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The Possibilities of Using Constructed Wetlands to Disinfect Water**

1. Introduction

Constructed wetlands are mainly used for all kinds of sewage treatment. Every available studies and researches relate to the analysis of physical and chemical quality of treated waste water [3–5, 9]. Only few publications report on disinfecting possibilities of constructed wetlands and in addition they focus on eliminating microorganisms from wastes [2, 7, 8, 11], grey-water [1, 6] or rainwater surface runoff [9]. As a matter of fact there are no publications related to the possibilities of using constructed wetlands for drinking water treatment or disinfection, even though the processes which take place in wetlands can successfully replace a number of processes used in water treatment plants. The microbiological contamination removal mechanisms of constructed wetlands are based on various processes. The contaminations are stopped in wetlands porous environment as a result of sedimentation, filtration and adsorption that is physical and chemical processes determined by the flow conditions and time. The elimination of microorganisms occurs as a result of biological processes between wetlands microcosm and bacteria and viruses contained in treated water. It includes predatory, competition and antagonism. The elimination can be also a result of unfavorable constructed wetlands condition such as: pH, temperature, UV radiation etc.

The wetlands vegetation also affects the number of bacteria and viruses in wastewater. The flora protects bacteria and viruses from solar radiation and eliminates them by slowing down wastewater flow which has a beneficial influence on sedimentation degree of particles with bacteria deposited on them. Also the roots system, inhabited with bacteria, produced substances which are toxic for other bacteria colonies [7, 9, 10].

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The researches described in the paper focus on the analysis of using constructed wetlands for water disinfection which helps to estimate the usage of pro--ecological method of water disinfection and becomes popular in many countries.

2. Materials and Methods

The research on the possibilities of drinking water disinfection was conducted on bed models created in a laboratory. The beds were constructed in the non--transparent PCV pipes (10 cm diameter and 55 cm high). The beds had the vertical direction of flow. The laboratory system consisted two pairs of bed models (with and without plants) to examine the vegetation influence on disinfecting possibilities of beds.

Two types of beds filling were used: sand (0.1–0.5 mm diameter) and gravel (9–10 mm). The porosity of sand beds was 46%, whereas the gravel ones – 54%.

Two beds were planted with umbrella papyrus (*Cyperus involucratus*) with 5–12 cm roots length. For all types of filter mediums three papyrus seedlings were stipulated. The umbrella papyrus was selected on the basis of its ability to grow indoors as well as outdoors, and the fact that as a marshy plant it easily adapts to the habitat conditions. The seedlings were planted directly under a mineral medium to provide light access for branches and their stable rooting. For better rooting the seedlings were planted a month before the research began. The disinfection was carried out on water from the Rudawa river. The water samples were delivered to the laboratory on a measurement day in the volume adequate to the number of experiments.

During the experiments the influence of the flow rate and the initial concentration of microorganisms on the disinfection effectiveness were examined. This effectiveness were measured by the number of culturable microorganisms after 48 h and 72 h incubation at 36°C and 22°C. The number of culturable microorganisms at 36°C and 22°C was defined in the sowing method according to Polish norm PN-EN ISO 6222:2004.

For one value of flow rate (0.04 m/h) and an initial bacteria concentration, the removal effectiveness was measured for bacteria from coli group, thermotolerant coli bacteria, *Escherichia coli*. The number of coliform bacteria was determined with the membrane method according to Polish norm PN-EN ISO 9308.1:2004.

3. Results and Discussion

As can been seen in figure 1 for the microorganisms at 36°C and in figure 2 for the microorganisms at 22°C, flow rate has a significant influence on achieved results.

Three levels of flow rate were investigated: 0.04 m/h; 0.05 m/h and 0.07 m/h, and for lower values of flow rate, the higher removal effectiveness of the number of microorganisms was observed. The lowest number of microorganisms incubated at 36°C and 22°C was observed in the sand bed with plants. For the gravel bed with plants the similar tendency occurred.

