

Diagnosis of High Fluoride Contents in Groundwater of Rio Grande do Sul State, Southern Brazil

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Abstract: *In the State of Rio Grande do Sul (RS), south of Brazil, was recorded by the Brazilian Institute of Geography and Statistics (IBGE) census a total of 10,6 million of people living in 496 municipalities. The water supply in the mostly of these municipalities is provided by groundwater, constituting an important resource for development of all economic activities. It is known through agencies responsible for monitoring water in the State and through various scientific studies, which are found in various places with groundwater fluoride concentration exceeding the maximum allowable values for human consumption (1,5 mg/L), usually from natural sources (geogenic). Fluoride may be an essential element for humans in beneficial element to the prevention of tooth caries. However, fluoride in high concentrations can also have an adverse effect like a dental fluorosis, or osteofluorosis disease. Furthermore, it is considered harmful to the development of the vegetation. This study aimed to gather analysis of groundwater from different databases with fluoride concentrations in the state of Rio Grande do Sul, spatializing all information in Geographic Information System (GIS) and produce a thematic map.*

Keywords - *Anomalous fluoride, groundwater, thematic map, Guarani Aquifer System, Serra Geral Aquifer System.*

I. Introduction

Concentrations above the maximum allowable values of fluoride in groundwater used to water supply are a major social problem in many parts of the world. Regions that depend on these resources for carrying out their daily activities are the most affected by this problem where the most vulnerable economically ends up being the most affected.

There are several studies involving the diagnosis and behavior of this ion in the underground environment and its origin is not the same everywhere, that is, not restricted to a particular rock in an aquifer.

Fawell et al. (2006), in their research for the World Health Organization (WHO), diagnose occurrences of belts fluorides anomalies (WHO, 2011). The largest and best known are in Africa, stretching from East Africa towards Malawi. These regions are known to have tectonic faults, and the Rift Valley the best known. The authors cite another belt in Asia stretching from Turkey through Iraq, Iran, Afghanistan, India, northern Thailand and China.

Also, are known anomalous occurrences of this ion in the Americas, in southern Argentina, highlighting the work of Gomez et al. (2008), Kruse and Ainchil (2003). In Mexico studies of Carrillo- Rivera et al. (1996; 2002). In the south of Brazil stand out work carried out by Goffermann (2013), Marimon (2006), Nanni (2008), Silvério da Silva et al. (2011; 2014), Viero et al. (2009).

Amini (2008) in his work about a statistical modeling of Geogenic Fluoride Contamination in Groundwaters build a predictive model in global scale in form a probability map of fluoride concentration in groundwater. The results are showed in figure 1.

Taking into account the significant increase in water demand in most part of the world and that much of the available fresh water is in underground environment, the knowledge of the quality of groundwater resources becomes increasingly necessary, since its characteristics physico-chemical determine its possibilities of use. In turn, the Brazilian authorities by law 2914/2011 of Health Ministerial and by the Resolution 396/2008 of CONAMA established a maximum limit of 1,5 mg/L for human consumption, 1,0 mg/L for water used for irrigation for rural lands and 2,0 mg/L for animal consumption.

Therefore, this study aims to conduct a descriptive study in order to gather hydrochemical information fluorides in groundwater of Rio Grande do Sul and spacialize them so that it can serve to better understand their distribution and develop theoretical subsidies improve water security of the State and made available to the scientific community in general.

