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Increasing the efficiency of pollutant removal from municipal wastewater using biological filters

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Abstract: *Biological filters use granular materials to form an active biological film essential for the bio-oxidation of impurities in wastewater. Recent research has improved these filters by using volcanic tuff. The filtration efficiency was evaluated through physico-chemical tests, analyzing indicators such as pH, COD, BOD5, ST, TN, and TP. Wastewater passes through the granular material, where the biological film develops. The effluent is recycled for efficiency, and the grown biological film is removed by decantation and treated with secondary clarifiers. Heterotrophic bacteria and fungi oxidize primary pollutants, while autotrophic bacteria continue the oxidation process. Biological filters improve wastewater quality and reduce energy costs.*

Introduction

Biological filters are an effective method for treating municipal wastewater. These systems use granular materials to support an active biological film that bio-oxidizes pollutants. Recent improvements have utilized volcanic tuff to enhance filtration efficiency.

The process involves wastewater passing through the granular media, developing a biological film that degrades impurities. Key indicators such as pH, COD, BOD5, ST, TN, and TP are used to measure effectiveness. The effluent is recycled to improve treatment, and the biological film is removed via decantation and clarifiers.

Microorganisms, including heterotrophic and autotrophic bacteria, play a crucial role in oxidizing pollutants. This method not only improves water quality but also reduces energy costs, making it a sustainable wastewater treatment option.

Material and method

Laboratory experiments were conducted on trickling filters and high-rate biological filters. The installation flow rate was set at 1.0 L/s, with 0.2 L/s for high-rate loading per line and 0.8 L/s for the trickling line. Depending on the size and purification degree of the granules, as well as the nature and height of the filter bed, water distribution, and ventilation, there are three models for each type of trickling filter or high-rate filters: microcellular pumice-filled model; medium porous pumice-filled model; crushed basalt-filled model.

The granulation of the filter material follows standard rules, namely: a superficial layer (distribution) with a thickness of h=20 cm, Ø=20 mm-40 mm; a working layer (Ø = 40 mm-60 mm); a lower layer (support) with a thickness of h=50 cm-60 cm, Ø=60 mm-120 mm.

The experimental models were fed with hydraulic surface loads recommended for these types of installations, approximately 10 m3/m2xh for trickling biofilters and approximately 1m3/m2xh for high-rate biological filters. The filter materials were placed under severe operating conditions, during cold weather, when the risk of freezing and thus degradation of the filter material is higher.

To investigate the biological treatment process, the models were loaded with primary settling municipal wastewater, and the efficiency of biological filtration was monitored throughout the continuous operation of the experimental setup through physico-chemical analysis of the water.

The monitored indicators included: air temperature, water temperature, pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD5), total suspended solids (TSS), total nitrogen (TN), total phosphorus (TP), nitrites (NO"), ammonia (NH), sediments. The analyzed wastewater samples were average samples taken at intervals corresponding to each purification step. The characterization of wastewater during the experiments is presented in Table 1.

Tabel 1.
CHARACTERIZATION OF WASTE WATER DURING THE EXPERIMENTS

Indicator	Unit	Range of values
Water temperature	^0C	10.5 ÷ 28
pH	pH units	6.0÷8.0
COD	mg O_2/dm^3	62÷203
BOD_5	mg/dm^3	25÷63
TSS	mg/dm^3	60÷246
TN	mg N/dm^3	9.3÷104.8
TP	mg P/dm^3	0.1÷1.5
NO_2^-	mg N/dm^3	0.018÷3.6
NH_3	mg N/dm^3	5.4÷11.3
Sediments	cm^3/dm^3	0.9÷3.0

Results and discussions

During water sampling, hydraulic loads (HL) for trickling filters with biological media ranged from 5.08 to 15.26 m3/m2xh, with organic loads between 39.03-126.18 g BOD5/m3xh. Hydraulic loads (H) for high-rate biological filters ranged from 0.46-2.29 m3/m2xh, with organic loads between 10.66-32.92 g BOD5/m3xh.

The purification efficiency was satisfactory for all specific indicators of wastewater treatment, considering the generally low raw wastewater load. Results are presented in Figures 1, 2, and 3.

