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Modelling natural attenuation of heavy-metal groundwater contamination in the Selebi-Phikwe mining area, Botswana

M. O. Schwartz · J. Kgumanyane

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Abstract Seepage from a tailings dam is the major source of groundwater pollution in the Selebi-Phikwe area, where mining of sulphidic nickel–copper–cobalt ore started in 1973 and will continue until 2014. The seepage water has a pH in the range of 1.7–2.8 and is strongly enriched in SO_4^{2-} (5,680 g/L) and heavy metals (6,230 µg/L: Ni, 1,860 µg/L Cu and 410 µg/L Co). The fracture aquifer affected by pollution from the dam exhibits a remarkable capacity of heavy-metal sorption. Most of the Ni, Cu and Co is scavenged at less than 500 m distance downgradient from the polluting source, whereas SO_4^{2-} is not immobilised significantly. The heavy-metal sorption process is assumed to be due to surface complexation, which is supported by a relatively high groundwater pH (in the range of 6.2–7.8 at >200 m distance from the tailings dam). The objective of this study is to demonstrate that the sorption process can be incorporated into a realistic three-dimensional reactive-transport groundwater model that is implicitly charge-balanced. The simulations are performed with the PHAST1.2 program, which is based on the HST3D flow and transport code and the hydrochemical PHREEQC2.12 code.

Keywords Numerical model · Acid mine drainage (AMD) · Groundwater pollution

Introduction

There are various computer codes that model three-dimensional reactive transport in groundwater. For aquifers rich in iron oxides and hydroxides, however, only those are suitable which model surface complexation. The programs PHAST1.2 (Parkhurst et al. 2004) and FLOTTRAN (Lichtenner 2005) have an option for surface complexation but most comparable codes have not; e.g., MT3DMS (plus PHT3D), MODCO or RT3D coupled to MODFLOW, and the stand-alone codes Chem3a, ChemTOUGH2, FE-FLOW and YOGGIBREACT.

PHAST1.2 models saturated media; the code is more user-friendly and offers a wider spectrum of hydrochemical features than FLOTTRAN, which is designed for saturated and unsaturated media. PHAST1.2 was found to be superior to FLOTTRAN and, therefore, is used in this case study, which comprises a 100 km² area termed Phikwe model area (Fig. 1). The study focuses on sorption processes and demonstrates the possibility of establishing a realistic three-dimensional reactive-transport groundwater model that is implicitly charge-balanced.

Materials

Code description

The PHAST1.2 program is a point-distributed finite-difference code which combines a modified version of the HST3D flow and transport code for groundwater (Kipp 1987; 1997) with the hydrochemical PHREEQC2.12 code (Parkhurst and Appelo 1999). The program simulates multi-component, reactive solute transport in three-dimensional flow systems. The flow and transport capabilities are similar

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Chapter 4

FUNDAMENTALS OF GROUNDWATER MODELLING

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Abstract

Groundwater Modelling is an efficient tool for groundwater management and remediation. Models are a simplification of reality to investigate certain phenomena or to predict future behaviour. The challenge is to simplify reality in a way that does not adversely influence the accuracy and ability of the model output to meet the intended objectives.

Despite their efficiency, models can be complicated and produce wrong results if they are not properly designed and interpreted. Regardless of the type of model being used, similar sequences should be followed in modelling. To help selecting the proper model, modelling objectives should be clear and well identified.

If the conceptual model is not properly designed, all modelling processes will be a waste of time and effort. To build a proper conceptual model, hydrogeological data should be sufficient and reliable. Calibration and verification are the last steps in modelling before writing the final model report.

This chapter discusses the stepwise methodology of groundwater modelling with explanation of each step. It contains a brief description of different types of models and different types of solutions. In addition, special difficulties and common mistakes in modelling have been discussed.

1.0. Introduction

Groundwater modelling is a way to represent a system in another form to investigate the response of the system under certain conditions, or to predict the behaviour of the system in the future.

