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# Study on Optimal Location of Permeable Reactive Barrier (PRB) in Remediation of Contaminated Groundwater Using Groundwater Modeling

Y. Sathya,
*Asst. Professor, Department of Civil Engineering, Valliammai Engineering College, Kancheepuram*

DR. D. Elango
*Professor& Head , Department of Civil Engineering, Valliammai Engineering College, Kancheepuram*

**Abstract:** Water is not always accessible, or fresh enough for use without treatment because of man-made activities. Hence, ground water requires an effective treatment process to remediate the contamination. Though, many in-situ groundwater remediation methods are available, Pump-Treat and Inject (PTI) method is widely used. However, it has its own limitations and Permeable Reactive Barrier (PRB) will replace the limitations of PTI method for in-situ remediation of contaminated groundwater. Since groundwater system is very complex in nature, mathematical model can be used to describe a simplified version of actual ground-water system and the future response of the system to be effects of management decision.
To demonstrate the applicability of the concept, highly polluted Noyyal River Basin of South India is considered as study area and also greatly in need of innovative techniques for remediation of ground water.
The PRB material which will be used for this study area is phosphate that will reduce the concentration of Zinc which is above the quality standards and need to be treated. All the inputs will be fed to the 3-D groundwater model (MODFLOW) to simulate the groundwater flow and contaminant concentration distribution over the study area. The results of the model will enable to predict the performance of PRB in remediation of ground water system in the future which will make the study area as an usable for irrigation purpose.
**Keywords**: component; Groundwater pollution , PRB, Modflow.

## Introduction

A great deal of money and effort has been spent on environmental restoration during the past 30 years. The most common technology used for remediating groundwater has been to pump the water and treat it at the surface. Although still useful for certain remedial scenarios, the limitations of pump-and-treat technologies have recently been recognized, along with the need for innovative solutions to the groundwater contamination.
One of the most promising of these innovative solutions is the use of permeable reactive barriers (PRBs) filled with reactive material to intercept and decontaminate plumes in the subsurface. The concept of PRBs is relatively simple. Reactive material is placed in the subsurface to intercept a plume of contaminated ground water which must move through it as it flows, typically under its natural gradient, thereby creating a passive treatment system. As the contaminant moves through the material, reactions occur that transform it to less harmful (nontoxic) or immobile species. (Powel)

## Need for modeling

The groundwater modeling is the management tool for making a decision to provide the information about the groundwater system concerned and the future response of the system to be effects of management decision. In other words, model could provide future distribution of contaminant concentrations, water levels, plume direction, etc.

## Need for the study

To date, a limited number of works have been published in which PRB has been used to treat the contaminated water through MODFLOW. Never the less the performance of PRB through groundwater model (MODFLOW) has not been used so far in the field of ground water remediation. It will be proposed that this technique will be appropriate to be applied to areas which require innovative methods for groundwater remediation. This has been the inspiration for carrying out the present work in which optimal location of PRB and its performance will be made with MODFLOW

The river Noyyal flows through the districts of Coimbatore, Erode and Karur and the urban centers of Coimbatore and Tiruppur, in western Tamilnadu. A number of industrial units such as textile units, chemicals are located in the river basin which discharges their untreated and partially treated effluents into the river, making the Noyyal one of the highly polluted rivers in the country.

## Permeable Reactive Barrier:

At the beginning of the 90's was developed the new remediation method – the method of Permeable reactive barriers (PRB). The method belongs to the group of the passive in situ remediation methods and it seems to be very useful alternative to the pump and treat method, which can be very often rather expensive, too lengthy or not too effective.

