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Permeable reactive barriers: A sustainable technology for cleaning contaminated groundwater in developing countries

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Abstract

Permeable reactive barriers (PRBs) are a proven technology for remediating contaminated groundwater, particularly on industrial and mining sites. PRBs are a sustainable technology that can operate over a long time scale with low maintenance. Over the past 10–15 years, there have been great strides in refining site characterisation techniques (i.e. geophysical techniques), developing/discovering reactive materials/sorbents (i.e. Fe^0 filings), and the installation and design of PRBs (i.e. funnel-and-gate design) which have increased the cost-effeciveness of this technology. Prior to installation, careful consideration of the ease of removal of the PRB should be considered as part of the design. This is important as the PRB may eventually need to be decommissioned. PRBs are a sustainable site specific remediation technology that has the great potential to work well as a part of a larger scale integrated water resource management programme in developing countries.

Keywords: Permeable reactive barriers (PRBs); Reactive materials; Sorbents; Remediation; Site characterisation; PRB designs

1. Introduction

Permeable reactive barrier (PRB) technology has been sucessful in remediating a variety of groundwater contaminants including heavy metals [1], organics [2] and radionuclides [1,3]. Most PRBs have been installed on industrial, mining and agricultural sites around the world [1–3]. PRBs use the natural hydraulic gradient of the groundwater plume to move the contaminants through the reactive zone giving it an advantage over traditional pump-and-treat technologies by being more cost effective and lower maintenance in the long-term [3]. Over the past decade, much work has been done on improving site characterisation techniques, developing reactive materials/sorbents, and the installation and design of PRBs. This work has increased the cost-effeciveness of this technology making it a more viable remediation option for developing countries.

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Geophysical techniques such as magnetic and ground probing radar are a form of non-invasive site characterisation that yields valuable information about site geology, *in situ* engineering properties, hidden cultural features, and contamination in the shallow subsurface. Non-intrusive investigations are a quick and cost effective means of obtaining data, especially when combined with old site plans, and are useful in planning the intrusive site investigations. These techniques are reducing the need for more expensive trial pitting or borehole drilling with lower risks and decreasing the chances of missing buried targets. Some of the instruments (EM units) are hand carried and generally do not contact the ground. All accessible areas of a site can be quickly surveyed (up to 2 ha/day) without disturbing the surface [4]. This is important because there may be considerable surface and near surface contamination on former industrial and mining sites. Comparing site historical plans with their geophysical surveys is a very beneficial ground truthing method and is generally part of the protocol of a study.

A variety of reactive materials and sorbents, which can be used separately or in combination depending on the groundwater contamination, have been successful in remediating contaminated groundwater in PRBs. These materials, such as Fe^0 filings [4], peat [3], limestone [4,8], granular activated carbon (GAC) [5,6] and zeolite [1], are easily available and some are fairly inexpensive. Bench-scale treatability studies are carried-out in the initial screening of the reactive or sorbent material to plan the design of PRBs using site groundwater. Batch studes using a number of likely reactive and sorbent materials are conducted to determine the best performing materials. Then column tests are carried-out on the best performers. Column tests can give information towards the design of the PRB and indications on how an *in situ* PRB will perform [7].

Installation of PRBs is a crucial stage, especially in the excavation of geological material. Improved equipment and techniques used to excavate geological material without obstructing the flow of the contaminated groundwater plume in and out of the PRB has helped to increase the success rate of PRB performance. During installation, loose geological material and soil can be packed, smeared and fill void space that the contaminated groundwater flows through adjacent to the PRB [8,9]. Methods in depositing of the reactive material in to the PRB have also been refined to reduce particle size grading which can alter groundwater flow through the reactive zone [9]. Prior to installation, careful consideration of the ease of removal of the PRB should be considered as part of the design. This is important as the PRB may eventually need to be excavated due to the completion of remediation; therefore, decommissioning could become an issue [7]. Of the two basic designs, i.e. the continuous trench and the funnel-and-gate, the funnel-and-gate design with the reactive material placed in single or sequenced containers is probably the most cost-effective design. This is because the funnel-and-gate usually uses less reactive material than the continuous trench. The reactive material(s) is placed in the canister(s) (reactors) and can be removed if it needs to be replaced. This is an important consideration as there could eventually be built-up of contaminant concentrations in the reactive/sorbent material(s) from the remediation process. The containers can be designed to be reused at other sites once remediation is finished.

PRBs are a sustainable site specific remediation technology that has the great potential to work well as a part of a larger scale integrated water resource management programe in developing countries. The objectives of the paper are to illustrate how PRBs are planned and installed, and highlight cost effectiveness which may allow them to be installed in developing countries.

2. Material and methods

If PRB technology is considered one of the options for the remediation of contaminated groundwater at a site, there are a series of steps that should be taken to ensure that the PRB is viable, and that it is designed and installed properly. One of the first steps is to collect as much information about the site as possible, such as blueprints, geological maps, and records. This will help in ground truthing and determining contamination. What are the possible contaminants? Have there been any buildings on site? Buried debris may imped PRB installation and groundwater flow across the site. Knowing what contaminants may be present at the site will also allow for better health and safety plans.