Visual MINTEQ simulation for prediction of the adsorption of arsenic on ferrihydrite

R. Irunde^{1,2}, P. Bhattacharya², J. Ijumulana^{1,2}, F.J. Ligate^{1,2}, A. Ahmad^{2,3,4}, F. Mtalo¹ & J. Mtamba¹

¹DAFWAT Research Group, Department of Water Resources Engineering, College of Engineering and Technology, University of Dar es Salaam, Dar es Salaam, Tanzania

²KTH-International Groundwater Arsenic Research Group, Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, Stockholm, Sweden

³KWR Watercycle Research Institute, Nieuwegein, The Netherlands

⁴Department of Environmental Technology, Wageningen University and Research (WUR), Wageningen, The Netherlands

ABSTRACT: The surface of ferrihydrite adsorbs arsenic (As) effectively. In this investigation, the As laced water samples collected from Geita and Mara regions within the Lake Victoria Basin (LVB) under DAFWAT project were simulated on Visual MINTEQ 3.1 software to determine the amount of ferrihydrite required to adsorb a given amount of As from water. Model simulations show that As concentration of ≤ 1 mM can be completely adsorbed by 4 g L^{-1} ferrihydrite. Previous studies show that the lower pH 4 to 4.5 influences adsorption, while it decreases as pH increases as well as when As concentration increases. The increase of adsorbent dose to 4 g L^{-1} has shown to improve As(V) adsorption on pH 5 to 8 at 100%. The amount of adsorbent can now be used for laboratory adsorption experiments by using iron-based materials or commercial ferrihydrite.

1 INTRODUCTION

High levels of arsenic (As) have been reported both in surface water and groundwater in several African countries (Ahoulé *et al.*, 2015). Elevated concentrations of As has recently reported in the northern part of Tanzania, particularly around the Lake Victoria Basin (LVB) and the Lake Victoria Goldfields (LVGF) (Ijumulana *et al.*, 2016a, 2016b, 2017; Kassenga & Mato, 2008; Lucca, 2017; Mnali, 2001).

Geochemical modeling tools such as PHREEQC (Parkhurst, 1995; Parkhurst & Appelo, 1999) and Visual MINTEQ (Gustafsson, 2009) are useful to model the mobility and fate of arsenic in water sources. The present study aims to use Visual MINTEQ for prediction of amount of iron oxide that can be applied on arsenic laced water samples for adsorptive removal. The simulation results of groundwater samples collected from Geita and Mara are presented.

2 MATERIALS AND METHODS

2.1 Study area and water sampling

Lake Victoria Basin, Tanzanian part, is one of the 9 river basins in Tanzania mainland covering area of 119,442 sq. km. The region has little seasonal variation but the eastern section where the study area lies (Geita and Mara), average only 750–1000 mm of rain. Favorable climatic conditions for agriculture and livestock and the abundance of natural resources have supported the livelihood of the rural population of over 35 million

Figure 1. Map of the study area around the LVB region (A) and water sampling area locations (B).

people (Lucca, 2017). The geology of the Tanzanian LVB consists of Archean granitoids-greenstone belts hosted in the Tanzanian craton. More than 80% of rural population depends on groundwater resources for various uses.

Water sampling was carried out at the end of dry season during October 2016 from Geita and Mara (Fig. 1). A total of 29 water samples collected from Mara and 18 samples from Geita were simulated using the Visual MINTEQ.

2.2 Visual MINTEQ parameter setting

Groundwater quality data for Geita and Mara such as pH and the concentration of As(V) and As(III) (Lucca, 2017) were imported in the Visual MINTEQ. The following parameters were fixed in the model

Figure 2. Adsorption of arsenic onto ferrihydrite from water sample from a) Geita and b) Mara sites.

for Geita sample; NaCl = 0.01M, temperature = 25°C, pH = 6.3 and ferrihydrite = 4 g L⁻¹; and for Mara sample; NaCl = 0.01M, temperature = 26°C, pH = 7.3 and ferrihydrite = 4 g L⁻¹.

3 RESULTS AND DISCUSSION

The results of the geochemical modelling were concentrations of As adsorbed onto ferrihydrite. The percentage of As sorbed was calculated using the following equation:

$$As_{\text{sorbed}} = (\text{Final } As_{\text{conc}} / \text{Initial } As_{\text{conc}}) \times 100\% \quad (\text{eq. 1})$$

The percentage of adsorbed As(V) and As(III) on ferrihydrite were plotted against pH to visualize the strength of Visual MINTEQ 3.1 on arsenic adsorption (Fig. 2).

The As(V) concentrations at Geita and Mara ranged from 10 µg L⁻¹ to 300 µg L⁻¹ which is equivalent to ≤1 mM and hence only 4 g L⁻¹ ferrihydrite added in the Visual MINTEQ was adequate to remove As from water samples in the pH range of 5 to 8.5.

The model results from Geita (Fig. 2a) and Mara (Fig. 2b) show maximum adsorption of As(V) leading to 100% removal, while As(III) is removed at 99%. This is because As(V) a negatively charged species, is strongly bound to surface of the ferrihydrite and is thus easily removable from water up to a pH close to 8.5 (Ahmad *et al.*, 2014). The groundwater of Geita and Mara have higher concentrations of As(V) because of an oxidizing environment where As(III) can be oxidized to As(V) as well as Fe²⁺ being oxidized to Fe³⁺.

4 CONCLUSION

The Visual MINTEQ software is a useful tool to gain insight on the adsorption processes. The software

is recommended for prediction of adsorbent amount that is required for As removal from water samples. Simulation results predict 100% of As(V) removal from Geita and Mara in the pH range of 5 to 8.5 when 4 g L⁻¹ ferrihydrite was dosed.

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