II-12 Study of Pollutant Transport in Groundwater Aquifer at Padaeng Industry's Zinc Refinery Plant Area

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Introduction The Padaeng Industry (PDI) Zinc Refinery Plant is located between the highway and the Ping river. The main product is zinc metal of special high grade (99.995%) of which raw metal (zinc ore) is mainly in the form of zinc silicate. The existing production capacity is 77,000 tons/year.

In the refinery process, ore residue of 850 tons/day is produced. This ore residue which contains zinc, cadmium, manganese, silica and oxides of metals, is transported through a screw conveyer belt to dump into two large mixers and mixed with lime. Then, it is dumped into PVC lined residue ponds. At present, there exist three residue ponds with the total capacity of approximately 2 million cubic meters.

Pollution problem which may arise from this zinc refinery plant is groundwater pollution caused by leachate from ore residue stored in the PVC lined storage ponds in case that the PVC sheet is broken. Groundwater pollution problem has been recognized and the PDI Co.,Ltd. has undertaken a regular monitoring program of water quality analysis in the observation wells drilled around the storage ponds (SPS,1993).

The objective of this study is to investigate the transport of pollutants which may leak from the residue storage ponds to the underlying aquifer using a mathematical model. The two-dimensional mass balance equation is considered. The finite element method is used in model development.

Hydrogeology of the Study Area The geological formations involved in the transmission and confinement of groundwater in the study area are basement rocks and terrace deposits which constitute the principal aquifers. The basement rocks consist of granite which is not a good aquifer. Groundwater can be found only in the weathered zone. The terrace deposits overlying the basement rocks consist of sand, gravel and clay with 5-10 meters. in thickness.

For more details about hydrogeology and groundwater flow, 24 wells were drilled down to the impervious rock of which depth varies between 3 and 11 meters. Soil samples were collected and analyzed for soil texture and grain size. A pumping test was conducted in 3 out of the 24 wells to determine the coefficient of transmissivity of the underlying aquifer. Measurement of piezometric head in the monitoring wells was undertaken. From groundwater table measurement, an approximate direction of groundwater flow can be determined.

Model Analysis In this study a mathematical model is used in predicting dispersion pattern of metallic ions in the underlying aquifer in case that leakage from the residue storage ponds located within the plant area has occurred. Since there exists an impervious rock layer at an approximate depth of 3-11 meters below ground surface, a two-dimensional unconfined flow is assumed. The developed pollutant dispersion model is based on the two-dimensional mass balance equation (Bear,1972) as shown below.

$$\frac{\partial c}{\partial t}=\frac{1}{R_d}\{\frac{\partial}{\partial x}(D_{xx}\frac{\partial c}{\partial x})+\frac{\partial}{\partial x}(D_{xy}\frac{\partial c}{\partial y})+\frac{\partial}{\partial y}(D_{yx}\frac{\partial c}{\partial x})+\frac{\partial}{\partial y}(D_{yy}\frac{\partial c}{\partial y})\}+\frac{K}{nR_D}\{\frac{\partial h}{\partial x}\frac{\partial c}{\partial x}+\frac{\partial h}{\partial y}\frac{\partial c}{\partial y}\}-rc+\frac{q_c}{R_d}$$

where c is pollutant concentration in groundwater, D_{xx}, D_{xy}, D_{yx} and D_{yy} are coefficient of hydrodynamic dispersion, K is hydraulic conductivity of the aquifer, n is soil porosity, R_d is retardation factor = 1+a(1−n)/n, in which 'a' is a proportional constant in the equilibrium isotherm, h is level of phreatic surface above some reference datum, q_c is the rate of pollutant added to the aquifer, r is decaying rate of the pollutant

The finite element technique which is one of the most effective numerical methods is used in model development. Using Galerkin's weighted residual method, the governing equation which is in the form of partial differential equation is transformed to a set of algebraic equations in which the values of pollutant concentration at all nodal points are unknown variables.

A number of nodal points are located on this area. The nodal points are then connected to form triangular elements as shown in Figure 1. In total, these are 138 elements and 85 nodes. Data obtained from groundwater table measurement are used as input data.With the assumed rate of pollutant leakage, together with specified values of pollutant concentration at those upstream nodes, the values of pollutant concentration at all remaining nodes are computed.