Groundwater modelling is a powerful tool for water resources management, groundwater protection and remediation. Decision makers use models to predict the behaviour of a groundwater system prior to implementation of a project or to implement a remediation

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Reduction of Nitrate in Groundwater by Fe(0)/Magnetite Nanoparticles Entrapped in Ca-Alginate Beads

Dong-Wan Cho · Hocheol Song · Bokseong Kim · Franklin W. Schwartz · Byong-Hun Jeon

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Abstract Calcium alginate beads entrapping a mixture of Fe(0) and nanosized magnetite (NMT) were prepared and evaluated for their capability to reduce nitrate in groundwater. Microscopic and spectroscopic analyses of the beads revealed that clusters of Fe(0)/NMT were entirely embedded in alginate polymer matrix containing a large number of carboxylic and hydroxyl functional groups. The extent of nitrate reduction increased with increasing content of Fe(0) and NMT in the beads, but there was a critical NMT mass limit relative to Fe(0) mass where no further increase in nitrate reduction occurred. The beads showed slower nitrate reduction kinetics than bare Fe(0)/NMT but had comparable capacity in overall nitrate removal. Nitrate reduction increased proportionally with an increase in bead dosage to give a maximum removal of 94.5 % at 37.5 g L⁻¹ in

48 h. Nitrate reduction with 50 g L⁻¹ beads achieved completion of two reduction cycles in 72 h to reduce 2.19 mM nitrate to less than 0.71 mM (10 mg-N L⁻¹) in each cycle. The overall results demonstrated that the beads developed in this study have a potential utility in remediation of nitrate in groundwater.

Keywords Zero-valent iron · Magnetite · Alginate bead · Nitrate · Reduction

1 Introduction

Nitrate is one of the most commonly found groundwater pollutants worldwide. Nitrate contamination has become a serious environmental health hazard, especially to the people living in underdeveloped countries where many still rely on groundwater for drinking water (Luo et al. 2010). Nitrate is regarded as a nonpoint source pollutant as it is released to the environment from diverse sources of both urban and rural origins. Some of the most prominent sources of nitrate include agricultural runoff, landfill leachate, leaking septic tanks, treated wastewater effluents, and municipal storm water runoff (Savard et al. 2010; Wick et al. 2012). Excess level of nitrate in aquatic environments often results in eutrophication of water bodies that severely disturbs aquatic ecosystems. Overconsumption of nitrate-contaminated water can induce methemoglobinemia and cancer in humans (Jamaludin et al. 2013; Suthar et al. 2009). The standard limit for nitrate in potable water has been set at 11.3 mg-N L⁻¹ by both the

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GROUNDWATER, WELLS AND PUMPS



Dr. M.K.Jha
Dr. P.B.S.Sarma

The principle of Virtual Work for Groundwater Flow

K.J.BAKKER 1

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During his lectures on soil-mechanics Verruijt used to begin with the fundamentals of a practical theory. For his lectures on groundwater flow, a number of lectures in sequence, he started writing down the fundamental equations; continuity of flow, Darcy's law etc. After introducing boundary conditions for a special problem and introducing simplifications, he explained in detail, a specific flow problem, quite often with an analytical solution. It was as if he wanted to be sure that we learned the fundamentals of our job first, before he trusted practical problems in our hands.

When discussing the numerical modelling of groundwater flow, i.e. Finite Element analysis he mentioned, though only slightly, that there was a minor fundamental problem with the numerical formulation of groundwater flow. Where for stress analysis one could rely on physical principles such as minimal potential energy for elastic problems, or the principle of virtual work for non-linear problems, such a physical principle for groundwater flow was not (yet) available. We had to rely on mathematical approaches, e.g. Galerkin's principle of variations. The analogy in the derivation, comparing the differential equations, made it trustworthy to rely on such principles, but on the other hand the lack of a physical principle was felt to be missing.

Later on working with Rijkswaterstaat, when I was involved with the design of water defences this question on the fundamentals of groundwater flow, came back to me, when analysing the flow under revetment blocks. Looking into the literature, it could be found that among others Van der Veer [4] analysed this problem. He introduced what he calls the energy flux per unit of time: $\epsilon = \rho g \phi \theta$. He postulates that the loss in energy flux should be minimal. This would mean that the groundwater head distribution should be such that the total loss of energy should be a minimum. Working out the equations, the result is nearly the same as found using Galerkin, but the contribution of the boundary condition is not included. The limitation to Van der Veer's approach is that for fixed boundary conditions; i.e. groundwater flowing from a point with high groundwater head to another point with a lower groundwater head, whatever the further distribution the total energy loss is constant. As the potential energy is the main energy component, the change in groundwater head visualizes this energy loss.

