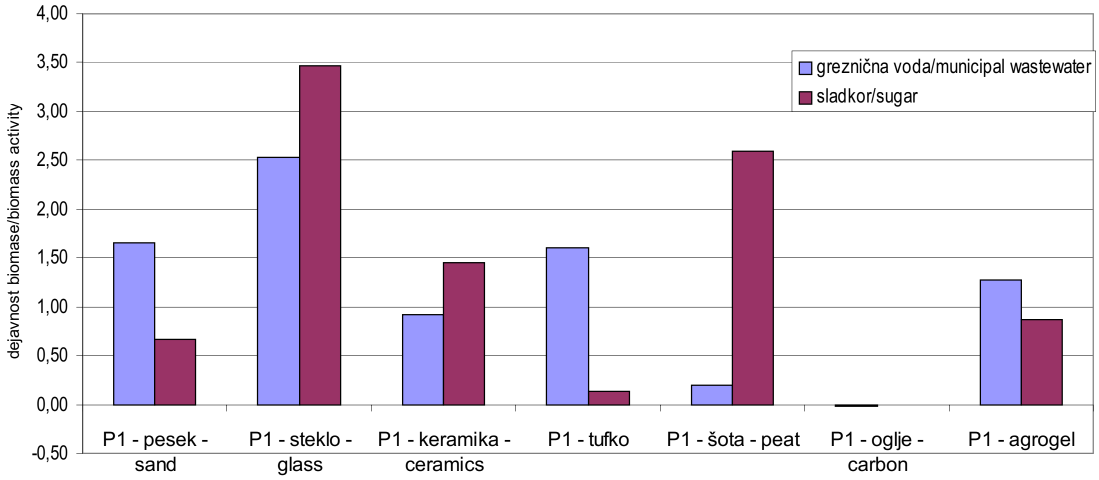
Our ceramic filter media had a significantly greater water permeability than the market product. However, there was essentially no difference in the pore size. In the case of our sample we have also established that the filter even withheld particles of 0.15 µm. Unfortunately it was not possible to measure the filtering of particles of 0.13 µm.

2.2 Testing of porous ceramics as a substrate in biological treatment plants

Pilot experiments were carried out on a pilot water-treatment plant made from Plexiglas, with the dimensions shown in Figure 2. The results are shown in Figures 8 to 12.

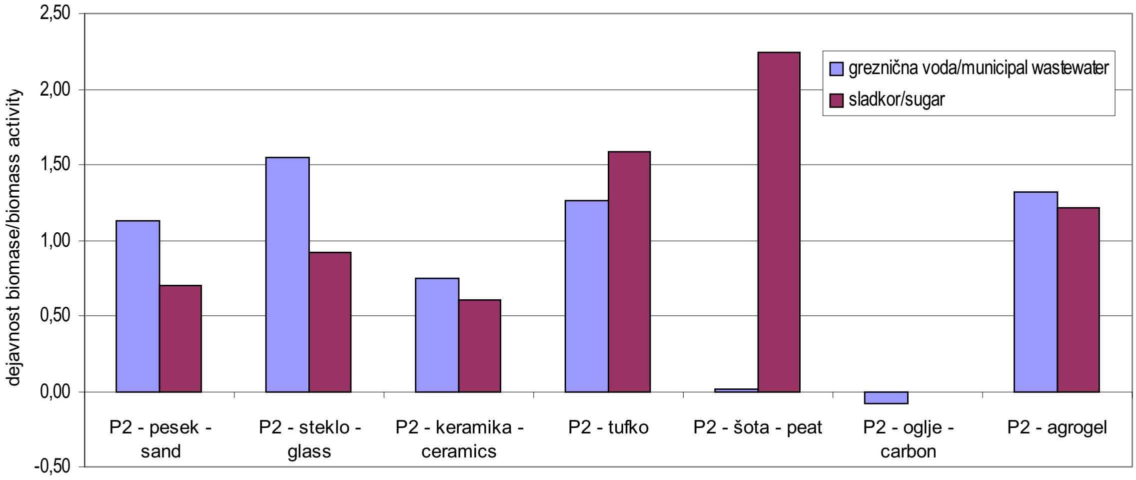
Preglednica 1. *Primerjava izdelanega vzorca porozne keramike z nekaterimi drugimi filtrirnimi snovmi*
Table 1. *Comparison of our porous ceramic sample with some other filter media*