From pumping test results, the coefficient of transmissivity can be determined. The values were found in the range of 5.0×10^{-6} to 13.0×10^{-6} m^2/sec. The values of hydraulic conductivity were in the range of 2.4×10^{-6} to 5.0×10^{-6} m/sec.

Tiwaree (1989) conducted an experiment to determine adsorption of zinc on soil samples taken from this area. It was found that the zinc concentration on soil sample expressed in milligram of Zn per liter of soil sample is as high as 5,600 times the zinc concentration in water with equilibrium zinc concentration of 0.1 mg/l in the liquid phase. Thus, the value of constant "a" is 5,600. This value was used in this modeling analysis.

The modeling study was conducted with the assumption that leakage occurred from all the three residue storage ponds in August, i.e. data obtained from groundwater table measurement conducted in August 1989 (Figure 2) was used as input data. It was assumed that leachage from each storage pond infiltrated into the underlying aquifer at the continuous rate of 0.1 m^3/m^2 per day and zinc concentration in the leaking leachate was 100 mg/l. The concentration of zinc at the upstream boundary was set equal to zero. The model was run step by step with a time interval of 1 hour for a total period of 3 months.

The results obtained from model analysis showed that zinc concentrations were in the range of 6-95 mg/l at nodal points inside or on the boundary of the residue storage ponds. However, the zinc concentration decreased to negligible values at the downstream nodal points.

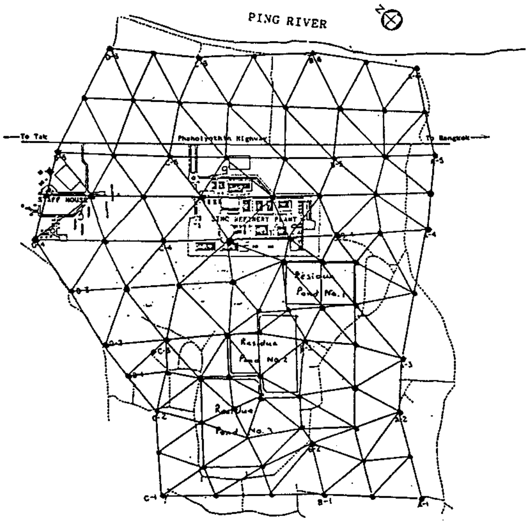

Figure 1 Finite Element Grid of the Study Area

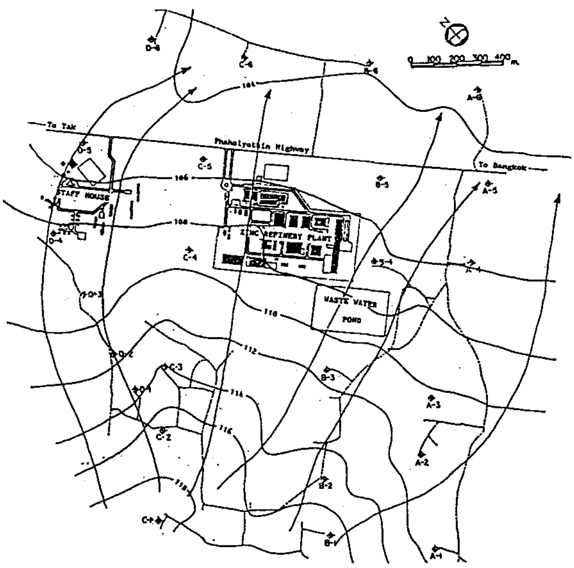

Figure 2 Groundwater Contour Map (August 5, 1989)

Conclusion Based on the results from modeling study, it can be concluded that if the leakage from the residue storage ponds occurs at the rate of 0.1 m^3/m^2 per day with zinc concentration of 100 mg/l, a remarkable increase in zinc concentration in groundwater can be detected in the aquifer just below the storage ponds while the concentrations at the adjacent downstream nodes are negligible during the 3 month period of pollutant leakage.

References

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