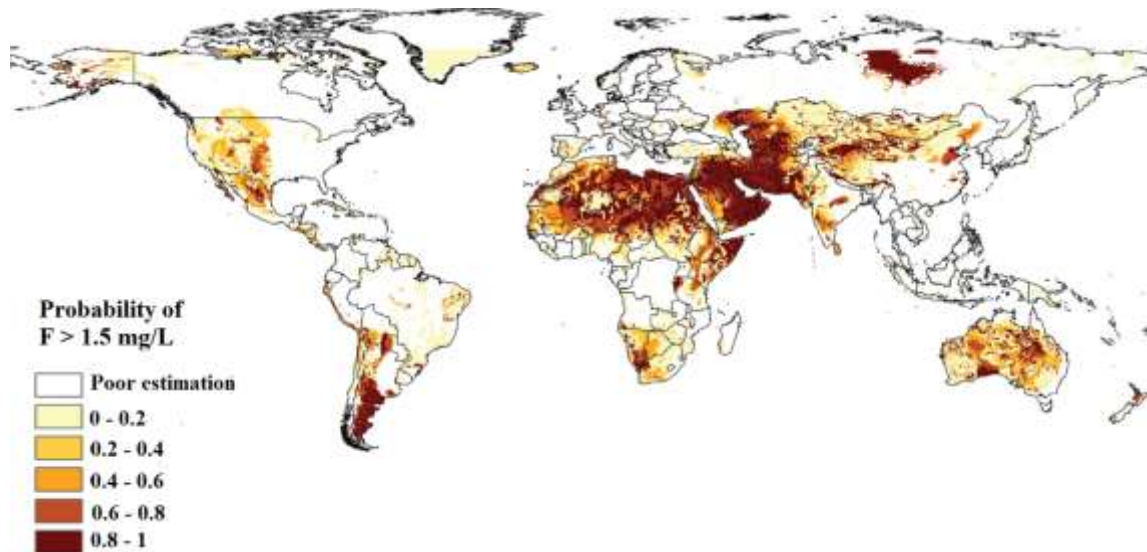


Figure 1: Predicted probability of fluoride concentration in the groundwater exceeding the WHO guideline for drinking water of 1.5 mg/L. Source: Amini (2008).

II. The Study Area

The State of Rio Grande do Sul is located in southern Brazil and has a population of 10,6 million divided into 496 municipalities. Much of the population is concentrated near its capital Porto Alegre and metropolitan area in the east of the State (Figure 2).

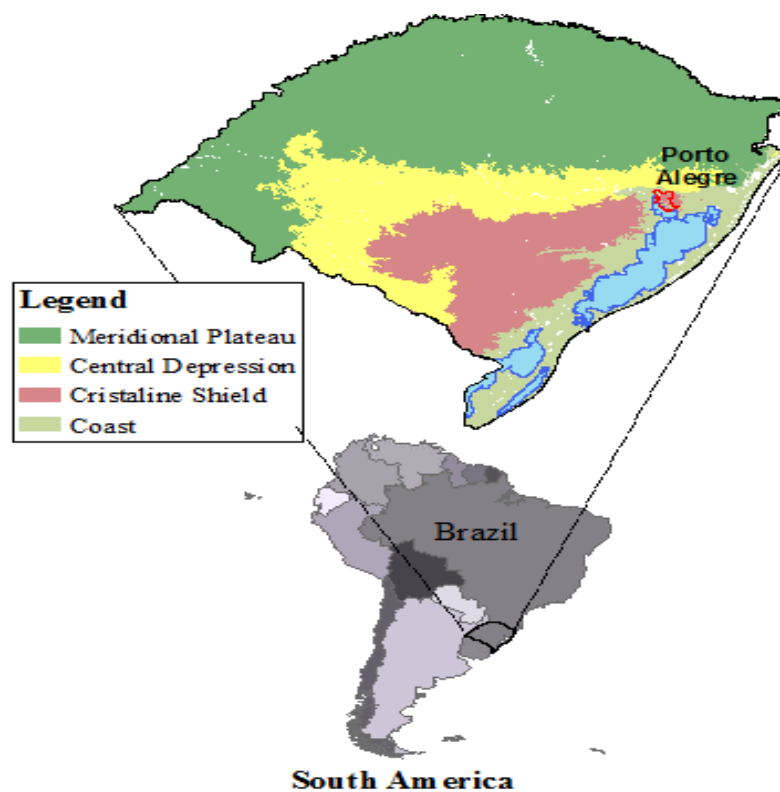


Figure 2: Rio Grande do Sul location with geomorphological regions.

The state is divided into 5 distinct geomorphological regions with geological features and characteristics: Meridional Plateau (Vulcanic rocks that constituted the Serra Geral Aquifer System), Granite Shield (Granite and gneiss rocks), Central Depression (Sedimentary rocks) and Coast. From the Central Depression to the north, the state englobes the Guarani Aquifer System, one of the largest porous sedimentary aquifer in the world that still runs in eight Brazilian States and the countries Uruguay, Paraguay and Argentina. (PSAG, 2009).

