Workshop on

"Water, Nitrogen, and Agriculture in the State of São Paulo, Brazil"

Proceedings

Room 217, Advanced Research Building A,

the University of Tsukuba

February 28, 2014

ワークショップ 予稿集

「ブラジル・サンパウロの水，窒素，農業」

筑 波 大 学

総合研究棟Ａ ２１７ プレゼンテーションルーム

2014年2月28日

University of Tsukuba

HIROSHIMA UNIVERSITY

HOKKAIDO UNIVERSITY

Universidade de São Paulo Brasil

Kumamoto University

Rissho University 立正大学

2677694

Eucalyptus phytoremediation capacity to attenuate groundwater contamination by nitrate. Preliminary results from Rio Claro and Itatinga (São Paulo state, Brazil) study areas

R. TERADA, R. HIRATA, & F. SARAIVA

Brazil is the largest country forested in eucalyptus in the world. There are several studies reporting negative environmental impacts of eucalyptus plantation such as over-uptake of water and nutrition, biodiversity loss, volatilized or emitted harmful substances. However, few of these studies address the process of aquifer remediation contaminated by nitrate, especially with eucalyptus trees.

According to Cunninghan (1996), phytoremediation is a process for cleaning contaminated soil, water and air that takes advantages of absorption properties of the plant. Phytoremediation offers a different way of looking at eucalyptus performance, one that focuses on nutrients and water uptake. Lima et al. (1996) compared the uptake of water between two species of high performances trees that live in Brazil, and found that eucalyptus is able to take up 1.5 times more water than the pines. Indeed the eucalyptus grows very rapidly, and as a consequence, it consumes a high quantity of nutrients. Its roots are also an important part of this process, because they can reach several meters (>15mbs) searching for water, which is an extremely important characteristic to phytoremediation of aquifers.

Groundwater cleaning is not ordinarily undertaken because it is an expensive process. It usually takes a long time to clean and it is not totally efficient. The ion-nitrate is very mobile and persistent, but the main problem is the contaminant plumes generally are associated to diffuse or multipoint sources (urban areas or agricultural activities) creating large impacts.

In sum, there are several advantages to use phytoremediation to clean up aquifers, including: a) the retention of the contaminant for a long time in the structure of the tree; b) there is no requirement for outside energy, maintenance or structure; c) the ability to cover great areas with a group of plants; and, finally, d) social acceptance. The disadvantages are that it takes long time to remediate depending on the plant and the process cannot remediate deep plumes due to physiological constrains.

Nitrate is a very common nutrient in groundwater. Many human activities can cause this problem, including leakages from mains sewerage and on situ sanitation in cities, and also excess of fertilizers in agricultural activities.

Acute intoxication in humans is manifested primarily by methemoglobin formation. Nitrite ion in contact with RBC oxidizes ferrous iron in hemoglobine to the ferric state, forming stable methemoglobin incapable of oxygen transport, which results in anoxia. Secondary effects due to vasodilatory action of the nitrite ion on vascular smooth muscle may occur. The nitrite ion may also alter metabolic protein enzymes. Ingested nitrates may directly irritate gastro intestinal mucosa and produce abdominal pain and diarrhea (Merck 2014).

The main objective of the *Fitorem* project is to verify the efficiency of using eucalyptus as a remediating agent for groundwater impacted by nitrate. In addition, this project proposes a sustainable crop producing system coupling eucalyptus plantation in land-use sequences, based on verifying environmental functions of eucalyptus, such as uptake of contaminated nitrate from ground-water.

Method

The first study site, Rio Claro, is located 180km NW of São Paulo city (SP), where sugar cane fields and eucalyptus forests are set out sequentially. The area is covered by silty sand layers on an undulating peneplain (Cenozoic Rio Claro Formation). The annual mean temperature is 21.4°C, and average annual precipitation is 1279mm. The stands of the eucalyptus were about 5 years old and their heights are around 15m until they were cut out in August 2013. Sets of monitoring wells with depths of 3m to 18m were installed, and groundwater chemistry is analyzed and water levels are surveyed regularly.

Itatinga is another study area that was chosen to evaluate the eucalyptus capacity to extract nitrate from a shallow and unconfined aquifer. The city is located approximately 250km west of São Paulo at USP Horto Florestal, This area is covered by Permian sandstone Piramboia Formation. The annual mean temperature is

20°C, and average annual precipitation is 1350 mm (similar to Rio Claro). The stands of the eucalyptus are about 3 years old and their heights are around 15m. Sets of 7 monitoring wells with at depths of 6m to 11m were installed.

In order to avoid the rainfall recharge as much as possible and permit that trees have full access to the groundwater, a plastic liner of approximately $400m^2$ was installed (Fig. 1). A plume of contamination was artificially induced by injecting a solution of 150mg/L KNO_3 and 90mg/L NaCl in Itatinga. Water level and electric conductivity have been monitored since January 20th, 2014. This preliminary injection aims to obtain aquifer hydraulic parameters and help to develop the final experiment, which will occur in the near future. A flow and transport model (Modflow and MT3D) will be used to evaluate the performance of the extraction of nutrients by plants as well as determine the best distribution of trees to a more efficient remediation.

