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HIROSHIMA UNIVERSITY

HOKKAIDO UNIVERSITY

Universidade de São Paulo Brasil

Kumamoto University

Rissho University 立正大学

Groundwater contamination by nitrate in the state of São Paulo (Brazil): research results and implications for management

R. HIRATA, C. VARNIER, S. PROCEL, & F. CAGNON

Introduction

Nitrate is a very insidious and persistent problem that affects almost all urban aquifer in the State of São Paulo. In the last 10 years, CEPAS (Groundwater Research Center, University of São Paulo) has conducted studies that evaluate the problem at different scales, from detailed experiments, in which the nitrogen (water and gases) dynamics were evaluated in both active (São Paulo city) and inactive cesspits (Urânia city), to intermediate scale (neighborhood in Vila Eutália, Parque Ecológico do Tietê and USP campus), and municipal scale studies (Urânia, Presidente Prudente, Marília, Bauru) (Hirata 2012).

This manuscript discusses the main findings of these studies focusing on groundwater management and land urban planning.

Results from detail studies

The evaluation of nitrogen dynamics in abandoned (since 2002) and active cesspits was conducted in two researches. In one of them a monitoring station was constructed (11.2m excavated well, 1.8m in diameter), in which 12 tensiometers and 12 suction lysimeters were installed to the unsaturated zone (0.5-9.0m) close to an inactive cesspit. It was demonstrated that nitrate remains up to 458mg/L NO_3^-—N) (Fig. 1) in the unsaturated zone, even after more than 10 years of abandonment.

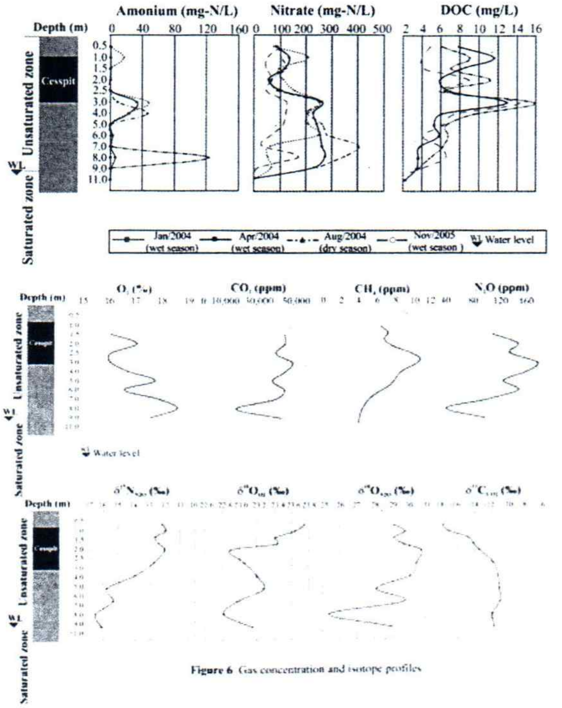

Fig. 1. Geochemical profile in an inactive cesspit in Urânia (Varnier et al 2007)

In the other study, a new cesspit, with pan/single lysimeters, Teflon gas extractors, and tensiometers, was constructed in order to monitor the unsaturated zone. The results of both studies show that denitrification and nitrification coexist on same level due to the presence of microcosms in the pore scale, associated to soil hydraulic conductivity heterogeneity (Fig. 2).

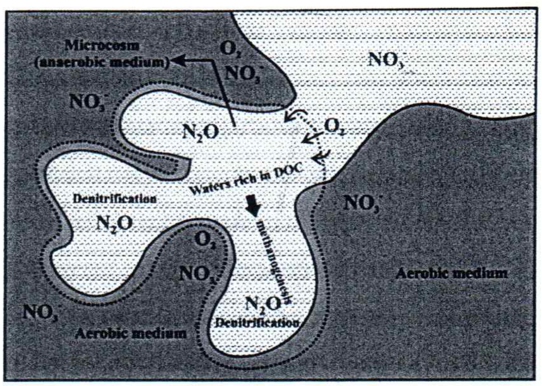

Fig. 2. Anaerobic microcosm generated in an aerobic environment (Varnier et al 2010)

Additionally, the reaction of nitrification and also denitrification is very fast (days-week) in aquifers. The conversion of all organic-N was done in less than 7m distance from the source in a shallow and unconfined aquifer, as observed in the Parque Ecológico do Tietê experiment (São Paulo).

