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ScienceDirect
Environmental Research 106 (2008) 170–177
Environmental Research
www.elsevier.com/locate/envres

Land use effects in groundwater composition of an alluvial aquifer (Trussu River, Brazil) by multivariate techniques

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Received 19 January 2007; received in revised form 18 September 2007; accepted 24 October 2007
Available online 11 December 2007

Abstract

Multivariate statistical techniques, cluster analysis (CA) and factor analysis/principal component analysis (FA/PCA), were applied to analyze the similarities or dissimilarities among the sampling sites to identify spatial and temporal variations in water quality and sources of contamination (natural and anthropogenic). The aquifer under study is supplied by the Trussu River, which has a general direction from west to east, within Iguatu County, Ceará, Brazil. Groundwater samples were collected in four shallow wells, located at the Trussu River alluvial, from October 2002 to February 2004. The samples were analyzed for 13 parameters: pH, electrical conductivity (EC), Na, Ca, Mg, K, Cl, HCO_3, PO_4, NH_4–N, NO_3–N, SO_4, and sodium adsorption ratio (SAR). Two zones were very well differentiated based on cluster analysis results, and implied a relation to geographic position and time variation. One zone called UL—upland region—corresponds to upland of studied area, used mainly for irrigation and livestock activities. The other zone called DL—downland region—corresponds to the region downstream and is occupied by human settlements. These results may be used to reduce the number of samples analyzed both in space and time, without too much loss of information. Three major independent factors that define water quality in the UL region and four in DL region were identified in the PCA. At both regions, rotated component (RC) loadings identified that the variables responsible for water quality composition are mainly related to soluble salts variables (natural process) and nutrients (high loads of NO_3–N, NH_4–N), expressing anthropogenic activities. RC also revealed that hydrochemical processes were the major factors responsible for water quality.

Keywords: Water quality; Alluvial; Cluster analysis; Principal component analysis; Pollution

1. Introduction

The impact of agricultural activities on water quality is gaining increasing attention. Groundwater quality in a region is largely determined by both the natural processes (lithology, groundwater velocity, quality of recharge waters, and interaction with other types of water aquifers) and anthropogenic activities (agriculture, industry, urban development, and increasing exploitation of water resources) (Helena et al., 2000). Groundwater may be contaminated upon leaching of chemicals in the soil surface towards the aquifer.

The agricultural irrigation effluent, industrial wastewater discharge, and domestic effluents have largely contributed to contamination of groundwater. The changes in agricultural practices during the last 50 years (use of fertilizers, simplification of the landscape, mechanization, drainage) have significantly contributed to increase the concentrations of pollutant substances in surface and shallow groundwater to such an extent that it has become detrimental to aquatic ecosystems which present evidence signs of eutrophication (Elmi et al., 2004).

Non-point sources of pollution by agriculture activities and livestock have appeared as major risks to the planet's

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0013-9351/$ - see front matter © 2007 Elsevier Inc. All rights reserved.
doi:10.1016/j.envres.2007.10.008

groundwater resources (Bouwer, 2000; Chowdary et al., 2005). The main non-point source pollutants are agrochemicals, fertilizers, and salts contained in irrigation leaching. These are the major pollutants in the water that percolates through the root zone into the shallow aquifer, limiting urban, industrial, agricultural, and ecological uses (Feng et al., 2005). Some environmental and health problems may be expected when these pollutants percolate into the groundwater. This is the case of high nitrate levels in humans' or animals' drinking water that has been associated with a number of health problems like methemoglobinemia. High nitrate and phosphorus levels present in groundwater that discharges into surface waters (McCobb et al., 2003) can contribute to long-term eutrophication of water bodies.

Throughout the world, accelerating increase of population has led to higher consumption of water for domestic, industrial, and irrigation purposes. Therefore, it became imperative to prevent and control water pollution and have reliable information on water quality for its effective management. In view of the spatial and temporal variations in the hydrochemistry of groundwater, regular monitoring programs are required for reliable estimates of its quality (Melloul and Collin, 1998; Singh et al., 2005; Andrade et al., 2005). This results in an enormous and complex data matrix composed of a large number of physico-chemical parameters, which are often difficult to interpret and draw meaningful conclusions (Wunderlin et al., 2001; Simeonov et al., 2003). Besides, for effective water resource management and pollution control, it is necessary to identify the pollution sources and their contributions. In the present work, the alluvial aquifer of the Trussu River sited west of Iguatu city, Ceará, Brazil, was studied. The shallow characteristic of the alluvial aquifer as well as its high permeability makes it highly vulnerable to pollution (Helena et al., 2000; Melloul and Collin, 1998).