Filtrirana snov Filter media	Velikost por size of pore (µm)	Prepustnost zraka permeability of air (m^3/m^2 h), Δ *P* = 400 Pa	Prepustnost vode permeability of water (l/m^2 min), Δ *P*
naš vzorec S 3 our sample S 3	0,2	126	0,75, 33 (Δ *P* = 100 Pa, 2 bar)
PTFE membrana PTFE membrane (W.L. GORE)	0,2	420	2 (Δ *P* = 100 Pa)
keramična membrana ceramic membrane Hoogovens Industrial Ceram. memb.	0,13	-	6 (Δ *P* = 200 kPa)



Sl. 8. Dejavnost *mikrobne biomase v* 1.10^{-9} O_2 *ml/(g.h) na različnih podstavah s hranivom grezično vodo in sladkorjem v prekatu P1*

Fig. 8. A*ctivity of microbial biomass in* 1.10^{-9} O_2 *ml/(g.h) on different substrates with added nutrition, municipal wastewater and sugar in the area P1*



Sl. 9. *Dejavnost mikrobne biomase v* 1.10^{-9} O_2 *ml/(g.h) na različnih podstavah s hranivom grezično vodo in sladkorjem v prekatu P2*

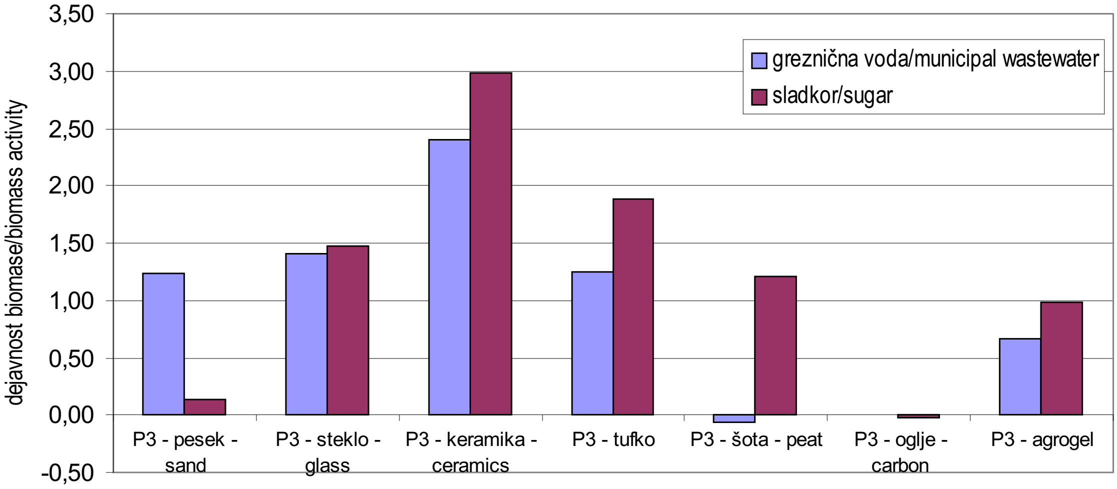
Fig. 9. *Activity of microbial biomass in* 1.10^{-9} O_2 *ml/(g.h) on different substrates with added nutrition, municipal wastewater and sugar in the area P2*

Raziskave so pokazale, da se na posameznih podstavah razvije bistveno več bakterijske združbe kakor na drugih. Ekspandirano steklo se je pokazalo kot najbolj ugodna podlaga za razvoj mikroorganizmov. Tudi rečni prod in porozna keramika sta dala dobre rezultate.

Vseh vplivov podstav ni mogoče natančno ovrednotiti, saj ne poznamo vseh mehanizmov delovanja posamezne snovi na postopek biokemijske razgradnje. Posebno poglavje so "informirane" podstave, ki dodatno pospešujejo postopke biokemijske razgradnje. Takšne

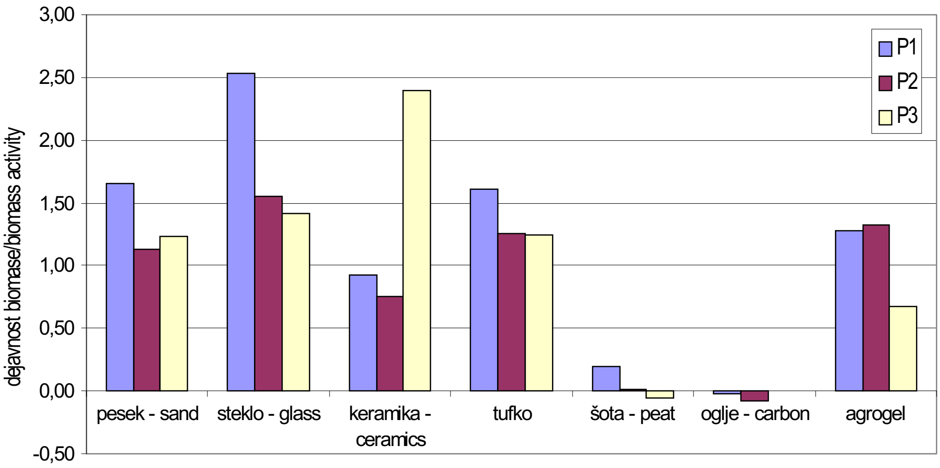
Our research has shown that on individual substrates significantly more bacterial communities develop than on others. Expansion glass has shown itself to be the most favourable base for the development of micro-organisms. Also, river gravel and porous ceramics have provided good results.

