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ScienceDirect

Procedia Engineering 162 (2016) 56 – 63

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development, 2nd EWaS 2016

Efficacy of sorption materials for nickel, iron and manganese removal from water

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Abstract

Some uncommon elements can sometimes be present in groundwater and surface water. Metals belong to such elements. Increased concentrations of iron and manganese can be expected in groundwater but higher concentrations of metals such as nickel or arsenic are not typical of such water. Nevertheless, water sources exceeding prescribed limits for drinking water in arsenic and nickel concentrations can also be found. Because of the toxicity of these metals, we started to make a research into the possibilities of removing these elements from water. Our research is funded by a grant from the Brno University of Technology.
There is a number of ways to remove heavy metals from water. Sorption on granular media based on iron oxides and hydroxides is currently the most used option. Our experiment was carried out using sorption materials GEH, CFH 0818, CFH 12 and Bayoxide, which are primarily designed to remove arsenic from water. We prepared four columns of an inner diameter of 4.4 cm for the purpose of the experiment. The thickness of the filtration media was 0.62 cm on average. Nickel, iron and manganese pollution was simulated in a laboratory. The efficacy of metals removal by four selected sorption materials was compared. During the experiment, the flow rate was set to reach the required retention time of 2.5, 7 and 15 minutes.
We have found out that the nickel concentration was reduced according to Regulation No. 252/2004 setting the limit value even after the shortest retention time (2.5 mins). Longer retention time had no significant effect on nickel removal. Our measurements also proved that all sorption materials have the ability to remove iron and manganese from water. Bayoxide sorption material achieved the best results in nickel, iron and manganese removal from water.

Peer-review under responsibility of the organizing committee of the EWaS2 International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development

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Peer-review under responsibility of the organizing committee of the EWaS2 International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development
doi:10.1016/j.proeng.2016.11.012

Keywords: Nickel; Iron; Manganese; Sorption materials; Removal; Water

1. Introduction

Groundwater and surface water sometimes contain substances that do not occur frequently in such water. Such substances include some of the metals. Increased iron and manganese content is expected in groundwater; however, metals such as nickel and arsenic in high quantities are not typical of such water. Still, there are sources where the occurrence of nickel, arsenic and other metals is in concentrations exceeding the prescribed values for drinking water.

Nickel can be found in minerals usually with sulphur, arsenic and potentially with antimony. These are, for example, gersdorfite (NiAsS), pentlandite [$(Fe,Ni)_9S_8$], nickeline (NiAs), millerite (NiS) and garnierite and pyrrhotite. It is also included in some of the aluminosilicates (serpentine). Anthropogenic sources of nickel include mainly wastewater from metal surface treatment where it is predominantly complexly bound, and wastewater from colour metallurgy. It is also used in ceramic and glass making industries and for some chemical syntheses as a catalyser. Another potential sources are nickel-plated parts of equipment that can in touch with water [1].

Besides simple Ni^{2+} ions, water in alkaline environment contains also hydroxo-complexes $[NiOH]^+$ - $[Ni(OH)_4]^{2-}$, then carbonato-complex $[NiCO_3(aq)]^o$ and sulphato-complex $[NiSO_4(aq)]^o$. Wastewater coming from galvanisation includes nickel usually in the form of cyano-complexes $[NiCN]^+$ - $[Ni(CN)_4]^{2-}$ and ammino-complexes $[NiNH_3]^{2+}$ - $[Ni(NH_3)_6]^{2+}$.

Nickel solubility in water is restricted either by carbonate $NiCO_3$(s) or hydroxide $Ni(OH)_2$(s). Sulphides are present, NiS(s) may also be considered.

Many studies demonstrated that some heavy metals (Ni, Cr and Cd) are complex carcinogens, and the mechanisms underlying these carcinogenesis are multifactorial. The major mechanisms of Ni carcinogenesis include aberrant gene expression, inhibition of DNA methylation, inhibition of DNA damage repair and apoptosis, and induction of oxidative stress. IARC classified metallic nickel in group 2B (possibly carcinogenic to humans) and nickel compounds in group 1 (carcinogenic to humans) [2].

Natural nickel background in groundwater is considered as concentrations that are not above ca. 20 μg/L. In sea water, the Ni concentrations reach between 0.1 - 2 μg/L. Flush water from metal surface treatment reaches nickel concentrations of tens up to hundreds of mg/L. For water intended for fish breeding it is recommended that the Ni concentration should not exceed the value of 0.1 mg/L. The same concentration is recommended for water used for irrigation purposes. The general pollution standard of permissible surface water pollution for nickel is 0.04 mg/L. Industrial wastewater discharged into municipal sewerage systems is subject to the concentration limit of 0.1 mg/L, when discharged into surface, water from electro-technical operations have a permissible nickel concentration set at 0.5 mg/L and for water discharged from metal surface treatment it is 0.8 mg/L [1].

For the quality of drinking water and the quality of table water and baby water the limit value is set at 20 μg/L. Average nickel concentrations in public drinking water systems in the Czech Republic are usually ca. 4.7 μg/L [1]. Drinking water rarely contains more than 20 μg/L of nickel, although elevated levels are possible in ground waters when contaminated by natural nickel deposits, or both surface and ground waters contaminated by industrial sources. Perinatal mortality is considered the major risk from nickel in drinking water with a WHO guideline set at 20 μg/L [3].

There are several technological methods for the removal of heavy metals and metalloids in water treatment: precipitation, ion exchange, membrane technologies, adsorption, electrochemical processes, and recently also biological methods [4].

2. Methodology

Some drinking water natural resources contain nickel concentrations that sometimes exceed several times the limit concentrations in drinking water as defined by Regulation No. 252/2004 Sb. For this reason, we focused on removing