Groundwater flow is an energy non-conservative process. During flow continuously potential energy is transferred into heat. Therefore, one of the suggestions was that a more fundamental formulation would have to come

Arnold Verruijt Symposium

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Schwartz Hubao Zhang Fundamentals of underground water: Franklin W. on the numerous modeling of heat transport in aquaverers in Täten in 1990. "... one of the most complete texts on the subject ... must be widely used as a vehicle of teaching ... "(Environmental geology, vol 45 (7), May 2004) within this, Wiley -VCH - Schwartz, Franklin W. Schwartz, Zhang: Fundamentals of underground water - Compää ± ero Student Welcome site. Books on the foundations of the Schwartz Solution Manual of underground water. / Zhang, Hubao - Fundamentals of. I sent this article by email to a colleague; Alert me when this article is cited;. Schwartz, Hubao Zhang. Â © 1996-2014, Amazon.com, Inc. Introduction to the numerous modeling of underground waters and. (1999) MODERN GLAMOUS ELECTRONIC BOOK: The art of the unexpected style book Les Quarante-Cinq-Tome 2 (French Edition) Book may ask: an introduction to thought as a sociólogo Read Download of Architecture Principles: The Corners of Enterprise Architecture (The Enterprise Engineering series) Read all the creatures of God: spiritual lessons of the animals of the surfers book Gossip Short Stories #3: Three's Company., â¿ ray? Houston Series in Mexico American Studies, sponsored electronic book Nashville Journal of Medicine and Surgery: V.8 1855 Jan-Jun Download Ebook blinded. Your Ph.D. Brief description Introduction to the hydrology of underground water provides readers with the fundamental principles of the hydrogen cycle. You are working on. Also complete with illustrations and "... OST comprehensive texts on the subject ... They must be widely used as a vehicle of teaching ..." (Environmental Geology, Vol 45 (7), May 2004) Product. Book review; Services. Also complete with real -life case illustrations and studies, this text takes Comprehensive and realistic approach to the theme of hydrology. The foundations of underground water: environmental geoscience and engineering the foundations of underground water can be divided into four parts ... or its affiliates The foundations of underground water provide the reader with the fundamental principles of the hydrogen cycle . Dr. Welcome to the website for the foundations of underground waters by Frank Schwarz and Hobao Zhang read the complete rules book: time tested in secrets to capture Mr. Rightmr's heart. Cool (I am reading) Electronic book of the book The Solar System (a guide of Lucia © Rnaga) The Book of Electronic Books of Body Language The Electronic Book of 2011 on facilities of Teligo and Telegraphs: â¿â¿ Segmentation of the World Market Water The original welcome patent application number 18,354 for pipes improvements to smoking tobacco, Fundamentals of the Schwartz solution of underground water: Download. Schwartz. It also contains interactive programs based â¿â¿â¿ on interactive computer to resolve and simulate hydrogen underground water processes. You can see a list of compatible browsers in our help center. Fundamentals of the Underground Water Aid Center: Amazon. Nea. Prof. enable Javascript or change to a compatible browser to continue using Twitter.com. Showing 1-30 begins its revision of the foundations of underground water Danny Chambers qualified by really like January 1, 2015 Jenni qualified, it was fine on February 1, 2008 Ratha really descried on January 31, 2019 erin Lo Lo Lo marked reading reading. On August 27, 2011 I marked it to read the uK uK yoj 9102 ed ozram ed 70 le reel arap omoc 'Ăcram ol rohB luhaR 8102 ed erbutco ed 82 le reel arap omoc 'Ăcram ol alyaK 8102 ed orene ed 01 le odneyel etnemlautcA SI SI SI LB indtonyV 7102 ed oinuj ed 61 le reel omoc 'Ăcram ol ttocS 5102 ed orene ed 72 le reel arap omoc 'Ăcram ol etvetS ,4102 ed otsoga ed 72 le odneyel ¡Âtse ol etnemlautca surevS subIA 3102 ed lirba ed Currently reading on October 15, 2019 Sutton marked it to read on October 29, 2020 Khatij Underground water Download Franklin W. W.

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