Fig. 1. Removal efficiency of BOD_5 with biological tower filters

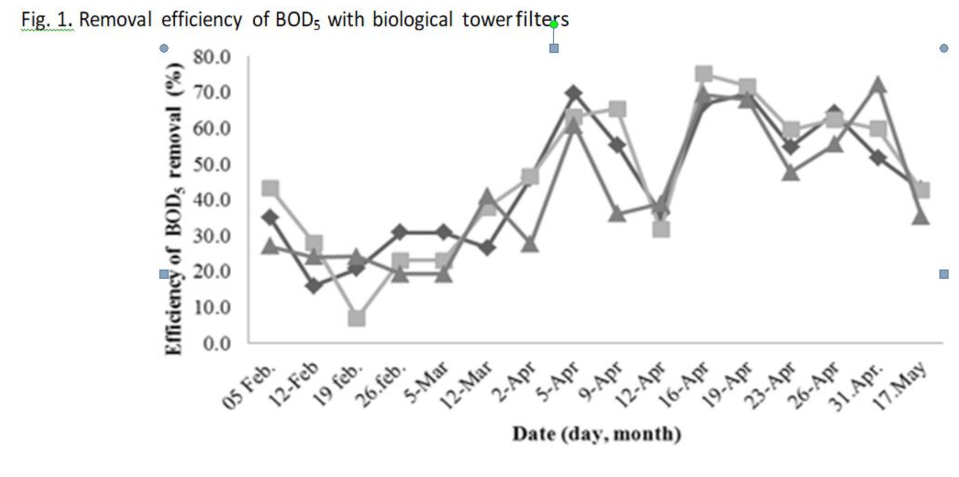


Fig. 2. Removal efficiency of COD with high loading biological filters

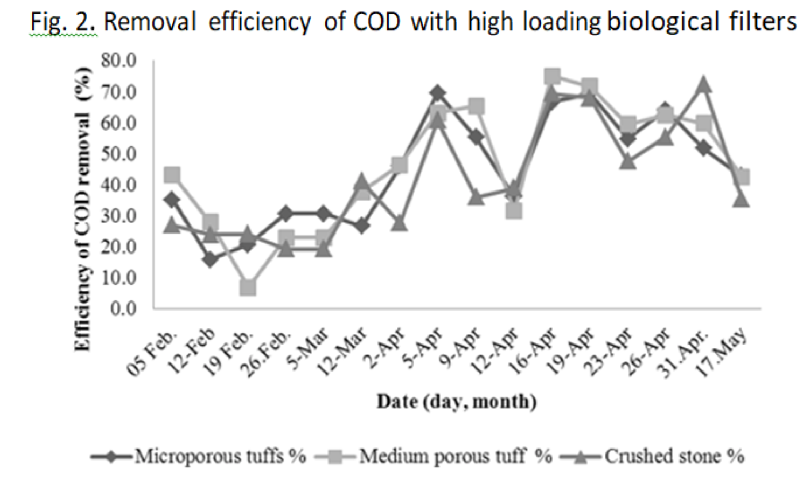
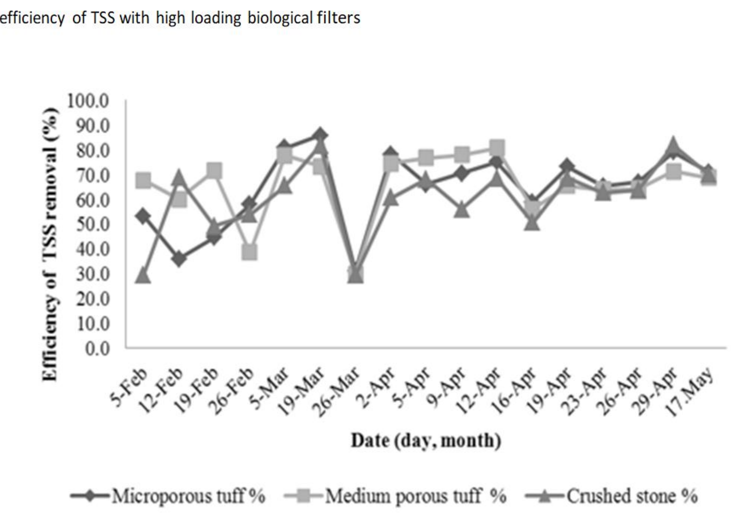


Fig. 3. Removal efficiency of TSS with high loading biological filters



During periods of higher temperatures, treatment efficiency significantly increased, reaching values of 72-75% BOD5 for trickling biological filters at optimal conditions (specific hydraulic load H = 10.18 m3/m2xh) and 62-72% BOD5 for high-rate biological filters at optimal specific hydraulic load H = 0.92 m3/m2xh. The development of the biological film was normal, although air temperatures were low initially, ranging from 14.2 - 38°C. This was due to the fact that the temperature of raw water did not drop below 9.5°C and reached up to 28°C during the summer period. A well-developed biological film was observed on both pumice and stone granules within 7-10 days of the experiment's start. Pumice granules exhibited a more advanced film development compared to crushed stone, reflected in the physico-chemical analysis results, which indicated more efficient purification with pumice granules during this period.

- A well-developed biological film was observed on both pumice and stone granules within 7-10 days of the experiment's start.
- Medium porous pumice exhibited the highest removal efficiencies, followed by microcellular pumice and crushed stone, in both trickling and high-rate filters.
- BOD5 removal efficiencies ranged from 15-72% for high-rate filters and 13-75% for trickling filters, depending on the specific hydraulic load and filter media.
- Medium porous pumice showed the highest BOD5 removal efficiencies, ranging from 48-75% for trickling filters and 41-69% for high-rate filters.
- Overall, the results indicate efficient BOD5 removal across different hydraulic loads and filter media types, with medium porous pumice performing consistently well.

Conclusions

The experimental results from wastewater treatment plants equipped with aerobic biofilm (trickling filters and high-rate biological filters) and operated with municipal wastewater have shown, through technological parameters and biological observations on fixed film, that these are very close for all three types of tested filter loads. Wastewater treatment efficiency had satisfactory values for all specific indicators, considering also that the raw water had a relatively low load. Considering the experimental results, it is considered that the use of additional biological filters with volcanic tuff material load in municipal wastewater treatment plants may lead to an increase in the efficiency of treating these types of water.