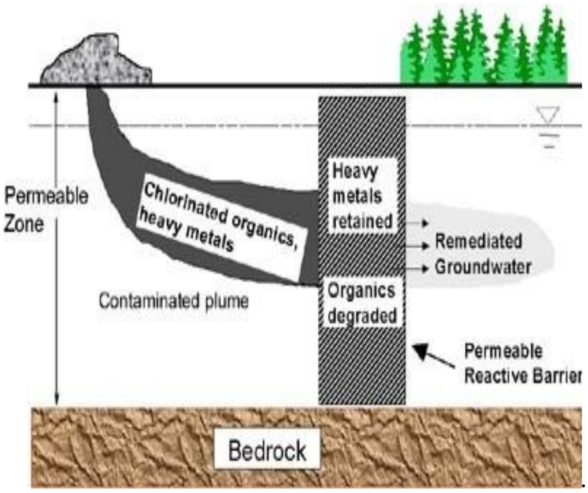


Figure 1.1 Permeable Reactive Barrier

## Objectives of the study

i) To select the appropriate Permeable Reactive Barrier (PRB) with respect to the contaminant characterization of the study area.
ii) To understand the plume behaviour through the simulation of groundwater flow and transport model using MODFLOW and MT3D.
iii) To evaluate the effectiveness of groundwater capture and treatment for various locations of PRB.
iv) To identify the optimal location of PRB and its performance in remediation of contaminated ground water system.

### The Noyyal River

The Noyyal River starts from the Vellingiri hills in the Western Ghats in Tamil Nadu. The river comes down to southeastern India and empties into the Kaveri River. The entire area of the basin is situated in the state of Tamilnadu, in parts of Coimbatore, Erode and Karur districts. The Noyyal confluences with the Cauvery River at Noyyal village.

The Noyyal river basin covers a total area of 3510 km2 and is located between north latitude 10° 56'N and 11° 19'N and east longitude 76° 41'E and 77° 56'E. The length of the Noyyal river is about 170 km from west to east. The average width of the basin is 25 km. The basin is widest in the central part with a width of 35 km.

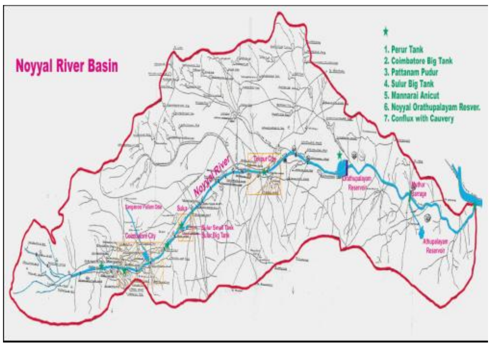


Figure 1.2 :Noyyal river basin

## Methodology

**Groundwater Flow Equations**

The ground water flow equations, which have to be solved or approximated by the groundwater modeling software currently in use, were developed from these simple equations. The 3-D groundwater flow equation for multi-aquifer numerical models or single aquifer numerical models needing vertical resolution

$$\partial/\partial x\,(Kxx \times \partial h/\partial x) + \partial/\partial y\,(kyy \times \partial h/\partial y) + \partial/\partial z\,(Kzz \times \partial h/\partial z) \pm W = S \times \partial h/\partial t \qquad (1)$$

Solute Transport Equations

$$M1 + M2 + M3 + M4 + M5 + M6 \pm W = \Delta \text{ storage.} \qquad (2)$$

$$\partial C/\partial t = [\partial/\partial x\,(Dx \times \partial C/\partial x) + \partial/\partial y\,(Dy \times \partial C/\partial y) + \partial/\partial z\,(Dz \times \partial C/\partial z)] - [\partial/\partial x\,(Vx \times C) + \partial/\partial y\,(Vy \times C) + \partial/\partial z\,(Vz \times C)] + q/n \times Cs \qquad (3)$$

Groundwater models that use these equations depend on accurate depiction of groundwater flow and biochemical reactions.

Transport Processes

The physical processes that control the flux into and out of the elemental volume are advection and hydrodynamic dispersion. Loss or gain of solute in the elemental volume can occur as a result of chemical or biochemical reactions.