1.1 The Guarani/Serra Geral Integrated Aquifer System (SAIG/SG) in South of Brazil.

The Guarani / Serra Geral Integrated Aquifer System (SAIG/SG) is an important and strategic water resource for Brazil. It is constituted by the Serra Geral Aquifer System (SASG) (fractured igneous rocks) and the Guarani Aquifer System (SAG) (porous sedimentary rock), which were put together considering that they are structurally and hydraulically interconnected and should be jointly managed.



Figure 3: The Guarani Aquifer System and Serra Geral Aquifer System. Source: Wolkmer et al. (2008).

In the south of Brazil, the occurrences of fluoride are associated with intracratonic tectonic and associated structures defined by geomorphology Lisboa (1996), structural geological Machado (2005) and definition of alignments hydrochemistry by Nanni (2008). In research paper and thesis Descovi Filho, (2015a; 2015b), hydrogeological tectonic blocks set defined three main structural arrangements (lifting, staggered and downcast – according by figure 4) may be associated occurrences of mineral waters (including the presence of fluoride and other harmful elements in high concentrations) and hydrothermal waters.

In research of Descovi Filho (2015a; 2015b) was proposed 13 geomorphological sections to define the morphosculptural levels and to delineate the boundaries of geomorphostructural blocks. The study shows the biggest fault throws along the sections are associated with the southeast (blocks 01, 02 and 03) and west block (block 11). From the interpretation of the geomorphological levels of 16 geomorphostructural blocks were outlined considering the drainage network, lineaments having the preferred directions NE and NW. (figure 4).

The geomorphostructural blocks formed the basis for the setting of 14 hydrogeological tectonic blocks, for which average absolute altitudes of the top of the Botucatu Formation (SAG) were assigned. These absolute altitudes differ 1851 meters (highest in the southeast and the minimum in the extreme west of the state). In these 14 blocks, the thickness of the Serra Geral Formation (SASG) range from zero (0) meters (SAG outcrop, in the most eastern regions), up to 1132 meters (extreme west of Santa Catarina). Geomorphological and hydrogeologic Tectonic evolution models have been proposed and a hydrogeological east to west section, showing the relative position of the hydrogeological SAIG/SG blocks, allowing their classification in elevated, staggered and slaughtered blocks, being related to different of groundwater hydrochemistry types (figure 5).

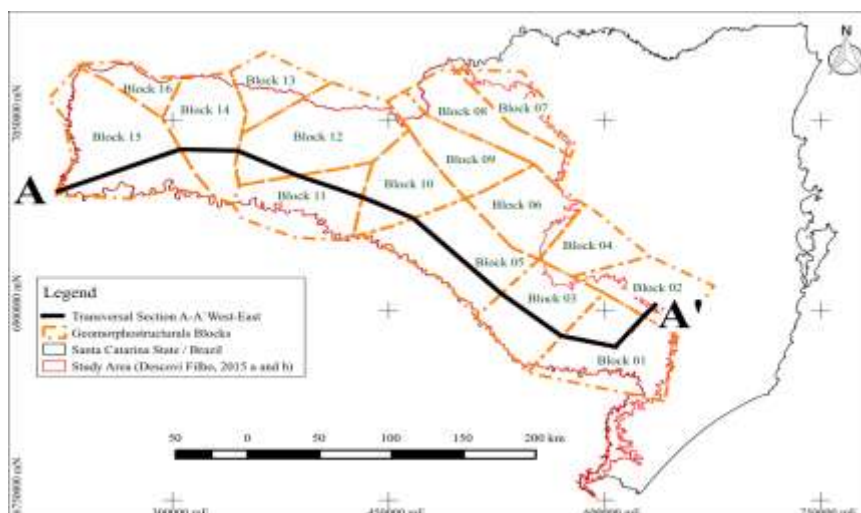


Figure 4: Main structural arrangements. Source: Descovi Filho (2015 b).

