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Effects of mixing granular iron with sand on the efficiency of methylene blue discoloration

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HIGHLIGHTS

- Mixing iron metal (Fe^0) and sand is a conventional approach in designing Fe^0 filtration systems.
- Reliable concepts to optimize Fe^0/sand systems are still lacking.
- Methylene blue (MB) discoloration is used to characterize the efficiency of Fe^0/sand systems.
- Results demonstrate that sand impairs MB discoloration by Fe^0 as a rule.
- The urgent need of systematic investigations for efficient system design is delineated.

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ABSTRACT

The influence of granular sand on the efficiency of metallic iron (Fe^0) for the discoloration of a methylene blue (MB) solution was investigated in the current work. The initial MB concentration was 10 mg L^{-1} and mass loadings within the range of 0–90 g L^{-1} for sand and 0–45 g L^{-1} for Fe^0 were applied. The batch reaction vessel used was a graduated essay tube containing 22.0 mL of the MB solution. Shaking intensities of 0 and 75.0 rpm were applied for experimental durations of 7, 21 and 45 days. Results provide clear evidence that both Fe^0 and sand were independently effective for the discoloration of MB. However, the latter material was significantly less effective, recording 54.0% compared to 82.0% recorded for the Fe^0 after 45 days in experiment with 45.0 g L^{-1} of each material. Similarly, mixing 90 g L^{-1} sand with 45.0 g L^{-1} of Fe^0 depicted a MB discoloration efficacy of 72.0% demonstrating that the discoloration capability of the Fe^0 was significantly 'masked' by the presence of sand. This observation provides clear evidence to question the common approach of using adsorbents for contaminant accumulation in the vicinity of Fe^0 materials in order to facilitate chemical reduction by Fe^0. Further research is required to determine the relative affinity of different materials that can be used in Fe^0 mixtures for maximum contaminant removal efficacies.

1. Introduction

Metallic iron (Fe^0) has been demonstrated in numerous studies to represent the best available material for subsurface permeable reactive barriers [1–5]. Fe^0 has also been demonstrated as a highly efficient material for wastewater treatment and safe drinking water provision [5–10]. In all these applications Fe^0 is routinely mixed with inert materials. The most used additive is sand [11–15]. Reported goals of mixing sand and Fe^0 are: (i) meeting design requirements (*goal 1*), (ii) saving Fe^0 costs (*goal 2*), and (iii) delaying particle clogging (*goal 3*). However, actually there is no conclusive experimental evidence to demonstrate that Fe^0/sand mixtures are more or less effective than pure Fe^0 systems [16].

The relevance of mixing iron and sand was recognized since the early phase of technology development [17]. However, the literature still contains limited information on Fe^0/sand mixtures [15]. The need for systematic work aiming at establishing the practical use of Fe^0/sand mixtures has been recently theoretically discussed as summarized in Ref. [18]. Results concluded that, when designing a Fe^0 treatment system, priority must be placed on the aforementioned goals number 1 and 3, stating that goal number 2 (low cost) is required, but not an instrinsic requirement of a Fe^0 filtration system. In fact, mixing Fe^0 and sand is regarded as reducing the proportion of Fe^0, and thus 'creating' or 'leaving' room for sustained iron corrosion [19,20]. In other words, theoretical studies disprove

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