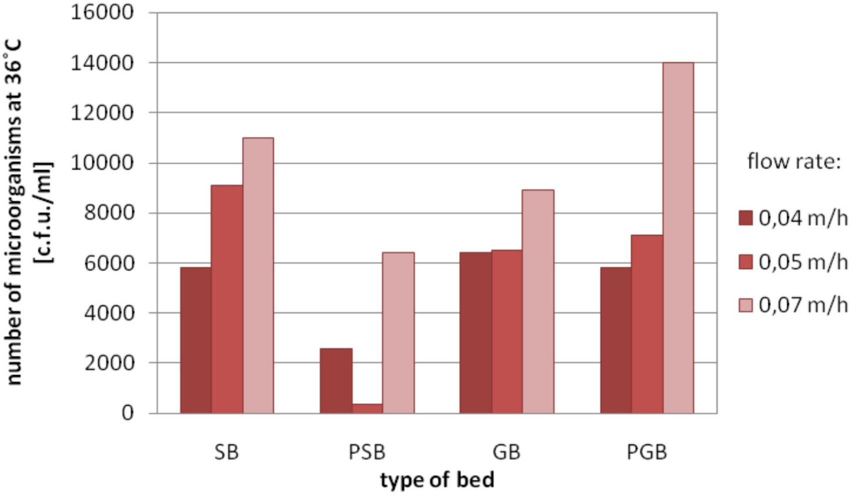

Fig. 1. The number of culturable microorganisms after 48 h incubation at 36°C related to the speed of filtration (initial number of microorganisms 13 300 c.f.u./ml): SB – sand bed, PSB – planted sand bed, GB – gravel bed, PGB – planted gravel bed

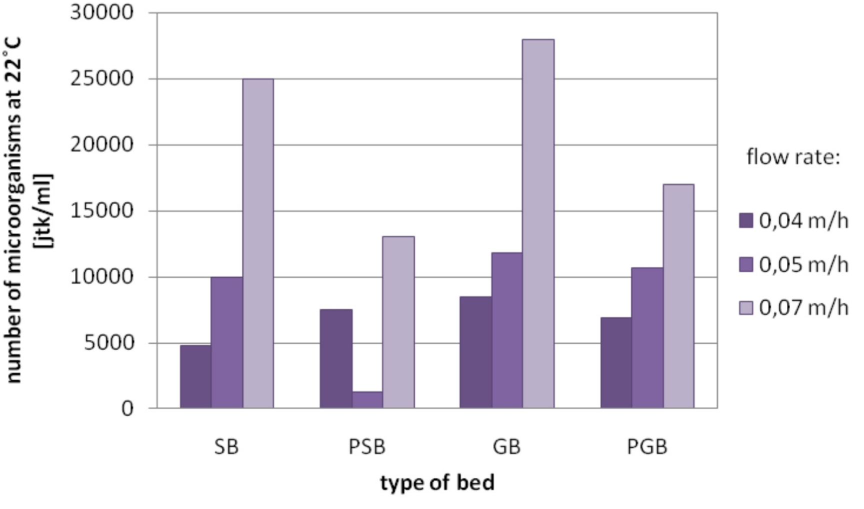

Fig. 2. The number of culturable microorganisms after 72 h incubation at 22°C related to the speed of filtration (initial number of microorganisms 10 900 c.f.u./ml): SB – sand bed, PSB – planted sand bed, GB – gravel bed, PGB – planted gravel bed

The influence of the initial number of microorganisms on the removal effectiveness was the other factor analyzed in the research. Water from Rudawa was diluted with redistilled water to achieve three values of the initial concentration. The experiments were carried out for the number of culturable microorganisms after 48 h and 72 h incubation at 36°C and 22°C (for the constant flow rate – 0.04 m/h). The values of the final number of microorganisms incubated at 36°C after 48 h in the effluents from all types of beds are presented on figure 3, and at 22°C after 72 h – on figure 4. As can be observed on figures 3 and 4, the disinfection effectiveness was increasing with the initial number of microorganisms.

