

Estimation of Filtering Potential of Charcoal for Iron and Manganese Removal from Groundwater

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Abstract. Groundwater ‘a renewable natural resource’ serves an elegant myriad of diversified purposes, however, physico-chemical parameters of ground water display a significant role in classifying and assessing the water quality to address its use for various purposes. Nevertheless, water scarcity is a future global problem, hence; demands practice of artificial recharge systems. However, the main enemy of any infiltration systems for artificial recharge is clogging. Artificial well recharge can lead to the precipitation of iron and manganese (hydr)oxides as dissolved oxygen levels change. The first choice for clogging prevention is water quality control. Clogging problems can be prevented by proper filtration as a low cost environmental friendly strategy to tackle this global problem in addition to other advanced preventive and redevelopment methods. Filtering ability of small sized bamboo charcoal (2-4 mm) is estimated for Fe and Mn retention/removal from underground water in a vertical down flow column experiment. From the experimental results, it is plausible to conclude that time periods for Fe and Mn saturation is different for same material under similar experimental conditions, and the tested material might not be a good choice for Mn removal.

Keywords: Artificial Recharge, Bamboo Charcoal, Clogging, Groundwater, Iron And Manganese Removal

1. Introduction

Groundwater is the most used natural resource which serves different diverse purposes. However, abrupt climatic changes may result in more flooding rather than groundwater recharging. To combat this situation, artificial recharge is an important alternate. Nevertheless, notorious enemy of any infiltrating systems for artificial recharge is clogging^[1], and is caused by a variety of interdependent mechanisms (physical, chemical, and biological), which may be different in fractured and porous media^[2-5]. Clogging can be mechanical from particulate matter in the water, chemical from precipitation reactions in the aquifer and biological from accumulation of bacterial and algal slimes and redox products^[6]. Clogging is a phenomenon that leads to reduction in available pores for fluid flow and resulting in reduction in permeability^[7-9]. Clogging can decisively reduce the recharge rate, increase the maintenance cost, and shorten the longevity of recharge facilities. Information documented in pertinent literature revealed that clogging problem is the key factor for implementing the artificial recharge facilities.

Clogging is caused by inorganic (clay, silt) and organic (algae, sludge) suspended solids in the water that accumulate on the infiltrating surface, and by microorganisms that grow on the soil particles (biofilms) and produce polysaccharides and other insoluble metabolites to form a soil-clogging biomass. Bacteria also can

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produce gases (nitrogen, methane, carbon dioxide) that can block soil pores. Gas also can be formed in aquifers when water from recharge wells contains entrained air or is cooler than the groundwater itself. As the recharge water then warms up in the aquifer, dissolved air may go out of solution to form pore blocking air pockets in the aquifer (called air binding). Also, well recharge can lead to precipitation of iron and manganese oxides or hydroxides as dissolved oxygen levels change, and to solution or precipitation of calcium carbonates due to changes in pH and carbon dioxide levels ^[10, 11].

The first choice for clogging prevention is water quality control. The mechanism and developing process of chemical clogging is very complicated because of too many influencing factors. These influence factors including the chemical components and blending of recharge water and native ground water, the mineral gradients of aquifer, the control conditions for solution and deposition (such as temperature and pressure, etc.). The weathering of igneous and sedimentary rocks brought ions in the groundwater. During weathering and circulation of water in rocks and soils, ions leach out and dissolve in groundwater. The abundance of major ions largely depends upon the nature of bed rocks, climatic conditions and mobility. In chemical clogging, role of some ions such as Fe and Mn is very important, however, any reliable handling mechanism in resource limited environments is not yet documented. Therefore, this needs prior concerns and efforts to formulate low cost environmental friendly strategies for future ventures to combat this serious global problem on a sustainable basis. Removal of Fe and Mn from groundwater by means of alternative filtering material such as charcoal efficiently on ideally low cost basis is the main objective of this study.