Municipal scale results

In another scale, studies carried out in several cities have shown that: a) nitrate contamination plumes are found at different depths (>120mbs), showing concentration (>210mg/L-NO_3^-) stratification in unconfined to semiconfined sandy aquifer as in the Bauru Aquifer System (oxidizing and neutral to alkaline pH environment), b) there is a strong correlation between the density of cesspits and nitrate concentrations observed in unconfined aquifers (concentration is directly related to population density and inversely proportional to volume of water use, rainfall infiltration, and capacity of denitrification); c) presence of high nitrate contamination (>100mg/L -NO_3^-), even in areas with sewer system already in place since the 1970s.

The nitrate contamination source in Urânia (9,000 inhabitants) is associated with domestic effluent from residential properties, which previous to mains sewerage construction in the 70s, was injected directly into the soil (Hirata & Cagnon 2004). Today, the mains sewerage covers almost 95% of the urban area, although some cesspits already exist. Basically, all today active cesspits and dug and tube wells were inventoried and an extensive and long sampling for hydrogeochemistry analysis was performed for many years. Considering the sewage system has been deployed for more than 40 years, the problem still persists, especially in the shallow zone (up to 30mbs) (Fig. 3). The numerical modeling shows that the time required for removing it is longer (more than 10 years) for the shallow and intermediate parts of the aquifer (30-100mbs). For the deeper part (100-160mbs), it will take more than 90 years, but the expected concentration after 10 years, is <11% of the original one.

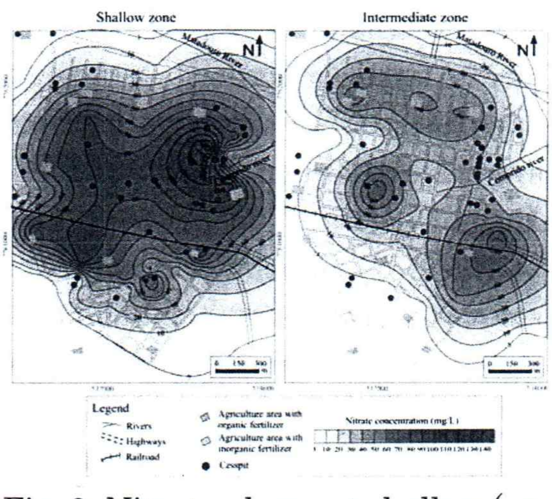

Fig. 3. Nitrate plume at shallow (up to 30mbs) and intermediate (30-100mbs) zones (Hirata & Cagnon 2004)

Presidente Prudente (200,000 inhabitants) has experienced a strong urbanization process in the 70s, initially without mains sewerage, releasing the domestic effluent into the soil. From the 80s, the septic tanks and cesspits were disabled almost completely and currently the sewer system covers approximately 98% of the city (Varnier et al 2010). For the study, the hydrogeochemical data were obtained from 82 production wells throughout the urban area in different time periods.

The results show a clear direct correlation with density of urban land occupation, and inverse with both the age of occupation (relation to the standard occupancy) and well depth (Fig. 4). It is also clear that in the oldest urban occupation areas is possible to recognize plumes with the highest concentrations of nitrate, probably due to the leakage of old

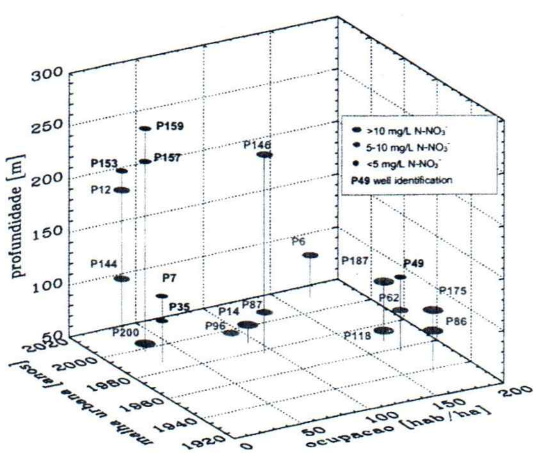

Fig. 4. Nitrate aquifer occurrence with relation to population density in Presidente Prudente (Procel et al 2013)

sewage systems and low maintenances.

Implications to management

The results obtained in studies conducted by CEPAS in the last 10 years have allowed some recommendations for better groundwater management and land use, including mainly: a) new settlements should be constructed only where sewer system (using plastic material) are previously installed and periodical maintenance is provided; b) new public supply wells (organized in wellfields) should be constructed in areas of low residential occupation or in parks/public places or even outside the urban area; c) in contaminated aquifers, groundwater exploitation should be encouraged for uses other than drinking (industrial uses, washing and irrigation) to allow more rapid nitrate plume dilution.

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