Rainfall-porous medium properties as controlling factors for nitrate leach from agricultural land

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Nitrate contamination in groundwater is commonly found in an agricultural area in Japan as well as in many other countries. It is often found that nitrate concentration in river water increases dramatically with heavy rains followed by large discharge increase. This fact implies that considerable amount of nitrate or nitrogen is ubiquitously stored in unsaturated zone and is flushed out by an intense heavy rain, but not by moderate rains. In a similar manner, groundwater may also receive nitrate from unsaturated zone only by heavy rains. Macropores that are relatively large openings formed by earthworms or plant roots are considered to play an important role in transporting nitrate quickly from surface to groundwater. The factors that physically controls nitrate leach were investigated by means of laboratory experiments. The purpose of this study was to elucidate rainfall and porous medium properties that generate fast nitrate transport in the subsurface system.

A sand box (Width 1m,Length 3m,Depth 0.6m) filled with .45m of homogeneous fine sand overlain by .15m of loam was fitted to the wind tunnel that was equipped with a rainfall generator. Artificial 100non-connected macropores (diameter=1mm or 2mm, L=0.2m(50 pores),0.3m(25 pores),0.6m(25 pores)) were formed within a part (1m2)of the surface, which makes macropore density be 100 macropores /m2. Tensiometers and suction water were installed in both non-macroporous and macroporous sections of the sand box without intersecting macropores. Water table was maintained at .55m below the surface. The soil water was allowed to evaporate into the air which had wind velocity of 1.5m/sec, temperature of 20degree Celsius and relative humidity of 60%.Tracer solution (1mm of 1000mg/l nitrate and chloride) was applied manually prior to the first rainfall in each case. Then, rainfall events were repeated at a certain intensity/amount and an interval. Drainage, evaporation rate, pressure head distribution were observed. Nitrate and chloride concentrations were obtained by extracting soil water and analyzing the aliquots by ion chromatography.

Evaporation equaled or exceeded rainfall applied during 4.8mm and 5.6mm repeating light rains, so that nitrate did not move downward under these conditions. The maximum concentration was always found at the top soil layer (less than .1m deep) in both macroporous and non-macroporous media throughout the experiments in these cases.

Rainfall amount exceeded evaporation during 6.8mm repeating rains and nitrate penetrated up to .2m below surface only in macroporous medium. The maximum concentration was, however, still found at the top soil layer throughout the experiments in both macroporous and non-macroporous media. It was also found that the smaller macropores are more efficient pathways for nitrate to reach the depth in these relatively light rain conditions.

The level of the maximum concentration started to move downward only in the macroporous medium during 13mm repeating rains. The effect of presence of macropores was most apparent in these intermediate rain conditions.

Solute displacement took place in both macroporous and non-macroporous media during heavy 26mm repeating rains. Bimodal solute transport was observed, indicating macropores are serving as express pathways, while matrix flow contributes to major nitrate transport.

Though larger macropores are more efficient pathways to conduct nitrate at heavy rains, smaller macropores serves as preferential pathways in smaller rains under which larger macropores does not affect solute transport. The ratios of nitrate transported through macropores and those through matrix will be discussed.