2. Materials and Methods

2.1. Experimental Set Up

From the previous experiments conducted by using diverse filtering materials (bamboo charcoal (small and large sized), slag, hotate shell sand, volcanic ash, and sand etc.), we concluded that small sized charcoal (2-4 mm in size) is an effective filtering material. Therefore, small sized charcoal was used in the present study. Some physical properties of small sized charcoal are presented in Table 1. Vertical down flow columns of 110 cm length with 10 cm inner diameter were used in the present study. Experiment was conducted in controlled temperature environment of 17 ± 3 °C. Columns were mounted vertically and operated continuously in down flow mode using a multi-channel peristaltic pump as outlined in Fig. 1. Filtering bamboo charcoal materials (free from inert material such as debris, dirt and clay etc.,) was washed twice with demineralised water and dried prior to the column packing. Initially, three columns were packed with filtering materials, and then saturated with water using reverse flow by taking care that no air entrapped/remained inside the columns, and then connected with the experimental components (Fig. 1). Ground water was pumped from the well for 40 minutes before sampling. Blank samples of groundwater were collected in clean glass tubes for comparison before the start of experiment. By using ground water having initial Fe/Mn concentration (C_0), constant flow rate (0.83 L/min) was maintained during the entire experimental flow from the columns. The groundwater tanks, pipe joints and upper surface of columns used during the experiments were replaced and cleaned after every one week in order to remove the flakes formed due to the oxidation of Fe/Mn. Effluents with concentration (C) were collected at the intermittent intervals (12 hr intervals; total time span 17 days considering the approximate yielded effluent with 90% initial Fe/Mn concentrations) to calculate the saturation point and filtered/retained amount of the interested element in the filtering media. All treatments were conducted in triplicate, and experiment was layed out according to complete randomized design (CRD). Two samples per column were collected in pre-washed clean dry glass tubes at the intermittent intervals during the entire experiment. Samples were immediately transferred to analytical laboratory for Fe/Mn chemical analysis.

Table 1: Some physical properties of small sized charcoal (2-4 mm in size)

Porosity	Specific Gravity (g/cm ³)	Bulk Density (g/cm ³)	Permeability (cm/s)
0.85	1.45	0.22	0.15

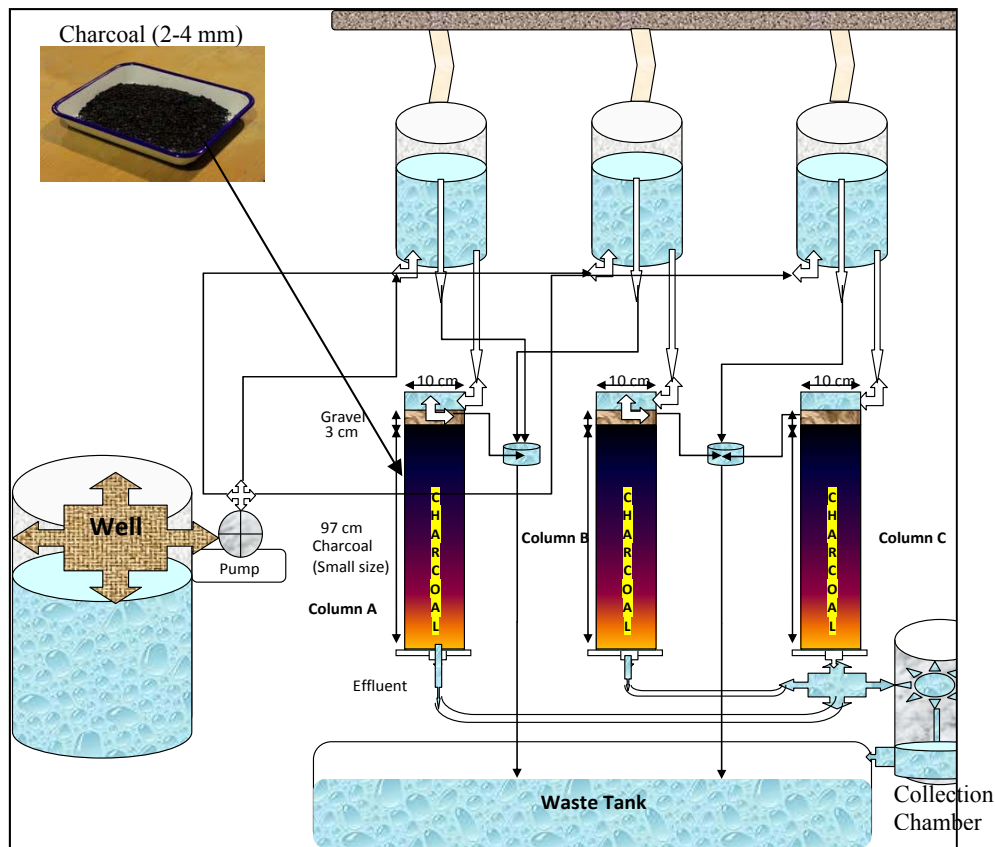


Fig. 1: Schematic illustration for vertical downflow column experiment using columns containing filtering materials (charcoal)

2.2. Elemental Analysis

Fe and Mn concentrations (mg L^{-1}) in the samples were estimated by using atomic absorption spectrophotometer (AAS) (Hitachi, Z-6100 polarized zeeman) after standardizing the instrument with standards of known concentrations. Fe- and Mn-concentrations in the blank samples (sampling was done before (BW1, BW3) and during (BW2, BW4) running the experiment for comparison), and the effluent samples were determined.