The effects of all of the possible substrates cannot be quantified because we do not know all the effects of the activity of individual materials on the processes of biochemical decomposition. "Informed" substrates are a chapter for themselves, because they can additionally accelerate the processes of biochemi-



Sl. 10. *Dejavnost mikrobne biomase v 1.10^{-9} O_2 ml/(g.h) na različnih podstavah s hranivom grezničnovodo in sladkorjem v prekatu P3*

Fig. 10. *Activity of microbial biomass in 1.10^{-9} O_2 ml/(g.h) on different substrates with added nutrition, municipal wastewater and sugar in the area P3*



Sl. 11. *Dejavnost mikrobne biomase v 1.10^{-9} O_2 ml/(g.h) na različnih podstavah s hranivom grezničnovodo*

Fig. 11. *Activity of microbial biomass in 1.10^{-9} O_2 ml/(g.h) in areas where the municipal wastewater is used as a nutrition*

"informacije" je mogoče vgrajevati v keramične in steklene snovi.

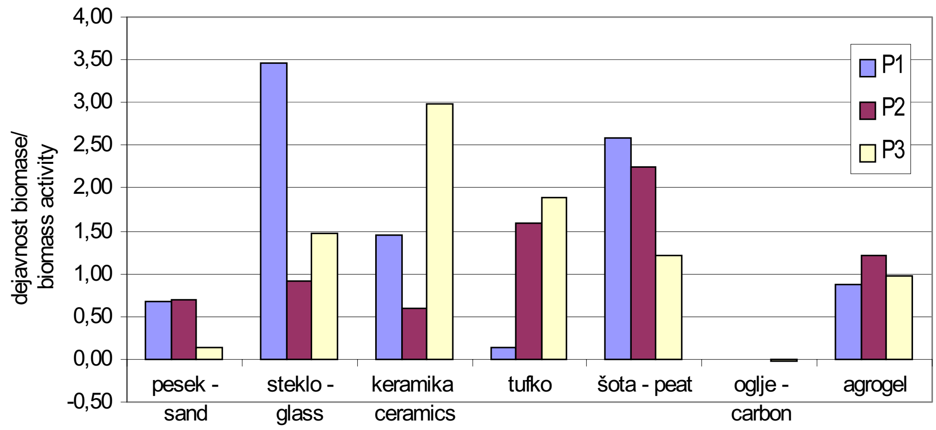
3 REZULTATI IN OBRAVNAVA

Pri čistilnih napravah s pritrjeno biomaso na pritrjeni nosilni podlagi ima izbira podstave velik vpliv na določanje čistilne naprave. Dejavnost mikrobne biomase je namreč zelo odvisna od vrste podstave. S poskusi smo ugotovili, da je lahko keramična podstava ena izmed najprimernejših nosil mikrobne biomase. Pri testiranju smo sicer dobili še

cal decomposition. It is possible to build-in such "information" into glass and ceramic materials.

3 RESULTS AND DISCUSSION

In water-treatment plants with fixed biomass on a fixed carrying base the choice of substrate has an enormous impact on the dimensions of the water-treatment plant. The activity of microbial biomass is very much dependent on the type of substrate. With the help of experiments we can conclude that a ceramic substrate is one the most suitable holders of microbial



Sl. 12. *Dejavnost mikrobne biomase v 1.10^{-9} O_2 ml/(g.h) na različnih podstavah s hranivom greznično vodo in sladkorjem*

Fig. 12. *Activity of microbial biomass in 1.10^{-9} O_2 ml/(g.h) in areas where the sugar is used as a nutrition*

Preglednica 2. *Preglednica razvrstitve od največje do najmanjše dejavnosti biomase na posamezni podstavi glede na dejavnost v vseh prekatih*

Table 2. A*rrangement of biomass activity on different substrates with regard to activity in all ventricles*

