

# Cotton-supported heterotrophic denitrification of nitrate-rich drinking water with a sand filtration post-treatment

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## Abstract

The biological denitrification (BD) process represents an interesting solution to remove nitrate from water and as well as to close the natural nitrogen cycle. Potential applications are related to both groundwater denitrification and treatment of nitrate-rich effluents from reverse osmosis and ion-exchange processes. This paper presents the results obtained from a pilot-scale cotton-supported heterotrophic denitrification reactor (HDR) where cotton acts as both organic carbon source and supporting material for the growth of a denitrifier biofilm. A trickling sand filter (TSF) was inserted as post-treatment to remove TOC released by the HDR and to re-oxygenate the treated water. The system is evaluated for drinking water treatment.

Nitrate removal efficiency of the HDR was over 90% for 85 mg/l of inlet nitrate concentration which is a mean groundwater value in many EU countries. The process maintained its high performance up to 358 mg of daily nitrate inlet with a maximum specific volumetric ratio of 24.5 gN/m<sup>3</sup>·d. A first-order kinetic value was shown for sequential nitrate-nitrite and nitrite-nitrogen gas transformations. For that, the kinetic constants of 2.6 l/d (K1) and 15.9 l/d (K2) were assumed. The TSF provided additional nitrification-aerobic denitrification at a rate of 20.7gN/m<sup>3</sup>·d. Although both reactors showed high performances in terms of nitrogen removal, this plant configuration cannot assure an adequate TOC outlet concentration (>3 mg/l).

**Keywords:** nitrate removal, drinking water, sand filtration, heterotrophic denitrification, cotton

## Nomenclature

|      |                                       |
|------|---------------------------------------|
| BD   | Biological denitrification            |
| CFU  | Colony-forming units                  |
| CSTR | Completely stirred tank reactor       |
| DBPs | Disinfection by-products              |
| DO   | Dissolved oxygen                      |
| HDR  | Heterotrophic denitrification reactor |
| MVNR | Maximum volumetric nitrate removal    |
| PRB  | Permeable reactive barrier            |
| PVC  | Polyvinyl chloride                    |
| SC   | Solid carbon                          |
| SCS  | Solid carbon source                   |
| TOC  | Total organic carbon                  |
| TSF  | Trickling sand filter                 |

## Introduction

Nitrate is one of the most important and widespread of the numerous potential groundwater contaminants. The main causes of nitrate pollution are the excessive use of fertilisers in intensive agriculture, the irrigation with domestic wastewater and change in land-use patterns (Canter, 1997; Soares, 2000).

Possible health consequences of nitrate ingestion include methaemoglobinemia, the blue-baby syndrome in infants under six months of age (Winneberger, 1982), and the possible formation in the gastric system of n-nitroso compounds which are known to be carcinogens in the digestive system (Tannenbaum

and Green, 1985; WHO, 2003). These reasons led to the adoption of a stringent limit around 50 mg/l of NO<sub>3</sub><sup>-</sup> as shown in Table 1.

Many technologies have been developed to remove nitrate from drinking water, in order to respond to the constant increase of the nitrate pollution problem. The US Environmental Protection Agency identified the best available technologies for nitrate removal as being ion exchange, reverse osmosis and electro-dialysis (USEPA, 1995). However, these technologies are still uneconomical and they have disadvantages such as producing more concentrated reject (reverse osmosis), increasing other ions in the outlet (ion exchange) and more complex processes to be operated (electrodialysis) (Soares, 2000). Alternatively, biological

**TABLE 1**  
Nitrate and nitrite limits

|                         | Nitrite (mg/l)     | Nitrate (mg/l) |
|-------------------------|--------------------|----------------|
| USA                     | MCLG <sup>1</sup>  | 3.28           |
|                         | MCL <sup>2</sup>   | 44.43          |
| EEC (1998) <sup>3</sup> | MCL                | 50             |
|                         | EDWTP <sup>4</sup> | 0.1            |
| WHO (2003) <sup>5</sup> |                    | 3              |
| MOROCCO <sup>6</sup>    |                    | 0.1            |

<sup>1</sup> Guide maximum contaminant level (GMCL)

<sup>2</sup> Maximum contaminant level (MCL)

<sup>3</sup> Must be respected according to equation of

<sup>4</sup> Effluent of drinking water treatment plant

<sup>5</sup> Guideline limit (GL)

<sup>6</sup> Guide limit applied by ONEP, Rabat Drinking Water Treatment Plant Authority

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