3. Results and Discussion

Fe- and Mn-concentrations in the blank samples and the effluent samples are depicted in Figs. 2-3. Significant differences in C values between the blank and effluent samples in all columns indicating that tested filtering materials had substantial potential for retention of interested elements particularly for Fe. There were no statistically significant differences in charcoal material with time interval (12 hr interval with total time span of 17 days) in terms of C values in case of Fe concentrations depicting that further time is needed to obtain the iron concentrations in the effluents, or otherwise, tested material has higher retention capacity for iron. However, tested material is not a good filtering option for Mn because within 2 days after loading the samples in columns, approximately yielded effluent C value is more than 90% of the initial concentration (C_0) indicating that these materials get saturated with very short time intervals (approximately 48 hrs), and have very less filtering/retention capacity for Mn. Furthermore, the effluent C value of Mn is slightly higher in next 48 hrs (between 3-4 days) than the control Mn concentration value of groundwater, and then tended to decrease and become equals to the original Mn concentration after 4 days of running the experiment. This increase in Mn concentration (between 2 and 4 days) might be due to the surplus addition of the native Mn concentration present in the tested bamboo charcoal material. Data highlights that time

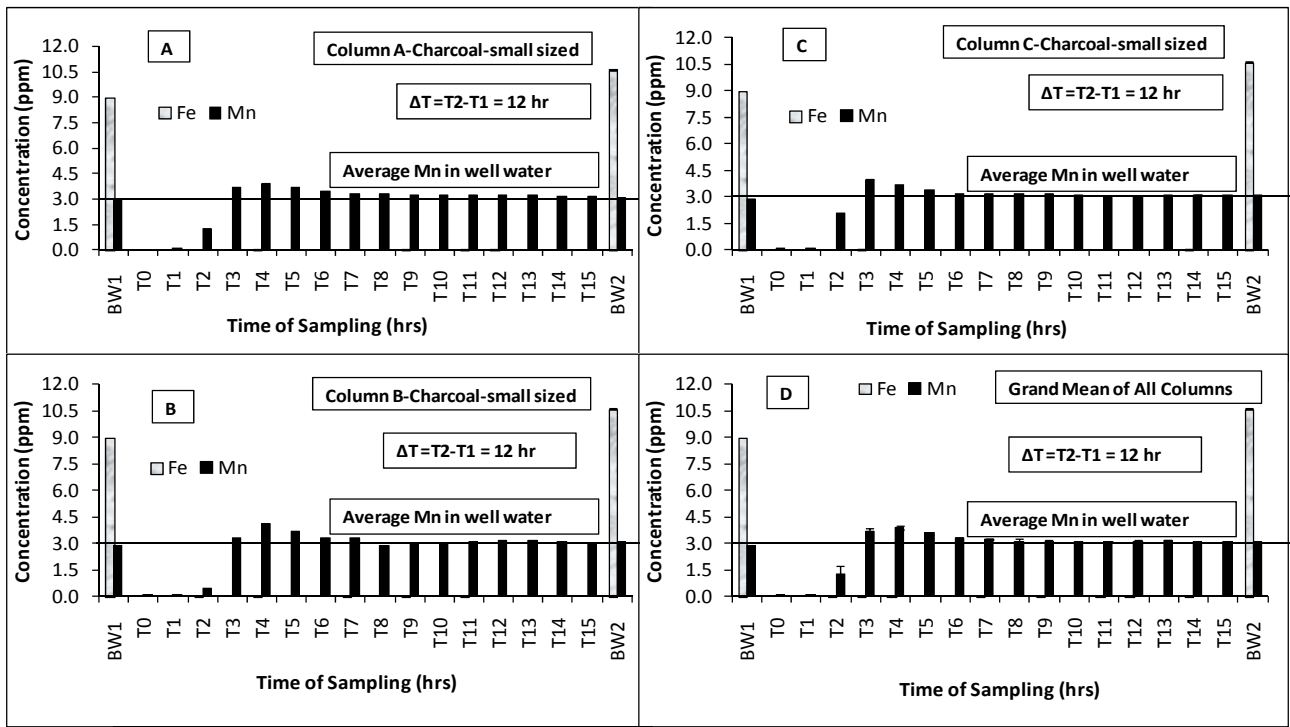


Fig 2: Fe and Mn-concentrations in samples of unknown concentrations (effluents); BW1, BW2: Blank water sample (having C_0 concentration) before and after experimental run up; T0-T15; Intermittent time intervals of 12 hr for each sample.