Podstava Substrate	1.mesto 1st place	2.mesto 2nd place	3.mesto 3rd place	4.mesto 4th place	5 mesto 5th place	6. mesto 6th place	7.mesto 7th place
steklo glass	3 x	2 x		1 x			
pesek sand		1 x		3 x	2 x		
tufko		2 x	3 x			1 x	
agrogel		1 x	1 x	2 x	2 x		
keramika ceramics	2 x		1 x		2 x	1 x	
šota peat	1 x	1 x		1 x		3 x	
oglje charcoal							6 x

nekoliko ugodnejše rezultate z ekspandiranim steklom, takoj za tem pa je bil vzorec keramične snovi. Steklo in keramika se po kemični sestavi bistveno ne razlikujeta, mnenja smo, da gre v bistvu za enako skupino snovi. Mnenja smo, da je mogoče razviti takšno keramično snov, ki bo zagotavljala še ugodnejše razmere za razvoj mikrobne biomase. V stekleno in keramično snov je mogoče vnesti tudi določene informacije, ki lahko pospešujejo postopke biokemijske razgradnje nečistoč. Izvedli smo več tovrstnih preizkusov, vendar pa raziskave niso končane in tudi rezultati niso dovolj natančni, zato jih ne navajamo v tem prispevku.

Keramična snov se lahko uporablja tudi kot mikroporozno filtrirno snov v membranskih filtrih.

biomass. Tests provided slightly better results when using expanded glass, but the ceramic materials were second best. The glass and ceramics do not differ much in terms of chemical composition, and that is why we think that this is basically the same group of materials. Our opinion is that it is possible to develop such ceramic materials, which will give even more advantageous conditions for the development of microbial biomass. In the case of glass and ceramic materials it is also possible to build-in some “information” that can accelerate the processes of the biochemical decomposition of impurities. We have conducted several such experiments; however, the results are not exact enough for them to be included in this paper.

Ceramic materials can also be used as microporous filter media in membrane filters. The sam-

Vzorec porozne keramike, ki smo ga izdelali, bi morda že lahko uporabljali v membranskem filtru. V odvisnosti od konstrukcije membranskega filtra bi morali zagotoviti dovolj velik pretok vode in zmožnost zadrževanja delcev. Za zadrževanje koloidnih delcev ne bi bilo posebno težko izdelati ustreznih mikroporoznih keramičnih naprav. Zadrževanje raztopljenih snovi v vodi pa je stvar obrnjene osmoze, kar pa ni predmet naših preiskav. Po našem mnenju bi lahko postala mikroporozna keramika ena izmed pogosto uporabljenih snovi za izdelavo membranskih filtrov. Takšne membrane bi bile zmožne zadrževati tudi bakterije, zato bi jih lahko uporabljali za sterilizacijo očiščene vode pred iztokom v vodotok. Pri našem vzorcu je bila velikost por manjša od 0,2m, kar pomeni, da bi ga lahko uporabljali za zadrževanje bakterij. V primeru izločanja blata iz čistilne naprave (koloidnih in grobih delcev), kar je prikazano v uvodnem delu, je treba zagotoviti sprotno odstranjevanje nastale pogače. Posamezni proizvajalci čistilnih naprav so to rešili z zrakom, po našem mnenju pa bi bilo mogoče tudi z vodnim curkom. Zaradi kemične in toplotne stabilnosti bi jih lahko temeljito čistili na bistveno preprostejši način kot občutljive polimerne membrane.

ple of porous ceramics we made could perhaps be used in membrane filters. Depending on the membrane filter construction, a sufficient influx of water and a sufficient ability to hold the particles would have to be ensured. For holding colloidal particles, however, it would not be particularly difficult to make suitable micro-porous ceramic modules. The holding of dissolved materials in water is covered by the field of reverse osmosis and is not the subject of our research. In our opinion, micro-porous ceramics could become one of the more frequently used materials for making membrane filters. Such membranes would also be capable of holding bacteria, and that is why we could use them for the sterilization of cleaned water before the outflow to the water course. In our sample the size of the pores was smaller than 0.2m, which means that it could be used for holding bacteria. In the case of mud excretion from the water-treatment plant (colloidal and rough particles), as was shown in the initial part of the paper, it is necessary to ensure the continuous removal of the formed cake. Individual producers of water-treatment plants have solved this problem by using air, but in our opinion this could also be done by using a water jet. Because of its chemical and thermal stability we could clean these membranes in a simpler manner than the more sensitive polymeric membranes.

4 LITERATURA
4 LITERATURE

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