For the culturable microorganisms incubated at 36°C, for the initial number of 60 000 c.f.u./ml of wastewater, the disinfection effectiveness ranges from 58% for the gravel bed with plants to 89% for the sand bed. For the initial values of 19 000 c.f.u./ml, the lowest effectiveness (32%) was observed for the gravel bed with plants, and the highest one (90%) for the sand bed. For the lowest initial number of microorganisms (13 300 c.f.u./ml) the maximum value of effectiveness was 80% and was observed in the sand bed with plants.

Similar tendency for the number of microorganisms incubated at 22°C was observed. For the highest initial number of microorganisms (39 000 c.f.u./ml) the effectiveness ranges from 58% for the planted sand bed to 77% for the sand bed without plants. For the initial value of 31 000 c.f.u./ml the effectiveness ranges from 51% for the sand bed with plants to 81% for the sand bed without plants. For the lowest initial number of microorganisms (10 900 c.f.u./ml) the effectiveness ranges from 22% for the gravel bed to 56% for the sand bed.

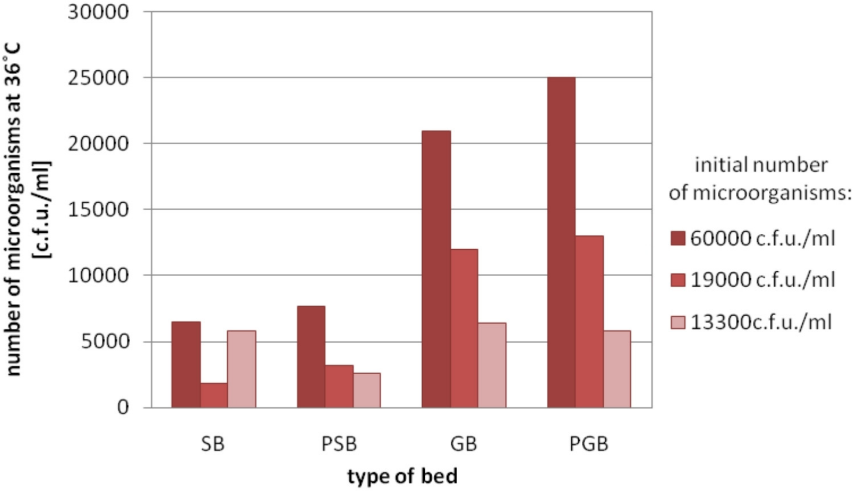

Fig. 3. The number of culturable microorganisms after 48 h incubation at 36°C related to the initial number of microorganisms (flow rate: 0.04 m/h): SB – sand bed, PSB – planted sand bed, GB – gravel bed, PGB – planted gravel bed