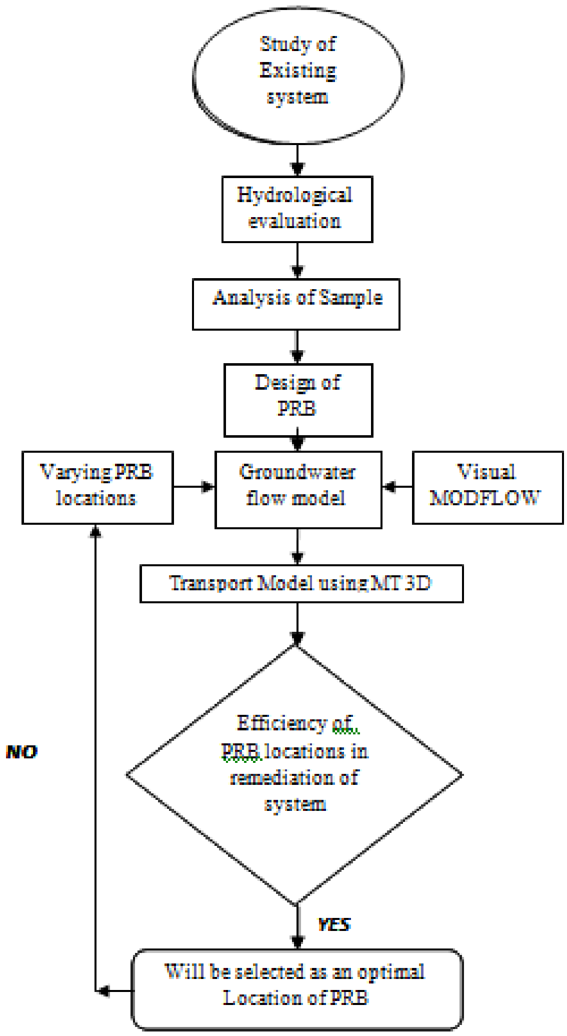


Fig 1.3 Methodology Flowchart

Advection is the component of solute attributed to transport by flowing groundwater. The rate of transport is equal to the average linear velocity, which depends on

i. The hydraulic conductivity of the sub-surface
ii. The porosity of the formation and
iii. The hydraulic gradient in the direction of groundwater flow.

In the study of flow and contaminant transport model to deduce the direction of groundwater flow and concentration of contamination of Noyyal river basin, The indigenously developed Genetic Algorithm optimization with the Mass Transport model was used for well location optimization.

**Conceptualization of Model**

The real system and its behavior may be complicated. Hence it needs to be simplify the description of the considered system and its behavior to the degree that will be useful for the purpose of planning and decision-making. Model conceptualization is the process aids in determining the modeling approach and which model software to use.

## Design & selection of Permeable Reactive Barrier:

Selection of Permeable Reactive Barrier (PRB) material
Since the test result shows that the sample has excess zinc metal , so to treat the excess Zinc metal the material chosen for PRB is Phosphate.

Reaction:

$Zn^{2+} + PO_4^{3-} + H^+ \rightarrow Zn^{2+} (HPO_4^{2-})$(4)(Zinc mono-hydrogen phosphate)
Second order reaction,

$\frac{1}{t}\frac{x}{a(a-x)}k = \frac{1}{t}\frac{x}{a(a-x)}$(5)

a – Initial concentration
x – Concentration after the time 't'
Rate constant,

$r = k*(\text{constant of reactant})^2$(6)

The dimensions of PRB are derived by desired level of contaminant concentration, which depends on the residence time of contaminant in the reactive media i.e. on the ground water velocity in the reactive wall. Thickness of Permeable Reactive Barrier,

$b = (v\, t_{res}\, SF)$ (7)
b - Thickness of PRB wall
v - Ground water velocity in the reactive
$t_{res}$ - Required residence time (d)
SF - Safety factor

Velocity of ground water in the reactive media,

$v = \frac{Ki}{n_p}$ (8)

K - Hydraulic conductivity of reactive media (m/d)

i - Hydraulic gradient across PRB

$n_p$ - Porosity of reactive media (9)

Residence time in the Reactive media

$t_{res}$ = -ln ($c_t/c_0$) / k (9)

tres - Required residence time (d)

$c_t$ - Target concentration down gradient the PRB(mg/l)
$c_0$ - Contaminant concentration entering the the PRB(mg/l )

k - Reaction rate ($d^{-1}$)

A Multibarrier study indicates multibarrier is a sustainable solution for preventing mixed contaminants spreading in the groundwater.(3).

