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Removal of ammonia, iron and manganese from groundwaters of northern Croatia—pilot plant studies

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Abstract

The removal of iron, manganese and ammonia from groundwater originating from four different locations in northern Croatia was studied. Four pilot plants, mainly differing in their aeration systems and operation pressures, have been used. Quartz sand, coated with a naturally formed layer of MnO_2 and a biofilm containing micro-organisms, were used as filter media. The bacteria of the genus *Siderocapsa*, as well as the bacteria of the genus *Nitrosomonas* and *Nitrobacter* were identified as taking part in the removal of iron and manganese, and of ammonia, respectively. It was demonstrated that a well-established bio-filter mass from one water treatment plant is applicable in other plants. Removal of iron, manganese and ammonia from groundwater was achieved by single-step filtration, for which an adaptation period of 3–4 weeks was required. The filtration rates were as high as 22–24 m/h. Under optimal operating conditions, ammonium is oxidized biologically to nitrates and no nitrites appear in the effluent. The treatability factors *k* and *n*, which characterize the processes in packed bed bioreactors, were determined in this pilot plant study as well. They indicated that the simultaneous removal of iron, manganese and ammonium involves processes having different mechanisms and kinetics.

Keywords: Ammonium removal; Iron removal; Manganese removal; Bio-filtration; Treatability factors; Pilot plant; Groundwater

1. Introduction

The groundwater in the alluvium of the river Sava of northern Croatia usually contains high concentrations of iron, manganese and ammonia, and is therefore unsuitable for use as drinking water without appropriate treatment. A simple and widely applicable water treatment procedure is thus needed. There are a large number of chemical water treatment procedures available, but biological procedures, especially in the presence of ammonia, seem to offer certain advantages. Nevertheless, many conventional plants still apply chemical processes and therefore produce drinking water of poor quality [1]. Biological processes can offer viable alternatives to chemical processes for conventional water treatment plants. It has been observed that various conventional iron removal plants operate satisfactorily, even though the raw water characteristics point to slow Fe(II) oxidation rates [2,3]. It was obvious that in addition to the chemical process, a secondary, biological process was occurring at some iron removal plants [1]. Observing such phenomena has led to the development of biological reactors based on the principle of bio-filtration through a submerged granular medium [4]. The design of such plants is much simpler, compared to conventional plants utilizing chemical techniques [1]. Comparison of chemical and biological oxidation of iron showed that the existence of bacteria in the filter could dramatically improve the filter efficiency under the same operating conditions [5]. Bio-filtration allows a combination of aerobic biodegradation and physical retention of suspended particles by filtration through the filter bed [4,6]. This process is enabled by the activity of micro-organisms, which represent an integral part of the groundwater microflora. The accumulation of a critical mass of micro-organisms, required to bring about the desired reactions, is the key to any biological treatment process. Cell retention is achieved by water flow through the filter bed where the natural attachment of cells to solid surfaces occurs, creating a biofilm [7]. One major advantage of natural immobilization is the fact that cells are not permanently trapped within the filter. Thus any micro-organisms that die will eventually be washed out, thereby maintaining the activity of the system at a high level [8].

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The aim of the present work was to examine the basic characteristics and kinetics, as well as to prove the applicability of a single stage, simultaneous biological removal process of ammonia, iron and manganese, by using pilot plants, from several typical groundwaters of different composition in northern Croatia. It was also investigated whether well-established biological filter material from one plant could be used at other plants treating water of different quality, with the aim of reducing the start-up period of these new bio-filters from typically months [9], to more acceptable times.

2. Materials and methods

2.1. The groundwaters investigated

The biological removal of iron, manganese and ammonia was studied in four typical groundwaters at different locations in northern Croatia. These were Ravnik near the city of Popovača; Sunja, east from the city of Sisak; the city of Požega; and Cerna, near the city of Vinkovci. The concentrations of iron, manganese and ammonia in the groundwaters of Ravnik, Sunja and Cerna exceed drinking water standards, whereas in Požega, only manganese is in excess.

2.2. Pilot plants

Four types of pilot plants, mainly differing in their aeration systems and operation pressures, were used. Open air or closed aeration systems were employed in the first treatment step, combined in the second step with bio-filtration units, working under different pressures. The pilot plants are schematically presented in Fig. 1.