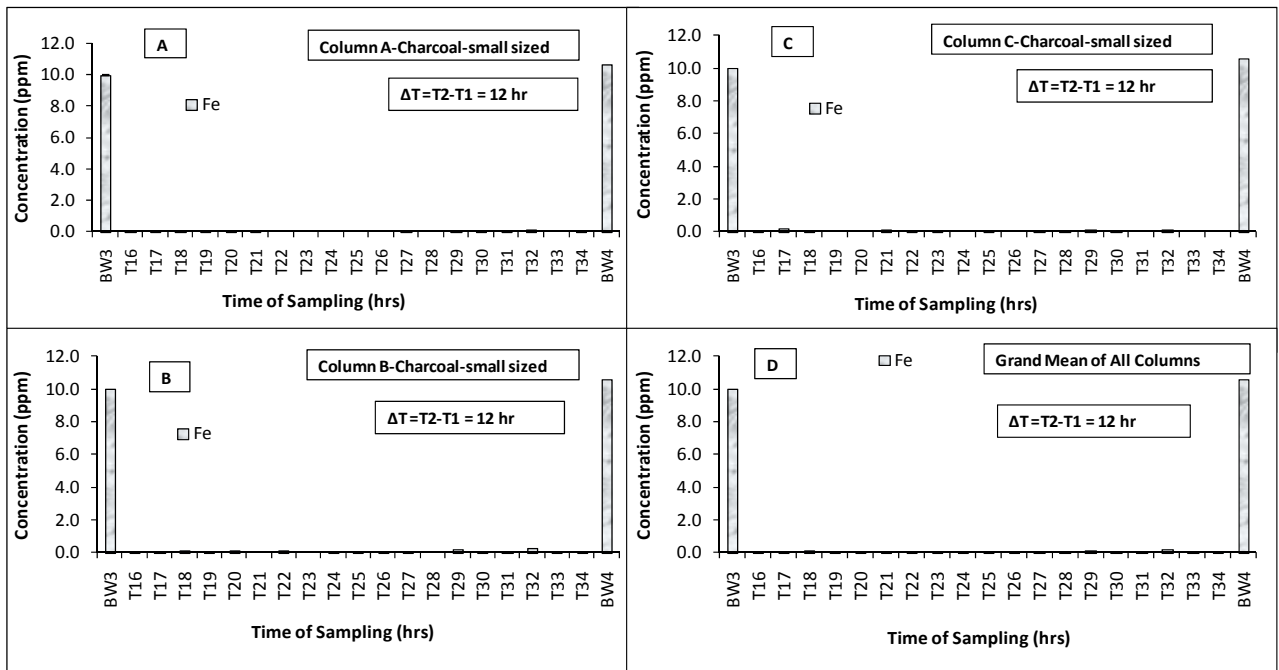


Fig 3: Fe-concentrations in samples of unknown concentrations (effluents); BW3, BW4: Blank water sample (having C_0 concentration) before and after experimental run up; T16-T34; Intermittent time intervals of 12 hr for each sample.

periods for Fe and Mn saturation are different for same material under similar experimental conditions. Nevertheless, the present experiment also highlights the need for longer time span study in order to get the saturation points of Fe for filtering material. Furthermore, in order to tackle some issues raised during this experiment further testing is need. These issues are (1). Slightly different flow rates in different columns during handling might arise and demands more uniform automated conditions with uniform flow, (2). Use of

material for Mn filtration is warranted, (3). The concerns regarding the variation in permeability with time in long term flow because permeability is decreasing with time due to clogging, (4). Concerns due to the flakes formed due to the oxidation of Fe/Mn in groundwater tanks, pipes and pipes joints and upper surface of columns used during the experiments in long term flow demands more controlled conditions. Therefore, we need long term experiment under more controlled uniform conditions and an up flow mode study for comparison in order to validate the above stated results.

4. References

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