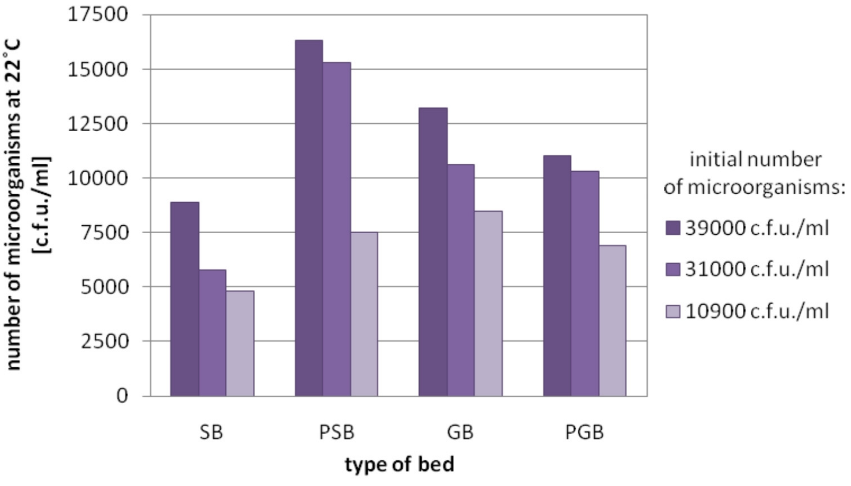

Fig. 4. The number of culturable microorganisms after 72 h incubation at 22°C related to the initial number of microorganisms (flow rate: 0.04 m/h): SB – sand bed, PSB – planted sand bed, GB – gravel bed, PGB – planted gravel bed

The research on the possibilities of using constructed wetlands for coliform bacteria elimination was conducted with one value of the initial number of microorganisms and one level of flow rate. As it can be seen on figure 5 coliform bacteria with fecal coliform bacteria and *Escherichia coli* included were highly eliminated on tested constructed wetlands. The gravel bed without plants was characterized by the lowest disinfecting effectiveness (67% for all types of coliform bacteria) and both sand beds (with and without plants) was characterized by the highest effectiveness (ranges from 92% for *Escherichia coli* to 92–94% for coliform bacteria and fecal coliform bacteria).

The research showed the high usefulness of constructed wetlands for the initial water disinfection. The results of the disinfection effectiveness related to the number of microorganisms incubated at 36°C ranges from 32% to 87% for planted beds and from 37% to 90% for beds without plants; results related to the number of microorganisms incubated at 22°C ranges from 31% to 72% for planted beds and from 22% to 81% for beds without plants; effectiveness of the coliform bacteria disinfection ranges from 57% to 92% for planted beds and from 67% to 94% for beds without plants.

No explicitly tendency of better disinfecting results for planted beds was observed. This can be caused by the fact that beds were relatively new and thus the root systems were underdeveloped, which can cause incomplete interactions between beds and bacteria present in treated wastewater. However the results are satisfactory and hopefully the disinfecting effectiveness will be higher while the roots system and the cultures of microorganisms will develop.

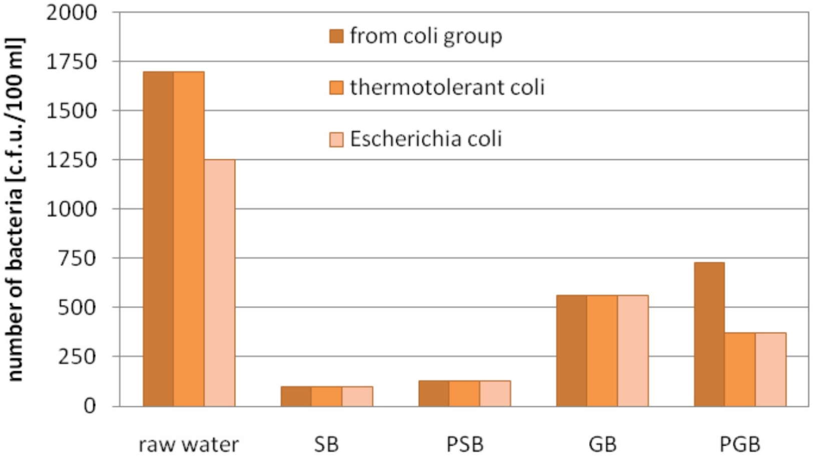

Fig. 5. The number of coliform bacteria after filtration on constructed wetlands (flow rate 0.04 m/h): ZP – sand bed, ZPR – planted sand bed, ZZ – gravel bed, ZZR – planted gravel bed

4. Conclusions

The researches focused on the possibilities of using constructed wetlands for the water disinfection showed that there is no significant difference in disinfection results between beds with and without plants. The removal effectiveness of microorganisms incubated at 36°C ranges from 32% to 87% for the planted beds, and from 37% to 90% for the beds without plants. For the microorganisms incubated at 22°C the effectiveness ranges from 31% to 72% for the planted beds, and from 22% to 81% for the beds without plants. The sand beds proved to be more effective than the gravel beds, so the bed porosity and the filtration of microorganisms play a significant role in the disinfection by the constructed wetlands. The disinfection effectiveness decreased with the flow rate, and increased with the initial number of microorganisms.