The pilot plant in Ravnik (Fig. 1a) contained no aeration unit in its first treatment step. The closed aerator of the existing water treatment plant supplied the aerated water. It was operating at a pressure of approximately 2 bars and produced

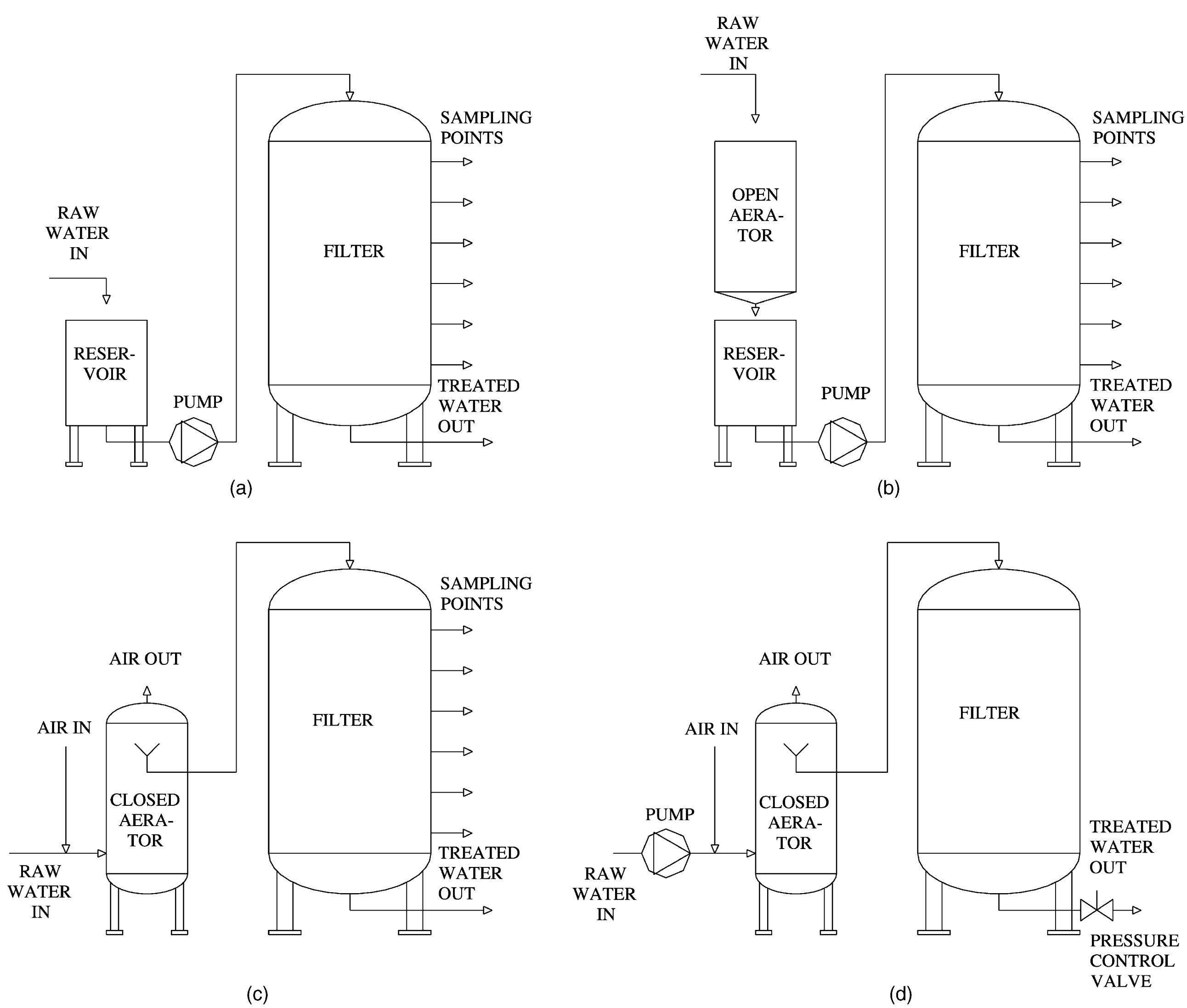

Fig. 1. Schematic representation of pilot plants in Ravnik (a), Požega (b), Sunja (c) and Cerna (d).