The multidimensional data analysis methods are becoming very popular in environmental studies dealing with measurements and monitoring. The most common multidimensional data analysis methods used are cluster analysis (CA), factor analysis/principal component analysis (FA/PCA), which have been used to identify important components/sources that explain the variations in water quality and influence the water system. Usually, CA is carried out to reveal specific links between sampling points, while FA/PCA is used to identify the ecological aspects of pollutants on environmental systems (Ganfopadhyay et al., 2001; Singh et al., 2005).

The purpose of the present study was to identify the effect of land use over the shallow groundwater quality to evaluate the potential for reducing the number of water quality monitoring stations for long-term monitoring purposes and to evaluate the importance of some water quality variables throughout the application of multivariate techniques (CA and FA).

2. Materials and methods

2.1. Studied site

The samples were taken in the alluvial of Trussu Valley located, approximately, between parallels 6°20′59″S and 6°16′48″S, and meridians 39°27′W and 39°16′12″W (Fig. 1), about 300 m above sea level. The aquifer is supplied by Trussu River, which flows from west to east in Iguatu County. The main activities carried out in this area are agriculture, crop irrigation, and dairy activities. The main human settlements are the villages of Suassurana, Santa Clara, and Barreiro, with a total of 5000 habitants.

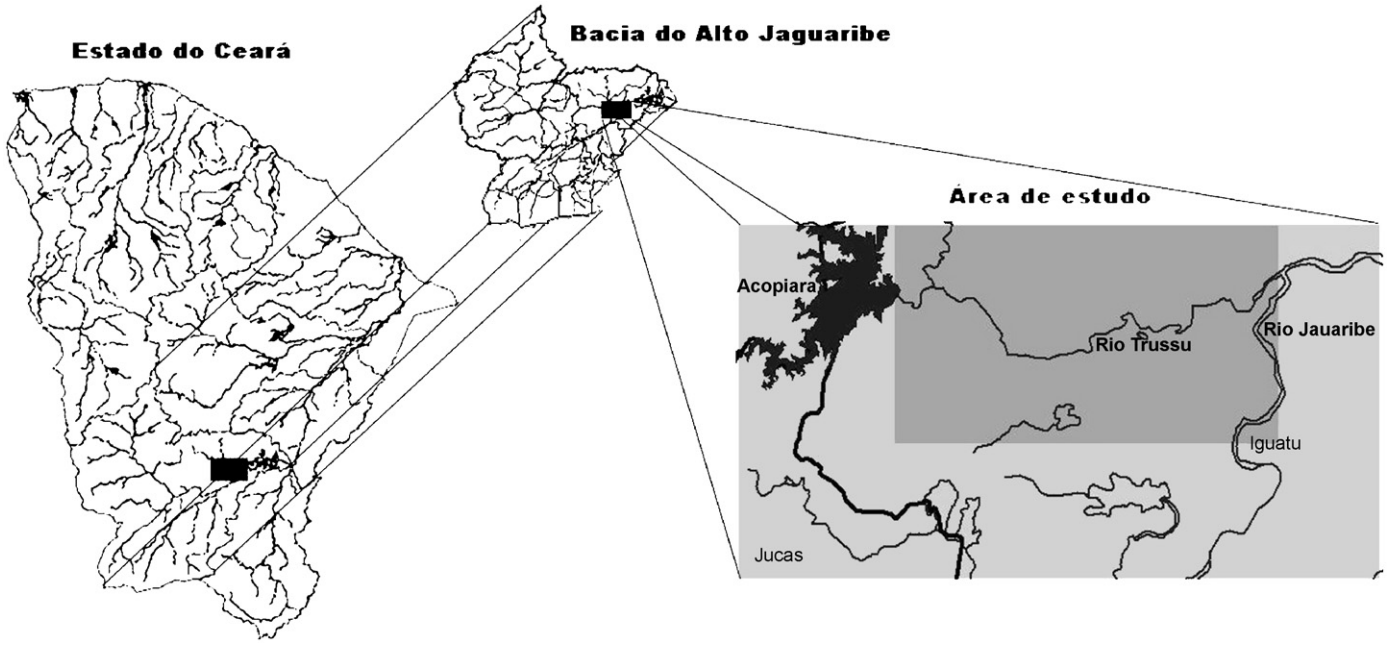

Fig. 1. Studied area location.