Previous Results

The potentiometric map of Rio Claro area indicates that the water flows to northwest, from the pond to the up topography.

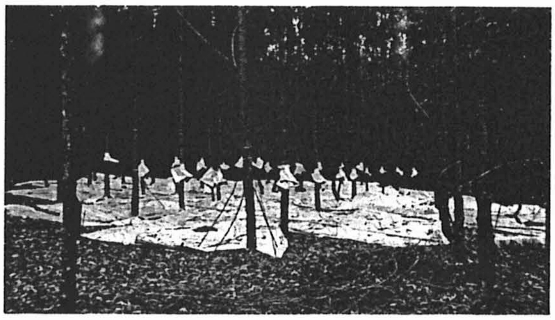

Fig. 1. Picture of the liner covering the Itatinga study area.

Chemicals analysis of all the campaigns have shown average of 5,81mg-NO_3^-/L. The average value below sugar was 2.29 mg/L and eucalyptus was 4.05 mg/L. The Piper diagram showed a Ca-HCO_3^- type of water, and the pHs have ranged between 4.5 and 7.5.

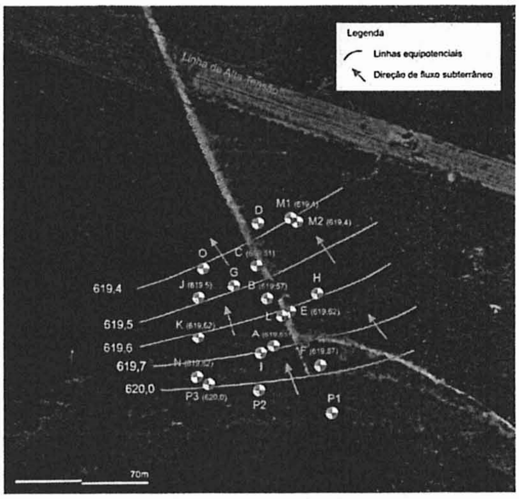

Fig. 2. Hydraulic head distribution in Rio Claro study area

After harvesting, new wells were drilled (Fig. 3) and the water level and electric conductivity have been monitored with a data logger device.

In addition, the water level has been also monthly checked up on. The purpose of this monitoring is to understand the relationships that eucalyptus has with the aquifer (ability to water withdrawal from saturated zone and capillary fringe), by comparing the periods with and without trees, permitting to compare with Itatinga area (Fig. 4) Analyses of background chemicals have shown that the nitrate concentration is low, as expected, comparing with Rio Claro experiment, however the chemical responses of the injection have not been observed yet.

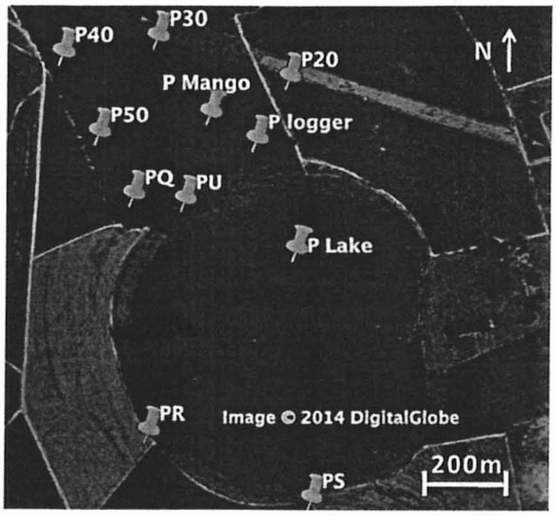

Fig. 3. Monitoring wells in Rio Claro study area.

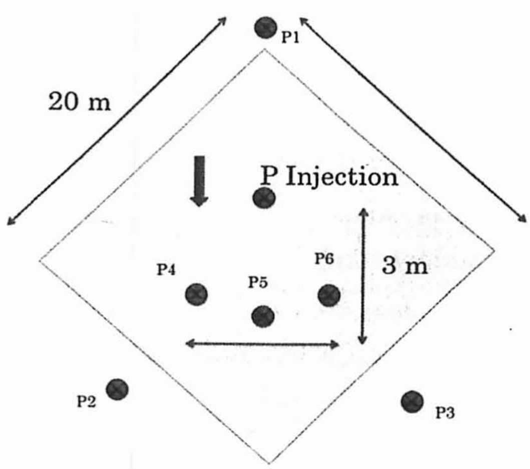

Fig 4. Itatinga area (out of scale) (Red arrow = groundwater flow, blue dots = monitoring wells)

Acknowledgments

This project is partly supported by Grants-in-Aid for Scientific Research, Scientific Research(B) of JSPS and Fundação de Amparo e Apoio à Pesquisa do Estado de São Paulo (FAPESP, 2012/20124-3), which are very appreciated.

References

Cunningham, S.D., and D.W. Ow. 1996. Promises and prospects of phytoremediation. Plant Physiol. 110:715-719

Lima, W.P.(1996) Impacto ambiental do eucalipto, edusp 2°ed. SP: Editora da Universidade de São Paulo 301p.

Merck Manuals web site: http://www.merck-manuals.com/vet/toxicology/nitrate_and_nitrite_poisoning/overview_of_nitrate_and_nitrite_poisoning.htm (accessed on 01Feb2014)