## Groundwater flow modeling using Modflow package

Input Data for Groundwater Flow Modeling
The input data requires for groundwater flow modeling are as follows

- The top elevation of the aquifer will be assigned using the secondary elevation data.
- The bottom elevation will be assigned based on the weathered thickness. Specified head will represent the river boundary
- The groundwater recharge will be adopted.
- The discharge from the wells will be assigned based on their utility.
- Hydraulic conductivity as determined from Darcy's law will be used for the entire study area.
- The water level data of 2011 will be considered for initial conditions.
- The size of the grid will be assigned based on the data available.

**Simulation**

Groundwater flow models are used to calculate the rate and direction of movement of groundwater through aquifers and confining units in the subsurface. These calculations are referred to as simulations.

**Model calibration**

The MODFLOW simulation will be checked for any omission or wrong entry and runtime error. The groundwater heads will be computed using MODFLOW simulation. The flow model obtained will be calibrated by adjusting the parameters within a narrow range of values until a best fit is obtained between observed data and simulated results.

## Solute transport model using MT3D

Mass Transport in 3-Dimensions (MT3D) is the package for simulating advection, dispersion and chemical reactions of the contaminant in 3-dimensinal groundwater flow system. The model is used in conjunction with the groundwater flow model obtained using MODFLOW.

Input Data for Solute Transport Modeling
The various input data required for solute transport modeling are as follows

- Total dissolved salts concentration of the effluent will be chosen for mass transport simulation.
- The value of porosity as determined from the laboratory test will be assigned.
- The value of longitudinal dispersion coefficient arrived using the experiment will be used. The values for vertical dispersion will be assumed.
- The recharge of the pollutant will be taken from the characteristics of the treated effluent.
- The source/sink mixing will be manipulated based on the data given for groundwater flow modeling.

## Model calibration

Model calibration consists of changing the model input parameters in an attempt to match conditions within some acceptable criteria. The calibration process typically involves calibrating to steady-state and transient conditions.

The contaminant migration in the study area will be simulated using the above data. The simulation will be checked for any omission or wrong entry and for any run-time error. The selection and installation of PRB will be based on the concentration values arrived by the solute transport model. Various locations will be considered for the PRB installation and the performance of PRB will be predicted under different operating conditions. From this analysis the optimal location of PRB will be selected to treat the contaminants.

## Future Scope of the Study

Groundwater remediation is an extremely important process to treat the contaminated water. Significant studies have already been done on effluent disposal and its effect on groundwater contaminants. Pump –and- treat method is a classical one which involves in pumping, treating and injection of treated water. Permeable Reactive Barriers offer potential to treat the groundwater in -situ, with the potential for lower long-term maintenance costs. This study aims at remediation of contaminated ground water by locating PRB using groundwater modeling which will indicate the ideal locations of PRB to minimize the head increases that will be resulted in reduced seepage of untreated ground water. The results obtained from the flow and transport model will be used to study the performance of PRB in remediation of groundwater system for different locations of the selected study area and to select an optimal location of installation of PRB with respect to treatment efficiency.

## References

[1]. Robert Powell M., Robert Puls W., David Blows W., John Logan L. (1998)- 'Permeable reactive barrier technologies for contaminant remediation' - Subsurface Protection and Remediation Division National Risk Management Research Laboratory Ada, Oklahoma. pp. 1-98.

[2]. Saravanan R. (2009), 'Optimization of pumping well location for containment and remediation of contaminated plume using heuristic algorithms' - Anna university , Chennai

[3]. Leen B. (2010)-'A project of multibarriers as a sustainable approach for ground water remediation', Proceedings of the fourth international symposium, pp. 87-90.