Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 55(5) (2023) 215-218
DOI: 10.22060/ceej.2023.22069.7894

# Investigation of nitrate removal from agricultural drainage water using PRB filter in loamy sand and sandy loam soil

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**ABSTRACT:** This study is focused on the treatment and reuse of agricultural drainage water using permeable reactive barriers (PRBs). To construct the physical model, a cubic iron tank with dimensions of 1×1×1 is used. Drainage pipes with a standard diameter of 16 mm are installed at a depth of 20 cm. To determine the depth of the static level, piezometer tubes are used in the model. After permeability tests and evaluating the obtained results as well as considering the availability of materials, the mixture weight ratios of the materials in PRB are selected as follows: 25% sand, 25% anthracite, 20% zeolite, 20% iron borings, and 10% poplar wood sawdust. The permeability coefficient of the PRB with this mixture after complete saturation over 24 hours is equal to 0.0322 cm/s. An initial nitrate concentration of 100 mg/liter is considered for the column to obtain the breakthrough curve of the synthetic wastewater. It takes 15 minutes to detect the nitrate breakthrough. The breakthrough curve is considered a normal curve, and the only unknown of the problem, i.e., the longitudinal diffusion coefficient (D_L), is obtained by trial and error as $1.5\times10^{-7}$ $m^2/s$, which is an acceptable value. The Peclet number for the proposed PRB is 14.344, which indicates the identical effects of the dispersion and diffusion processes. In this study, the drainage filter, which includes PRB and sandy loam soil, is able to eliminate nitrate by 99.44% after 24 days..

**Review History:**

Received: Dec. 29, 2022
Revised: Feb. 27, 2023
Accepted: Mar. 31, 2023
Available Online: Apr, 21, 2023

**Keywords:**

Agricultural drainage
Earth filter
Permeable reactive barrier
Loam soil
Nitrate removal.

## 1- Introduction

The excessive use of nitrogen fertilizers in agricultural fields causes nitrate leaching into aquatic environments. Nitrate eutrophication has drawn attention both as part of the United Nations (UN) Sustainable Development Goals (SDGs) and as part of water regulations [1,2]. In the 1990s, permeable reactive barriers (PRBs) were used for the first time in North America for groundwater treatment. This new technology includes creating a permeable reactive zone in the flow path of contaminated groundwater. Depending on the type and compounds of the contaminants, a series of biological, chemical, or biochemical processes are initiated in these PRBs to treat a wide range of soluble organic and inorganic materials and finally prevent the movement of the contaminated groundwater plume [3].

More than 110 pilot-scale and field studies on the use of PRBs have been conducted around the world. The majority of these studies investigate the use of zero-valent iron, which is a commercial product, and the use of modern barriers that are embedded under landfills or chemical storage tanks [4-8].

Therefore, this research is aimed to construct a PRB with different low-cost absorbents and earth materials as a drainage filter to remove or reduce nitrates in agricultural drainage water. In this way, the related environmental problems are resolved and the treated water can be reused especially for the use in aquaculture industry or other farms.

## 2- Methods

### 2- 1- Column tests

In treating agricultural drainage water based on the absorption method, some column tests are required, and the work performed in this part is summarized in the following steps:

1) Plotting the breakthrough curves for the PRB using a pilot column in which the adsorbent materials in a mixture with optimal weight percentages are analyzed.

2) Estimating the hydrodynamic dispersion coefficient, which is an important parameter in the transport equation of pollutants. This parameter can be measured using the laboratory results obtained from the column tests.

3) Determining the Peclet number for the drainage filter.

4) Examining the efficiency of the drainage filter in absorbing and reducing/removing soluble nitrate.

For this purpose, a physical model of the filter, which is a column of loamy soil, sandy loam, and absorbent materials, is constructed in the laboratory.

To construct the physical model, a cubic iron tank with dimensions of 1 m × 1 m × 1 m (width × length × depth) was used. Drainage pipes with standard 16-mm diameter bore were installed at a distance of 20 cm from each other, 20 cm from the tank wall at a height of 20 cm from the bottom.

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**Fig. 1. Layout of filter drainage pipes in the present study**

**Fig. 2. Semi-industrial system designed for nitrate removal test of the drainage filter**

Figure (1) shows the placement of drain pipes in the filter system in the current research.

The PRB was extended to 10 cm under the drainage pipe, and 10 cm of sandy loam was used on the bottom of the tank, i.e., at the bottom part of the PRB. At the end of the drainage pipe, a valve and a flowmeter were installed to keep the water table depth and measure the amount of the discharged water.

Several more holes were drilled into the body of the physical model to insert piezometer tubes for determining the water table depth. Piezometers were installed on the left side of the tank at heights of 30, 50, and 70 cm from the bottom of the tank. To fill the left side of the model, two subsurface agricultural soil types with the textures of sandy loam and loam were used.

A storage tank, pump, and several water sprinklers were used to simulate irrigation. The amount of irrigation water was such that the soil in the drainage area was saturated. Irrigation was carried out for several consecutive days so that the biomass inside the PRB grew sufficiently. Then, the soil was irrigated using water with known nitrate concentrations.

The amount of nitrate in the drainage water was measured at different time intervals and three times with different nitrate concentrations. The drain filter system can be seen in Figure (2) after arranging all the layers.

## 3- Conclusion

The results of the permeability coefficient of a mixture of sand, sawdust, iron borings, zeolite, and anthracite in two homogeneous and layer-by-layer structures were compared. The comparison results showed that the permeability rate in the homogeneous structure was lower than that in the layer-by-layer structure. The PRB mixture containing sawdust had lower permeability than the PRB with other materials. This can be attributed to the swelling of sawdust upon the absorption of water. The permeability of the mixture containing sawdust did not change much over time after reaching saturation.

The breakthrough curve was plotted for synthetic wastewater with an initial nitrate concentration of 100 mg/L in the column. Nitrate detection and breakthrough occurred in 15 minutes. The non-uniformity in the PRB breakthrough curves indicates that the breakthrough curve can be classified as pseudo-Gaussian based on engineering approximation. The breakthrough curve was considered a normal curve, and using trial and error, the only unknown of the problem, i.e., the longitudinal dispersion coefficient (), was obtained to be , which is an acceptable value. The Peclet number for the studied PRB was 14.344. According to the obtained Peclet number, the effects of dispersion and diffusion on the material transport are not the same.

According to the experimental results in this study, the earth filter operating process includes the following four steps:

1) Filtering suspended substances and microorganisms on them (if there were any) as well as removing a fraction of the dissolved contaminants through absorption processes and chemical reactions

2) The growth of active biomass in the filter medium

3) Absorption of soluble nutrients by the biomass

4) Biorefining of the soluble nitrate

In the study conducted by Ghasemian in 2009, the filter was not able to remove all organic compounds and other contaminants including nitrate [9]. However, due to the use of absorbents, which are highly efficient and low cost, the biological drainage filter examined in this study can remove nitrate from agricultural drainage as well as remove organic substances. In this study, the drainage filter, which included PRB and sandy loam soil, was able to reduce nitrate by 99.44% after 24 days.

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**HOW TO CITE THIS ARTICLE**

*M. Motafares, A Asareh, M. Parvin nia , M. Asadi lor1, D. Khoddadi Dehkordi1, Investigation of nitrate removal from agricultural drainage water using PRB filter in loamy sand and sandy loam soil, Amirkabir J. Civil Eng., 55(5) (2023) 215-218.*

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