

DOI: <http://doi.org/10.21698/simi.2020.ab06>

DEVELOPMENT OF BIOFILTERS FOR THE REMEDIATION OF GROUNDWATER CONTAMINATED WITH NITRATE AND PERCHLORATE

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Keywords: *biofilters, groundwater, nitrate, perchlorate, remediation*

Introduction

In many locations worldwide, groundwater contamination by nitrates is a global problem, resulting from agriculture fertilization and wastewater reuse. Nitrate is considered a harmful compound due to *methemoglobinemia*, which harms children under the age of 3. The most common approach to remove nitrate is through biological denitrification. In this process denitrifying bacteria can utilize nitrate (and nitrite) as electron acceptors in the oxidation of organic matter. Since the use of oxygen is thermodynamically favourable over nitrate reduction, in treatment processes aimed at denitrification, presence of oxygen should be eliminated. A similar compound present in contaminated groundwater is perchlorate, resulting from ammunition & rocket fuel production. Perchlorate is much more toxic than nitrate and might affect the endocrine system. Removal of perchlorate can be achieved via specialized bacteria, which can use perchlorate as electron acceptor in the oxidation of organic matter. Optimization of nitrate and/or perchlorate removal requires the control of several parameters, including oxygen concentration, pH and C/N ratio. Many studies have reported on the use of alternative carbon sources for denitrification and perchlorate reduction. These sources include dissolved carbon compounds such as methanol and acetic acid, and solid carbon sources such as wood chips and cotton.

Materials and methods

During the first stage of this study, the experiments were conducted in PVC columns with a height of 120 cm and a diameter of 10 cm. A water-saturated zone of 100 cm in the column was established. Raw cotton served as a solid carbon source which was mixed with polyethylene beads along the column. In the second stage new columns were established based on common design practice of storm water biofilters. The columns built of PVC had height of 121 cm and diameter of 23.5 cm. Each column was filled with quartz sand in three layers: bottom 2.5-3.5 mm, middle 0.8-1.5 mm, and top layer of 0.6-0.8 mm. Each column had a drainage outlet at the bottom connected to a solid pipe up the column, which can control various levels of column saturation (to form an anoxic zone for denitrification). Two 250 litre tanks were filled with a nitrate solution (KNO_3) to form concentration of 100 mg/L in tap water. The carbon source for the second stage was glucose (100 mg/L) in the liquid form, and perchlorate was also added (20 mg/L). This solution served as the feed for the columns, through continuous pumping. The hydraulic load in the first stage was 30 mm/h and during the second stage 3 mm/h.

Results and conclusions

As shown in Table 1, nitrate removal in stage 1 was very high and no intermediate nitrite accumulated. However, the residual TOC became high and served for sulfate reduction under the anaerobic conditions formed.

Table 1. Summary of biofilter performance in stage I.

	NO_3^- [mg/L]	NO_2^- [mg/L]	TOC [mg/L]	SO_4^{2-} [mg/L]
Inlet	137.16 ± 11.60	0	0	54.73 ± 2.19
Outlet	2.08 ± 5.52	0.17 ± 0.42	24.14 ± 6.43	16.22 ± 13.56

In the second stage, natural bacteria which acclimated to nitrate reduction within the soil columns were gradually adjusted to the presence of perchlorate in the feed solution. Figure 2 shows the chronological changes of the various constituents in the tested columns.

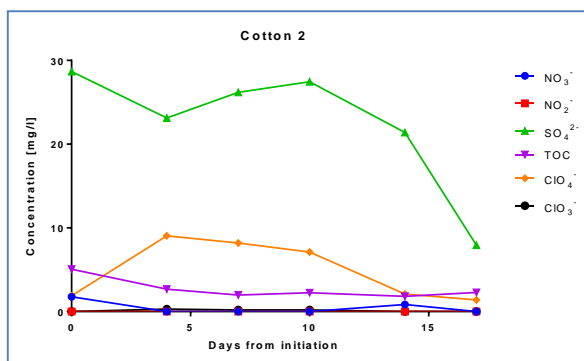


Figure 1. Chronological plot of biological transformations in the biofilter during stage 2

The main conclusions derived from this study are:

- Solid and liquid carbon sources can be utilized easily by natural bacteria to reduce both nitrate, perchlorate, and sulfate.
- It is essential not to completely remove nitrate from the treatment system in order to prevent TOC leaching.
- Nitrate and perchlorate can be reduced simultaneously.
- Complete reduction of nitrate and perchlorate creates anaerobic conditions. This leads to sulfate reduction and formation of sulfide, which is toxic and constitutes an odor hazard.