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A controlled-release molasses barrier system for controlling nitrate plume in groundwater: A large flow-tank study

B.S. Lee (1), J.Y. Um (1), K.Y. Lee (2), Y.B. Kim (1), K. Nam (2), N.C. Woo (3), J.H. Kim (1), and J.M. Lee (4)

(1) Rural Research Institute, Korea Rural Corporation (KRC), Ansan, Korea, (2) Dept. of Civil and Environmental Engineering, Seoul Nat'l Univ., Seoul, Korea, (3) Dept. of Earth System Sciences, Yonsei Univ., Seoul, Korea, (4) Jinbo E&C Co.Ltd., Anyang, Korea

A well-type permeable barrier system containing controlled-release molasses as a reactive material to promote the indigenous denitrifying activity (termed CRM system hereafter) has been developed for controlling nitrate plume in groundwater. To control the release of molasses as an extra carbon and energy source, CRM rod (OD x L = 4 cm x 30 cm) was manufactured using molding technique by dispersing molasses in paraffin wax-cellulose-silica matrix. A large scale flow-tank (L x W x D = 8 m x 4 m x 1 m, 95 m3 of sands, porosity of 0.45) was prepared to test the CRM system (L x W x D = 3 m x 4 m x 1 m) in destroying nitrate, which was consisted of three layers of discrete barriers installed at 1-m interval. Nitrate plume (1.2 m/d of velocity, 142 mg/L of nitrate) was generated by introducing both tap water (1.1 m3/d) and diluted nitrate solution (0.5 m3/d, 312 mg/L of nitrate) daily. Changes in nitrate concentrations were monitored at 30 monitoring points across the flow-tank. For 14 (i.e., the first test), 21 (i.e., the second test), and 42 (i.e., the third test) days, 80, 140, and 140 CRM rods were placed into the barriers to construct the CRM system, respectively. An indigenous microorganism Ensifer adhaerens (97% similarity) was identified from the flow-tank sands, which was probably the main denitrifier in the system. After the second test, a heterotrophic denitrifier Pseudomonas sp. KY1 was inoculated to increase destruction efficiency into the flow-tank sands for the third test. For the first test, nitrate concentrations decreased by 29, 59, and 80% after the 1st, 2nd, and 3rd barriers, respectively. For the second and third tests, nitrate concentrations decreased by 32 and 26% for the 1st, 68 and 74% for the 2nd, and 84 and 81% for the 3rd barrier, indicating little effects of inoculating KY1 on destruction efficiencies. At 5.5 m downstream (i.e., 1.75 m behind the 3rd barrier), nitrate concentrations decreased by 81, 90, and 90% at the first, second, and third tests, respectively. COD values were determined as an indirect indication of molasses concentrations ranging from 161 to 329 mg/L for the 1st, 81 to 287 mg/L for the 2nd, and 105 to 377 mg/L for the 3rd barrier. Incomplete destruction of nitrate plume could be attributed to the lack of transverse dispersion in flow-tank sands. The present study suggests that the CRM system may provide a practical tool for a long-term treatment option of nitrate plume in groundwater.