# IMPLICATIONS OF REACTIVITY OF PERMEABLE REACTIVE BARRIER (PRB) FOR REMEDIATION OF MULTIPLE CONTAMINANTS AND ITS LONG-TERM PERFORMANCE EVALUATION

by


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# ABSTRACT

The study aims to investigate the reactivity of permeable reactive barriers (PRBs) for the remediation of multiple contaminants using selected reactive materials and their respective production batches. PRBs are significant among all the established remediation technologies for the in-situ treatment of contaminated aquifers and groundwater. Various permeable reactive media are available for treating different organic and inorganic groundwater contaminants or even mixtures of them successfully in groundwater. Among them, zero-valent iron (ZVI), supplied by different brands worldwide, dominates reactive material applied to PRBs. However, many of those ZVI brands have predominantly been produced for entirely different industrial purposes, such as food and electronic industries but not explicitly for groundwater remediation. Therefore, ZVIs do not represent tailored reagents specifically regarding destroying or immobilizing pollutants in groundwater. Thus, their reactivity towards certain contaminants in groundwater may vary significantly in a wide range. Further, it defines that different reactivity can be encountered among certain single ZVI brands, which has already been known since the technology started in the 1990s. At the same time, different reactivity may also depend on different production batches of a particular ZVI brand, which has rarely been known and consequently not comprehensively addressed and resolved so far.

Therefore, the research implemented an extensive, long-term study to develop a semi-empirical test methodology for establishing improved quality assurance guidance regarding proper field-scale implementations of different ZVI brands in PRBs. In particular, focusing on different production batches of the same brand avoids potential major failures regarding field-scale applications. Extensive long-term column experiments were followed by short-term batch experiments covering kinetic analyses to investigate the impact of two technical ZVI brands. That is, Gotthart Maier and Sponge Iron, as well as their different production

batches from the same supplier, on the degradation efficacy regarding organic pollutants, i.e., polychloroethene in groundwater. Further, the study also investigated the possible amendments of ZVI to treat hexavalent chromium (Cr(VI)) in alkaline and hyperalkaline medium. Therefore, this study extended to analyze the reactivity improvement of micro-ZVI and nano-ZVI with copper (Cu) and nickel (Ni) catalyst precursors to enhance its Cr(VI) removal capacity of ZVIs in alkaline and hyperalkaline mediums. Furthermore, the research work also focused on the long-term performance evaluation of PRBs and the impact of essential factors that can significantly drive PRB performance in the long run, using numerical modelling to treat contaminants released from multiple sources.

The result of the study showed the reactivity difference in the ZVI brands and their respective production batches for the removal of PCE from groundwater. To encounter this reactivity difference during the field-scale application of PRB, a short-term effective batch experiment guidance is proposed for the right selection of the production batch of PRB reactive material just prior to its field emplacement. Further, the study also emphasizes the necessity of catalyst precursors with ZVI for the high Cr(VI) removal efficiency, especially in alkaline and hyperalkaline mediums. Metal catalyst precursors and ZVIs provide 100% removal efficacy for Cr(VI) removal within 5 mins in hyperalkaline medium. Therefore, a modification of ZVI brands with Ni and Cu catalyst precursors is highly recommended for Cr(VI) remediation sites in hyperalkaline medium.

Furthermore, the study also suggests the performance evaluation of multi-permeable reactive barrier systems through numerical modelling and its significance for the effective and efficient remediation of a contaminated site. However, the PRB's installation cost is very high for the treatment of aquifer and groundwater, irrespective of the target contaminant. However, its in-situ passive treatment of various contaminants, with high longevity and sustainability of 20 – 30 years at low maintenance cost, makes it the best remediation technology available. However, multiple reactivity issues and a lack of long-term performance study before its field-scale emplacement raise various long-term performance issues. Our investigations prove that appropriate guidance for successful full-scale in situ remediation is required to always properly select the right production batch of the reactive materials. Therefore, with the unique development of quality assurance guidance and proper understanding of long-term performance evaluation for different contaminants with some efficient reactive material amendments, this study may most likely prevent stakeholders from potentially severe failure after setting up a field-scale PRB for groundwater remediation.