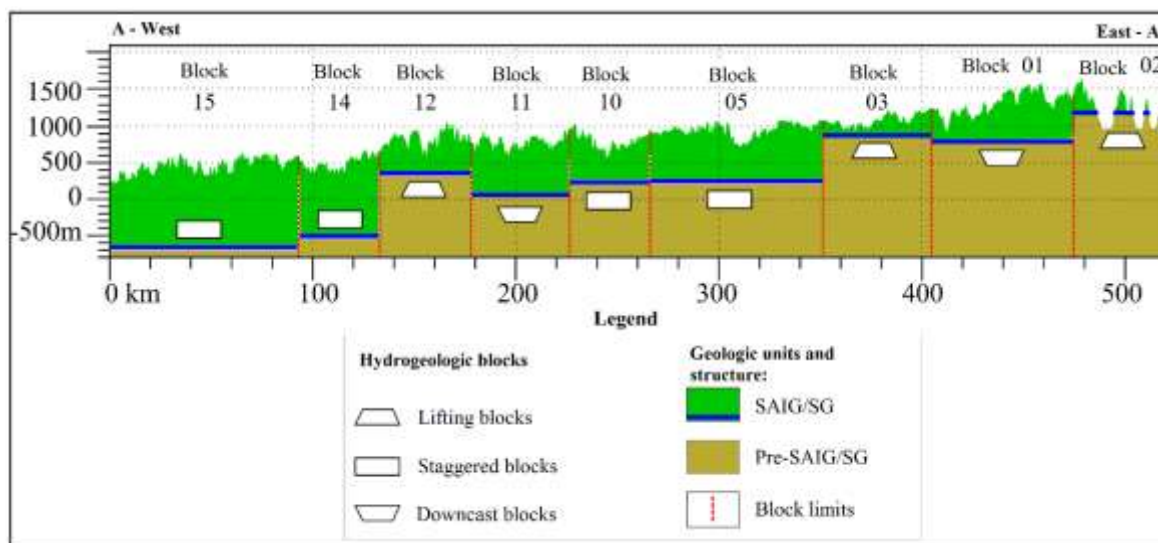


Figure 5: Hydrogeological Section of SAIG/SG in Santa Catarina State in South of Brazil (section A – A'). Source: Descovi Filho (2015 b).

The limit of blocks has a high probability of occurrence of anomalous fluoride. The major basement structural alignments of the Paraná Basin influenced the blocks structure and may serve as interconnection between the SASG and the SAG.

III. Material and Methods

3.1 Adopted procedures:

In this study, the methodology used was based on the following steps:

- a. Hydrochemical data compilation of government agencies and studies related to the topic;
- b. Determination of descriptive statistics of all data;
- c. Mapping wells that have fluoride contents information and plot then in geomorphological regions of Rio Grande do Sul State through geoprocessing techniques;
- d. Diagnose new regions with probability to found anomalous fluoride contents and related to limit of SAIG/SG blocks;

IV. Results and Discussion

In total, were used hydrochemical data from responsible government agencies for monitoring the quality of groundwater, dissertations, doctoral thesis and field research. Were consulted the database of Geological Survey of Brazil (CPRM) and the Sanitation Company Riograndense (CORSAN) through the Program of Wells (PAP) of the Department of Public Works, Irrigation and Development State Urban (SOPS). Besides these, was used the Hydrogeology Laboratory database (LABHIDROGEO) of the Federal University of Santa Maria (UFSM), doctoral thesis and dissertations related to the theme. The data used is listed in Table 1.

Source	Data
CPRM	SIAGAS
PAP/SOPS	CORSAN
LABHIDROGEO/UFSM	Field research
Nanni (2008)	Thesis
Marimon (2006)	Thesis
Goffemann (2013)	Master Dissertation
Silvério da Silva et al. (2011; 2014)	Field research
Viero (2009)	Field Research

Table 1: Database and reference info.

The hydrochemical analyzes over 4.000 drilling wells were pooled, where were detected 310 wells containing up maximum allowable values of fluorides for human consumption and 202 wells containing maximum allowable values above for irrigation (Figure 6). All information has been processed in Geographic Information System (GIS) and organized from the geomorphological regions found in the state.

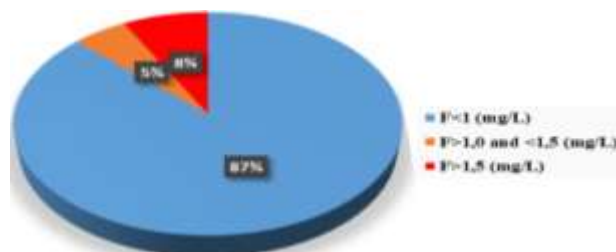


Figure 6: Hydrochemical analyzes of drilling wells in RS.