The high removal effectiveness was observed for coliform bacteria. For bacteria from coli group the results of disinfection range from 57% for the planted gravel bed to 94% for the sand beds without plants; for thermotolerant coli bacteria – from 67% for the gravel bed to 94% for the sand one, and for Escherichia coli the disinfecting effectiveness was 92% for sand beds (with and without plants) and the worst results were observed for the gravel beds.

The research showed the high usefulness of the constructed wetlands for the water disinfection. The research was conducted after a short time after the construction of the model beds (1 month). Probably the elimination effectiveness of microorganisms by the planted beds will be much better when root system is well developed.

References

[1] Avery M.L., Frazer-Williams R., Winward G., Shirley-Smith Ch., Fayyaz M.A., Jefferson B.: *Constructed wetlands for grey water treatment*. Ecohydrol. Hydrobiol., 7 (3–4), 2007, pp. 91–200.

[2] Axler R., Henneck J., McCarthy B.: *Residential subsurface flow treatment wetlands in northern Minnesota*. Wetland Systems for Water Pollution Control, 44 (11–12), 2001, pp. 345–352.

[3] Bergier T.: *Mechanizmy usuwania zanieczyszczeń w oczyszczalniach hydrobotanicznych*. Inżynieria Środowiska, 8 (2), 2003, pp. 237–249.

[4] Bergier T., Czech A., Czupryński P., Łopata A., Wachniew P., Wojtal J.: *Roślinne oczyszczalnie ścieków. Przewodnik dla gmin*. Natural Systems, Krakow 2004.

[5] Damurski J., Bergier T., Liszka M.: *Partycypacyjne planowanie gospodarki ściekowej w Dziewinie*. Centrum Rozwiązań Systemowych, Wrocław 2007.

[6] Frazer-Williams R., Avery L., Winward G., Jeffrey P., Shirley-Smith Ch., Liu S., Memon F., Jefferson B.: *Constructed wetlands for urban grey water recycling*. International Journal of Environment and Pollution, 33 (1), 2008, pp. 93–109.

[7] Łuczkiewicz A., Kulbat E., Olańczuk-Neyman K., Quant B., Rymszewicz A.: *Mechanizmyi efektywność usuwania zanieczyszczeń mikrobiologicznych na filtrach gruntoworoślinnych*. Inżynieria i Ochrona Środowiska, 9 (4), 2006, pp. 349–363.

[8] Masi F., Conte G., Martinuzzi N.: *Sustainable Sanitation by Constructed Wetlands in the Mediterranean Countries: Experiences in Small/Medium-Size Communities and Tourism Facilities*. Efficient Management of Wastewater, 2008, pp. 125–138.

[9] Obarska-Pempkowiak H.: *Oczyszczalnie hydrofitowe*. Wydawnictwo Politechniki Gdańskiej, Gdańsk 2002.

[10] Stottmeister U., Wießner A., Kuschk P., Kappelmeyer U., Kästner M., Bederski O., Müller R. A., Moormann H.: *Effects of plants and microorganisms in constructed wetlands for wastewater treatment*. Biotechnology Advences, 22, 2003, pp. 93–117.

[11] Świontek-Brzezińska M., Lalke-Porczyk E., Donderski W.: *Stan sanitarno-bakteriologiczny ścieków w przydomowej oczyszczalni wierzbowej*. Biotechnologia Środowiskowa, Materiały Zjazdowe VIII Ogólnopolskiego Naukowo-Technicznego, 2005, pp. 229–232.