The approach from its geomorphological zones allows to view the occurrences of fluorides in groundwater anomalies in its geological context, getting clear its territorial distribution. However, the values presented are not absolute and not necessarily mean higher incidence in regions with more anomalies, but give an idea of its distribution from data produced by many researchers. A descriptive summary of the information is describing in barplot of figure 7.

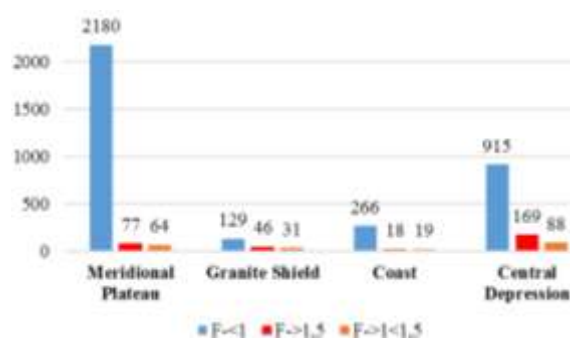


Figure 7: Barplot of fluoride contents information in geomorphological zones of Rio Grande do Sul.

The low number of analyzes in the Granite Shield, due to the fact that this region is considered low aquifer productivity because of its geological conditions, with low specific capacities and experiencing dry wells. (MACHADO; FREITAS, 2005). However, it has a significant number of anomalies recorded in the total number of analyzes. The coast comprises the aquifers associated with the sediments of the coastal plain of the State and is composed of a succession of unconsolidated sandy layers of thin to medium grain size, whitish and interspersed. The specific capacities in general are high, there may be water with a higher salt content.

The Central Depression and Meridional Plateau were the regions that have more information recorded fluorides anomalies, which is very worrying from the point of view of public health since the largest share of agricultural production of the state comes from these regions.

Finally, built up the thematic map with all the information gathered (figure 8). To map building, was became due care as the geographical reference systems, designing all information in SIRGAS 2000.

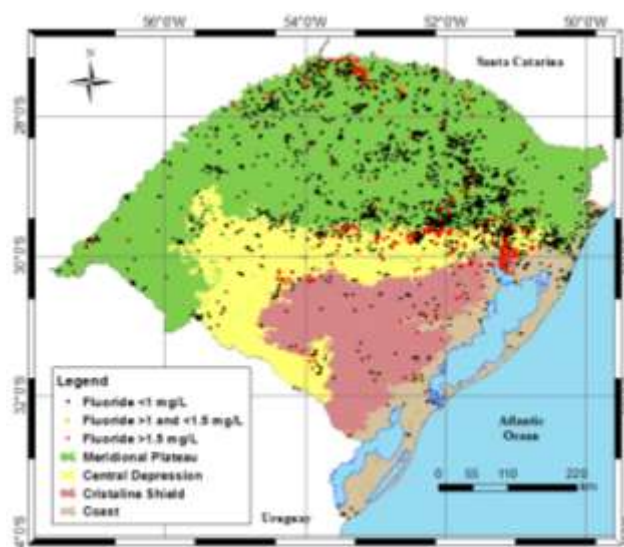


Figure 8: Thematic map of fluoride contents information in groundwater in Rio Grande do Sul.

The origin of these anomalies of fluorides in the state of Rio Grande do Sul are not yet consensus among researchers, where several factors may be responsible for their concentrations, including: soil types, geological types, tectonic faults, rainfall, temperature, pressure, mixing water from different aquifers etc.

V. Conclusions

The spatialized diagnosis of the groundwater with anomalous contents of fluoride through the geoprocessing techniques aloud observe its coverage in the State of Rio Grande do Sul.

It is seen the most of fluoride anomalies detections are located close to urban centers, especially in capital Porto Alegre and their periferic region. Many anomalies were observed in the northern part of the state in the region of Meridional Plateau, this region that had not been diagnosed with high probability to found anomalies of fluoride.

This research supports the hydrogeological understanding of fluoride contents in SAIG/SG, through geomorphological and structural interpretation and geographic information systems.

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