

## Groundwater Discharge and the Nitrate Impact on Water Quality in Natal (Brazil)

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**Abstract:** Neoplasias related to sanitation are actually inserted on a context of great challenge for the public health, due to the increasing mortality rates, where sanitation and water pollution may represent sources or causes for emerging difficulties. In that sense, this work presents a spatial analysis of the incidence of endemism caused by the lack of sanitation, associating parameters related to the quality of water in Natal (Brazil). A Geographic Information System was used; with the purpose of analyze the situation of neoplasias in the area and establish a database with several information of incidence of diseases, sanitation and quality of water resources, comprising the period from 1999 to 2004. The several sources of pollutants were punctually registered and include sewers, gas stations, cemeteries, factories, industrial dejections and sewages. The data treatment was accomplished by statistical spatial analysis, presenting results through absolute values, percentages and averages. With this data, a cartographic basis was generated, and a scale from one to six (06) classifications was assigned, from low to high concentration of pollutants and water quality. The epidemic data were also crossed with data of quality of the water and with other environmental data, making possible to accomplish an analysis of the current context of the hydro system of Natal

**Key Word:** Public Health, GIS, Environmental Administration, Hydro Resources.

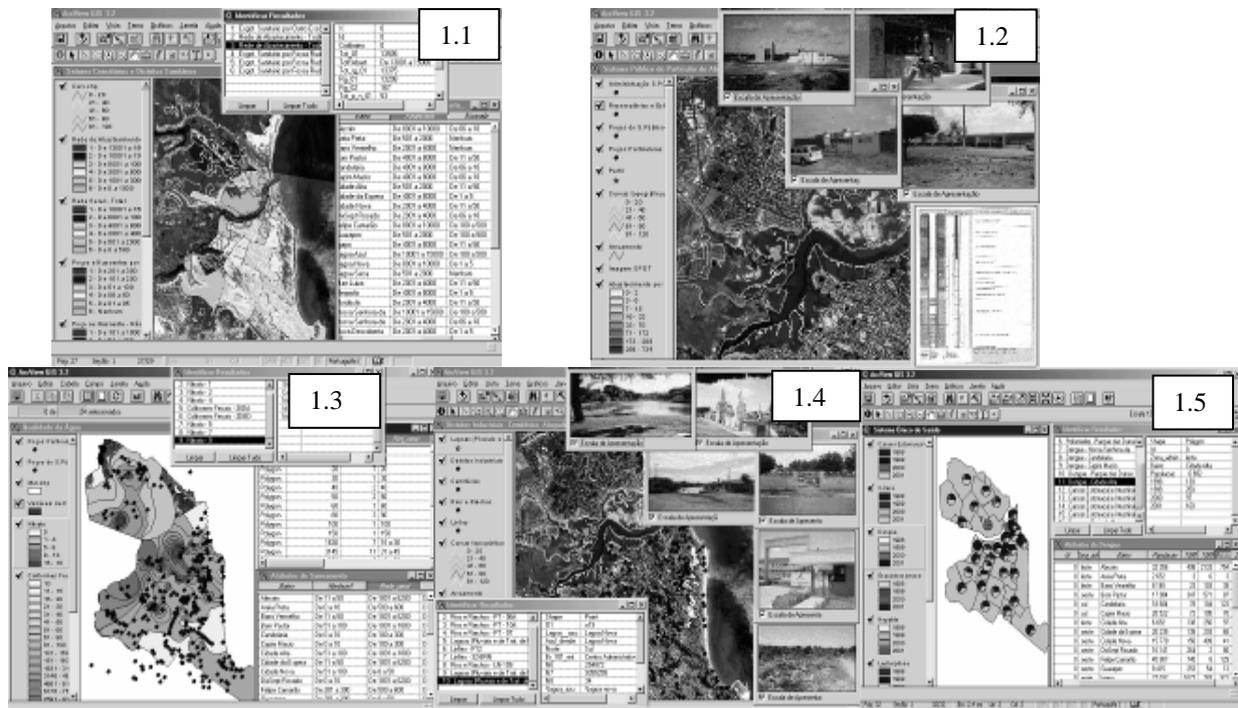
### 1- Introduction

The city of Natal has been going by a process of strong growth disorganized on these last 15 years. Formerly when a tourist or resident opened the faucet of his residence, of the hotel or of the lodging, could expect water with quality of mineral water. Today, the situation is very different. Since the beginning of last century, the whole sewer produced in the city (only 17% cleaned up) it is thrown '*in natura*' in Rio Potengi, or then it is stored in septic tanks and "drains" of the back yards of the houses, with percolation affecting directly the underground water, from where are captured more than 70% of the water that supplies the city. Could be added to this fact the impermeability of the soil and the asphalt covering that transfer a good part of the rain water that could recharge of the aquifer, to be drained for the sea. There is no control of the number of sewages and existent clandestine wells in the city, however the estimate is that, every year, just the capital of Rio Grande do Norte drops about 42 million cubic meters of sewer in that immense natural filter, denominated Dunas/Barreiras Aquifer System, however there are indications that that number can be very larger.

The direct consequence of that behavior makes the underground water reservoir receive more sewers and less water every year, and it can be measured by the several studies accomplished by the Federal University of Rio Grande do Norte (UFRN), by NGOs and even for the Company of Waters and Sewers of Rio Grande do Norte (CAERN). Today, the Dunas/Barreiras Aquifer (main ground water reservoir) is almost totally polluted. In some capitation well points, the amount of nitrate (a sub-product of the contamination for fecal collyphorm) get the level of 100ppm. In other words, it is clearly above the 45 ppm considered acceptable for the World Health Organization (WHO).

Our proposal intends to demonstrate the application of a Geographical Information System - GIS, working as a support tool, that makes possible complementally actions of the monitoring programs and administration of the quality of the water and of the resources of environmental sanitation, allowing to analyzed the information by a spatial form.

Starting from this data, were built a GIS that allow integrating the several interrelated layers involving the database (**Fig 01**):

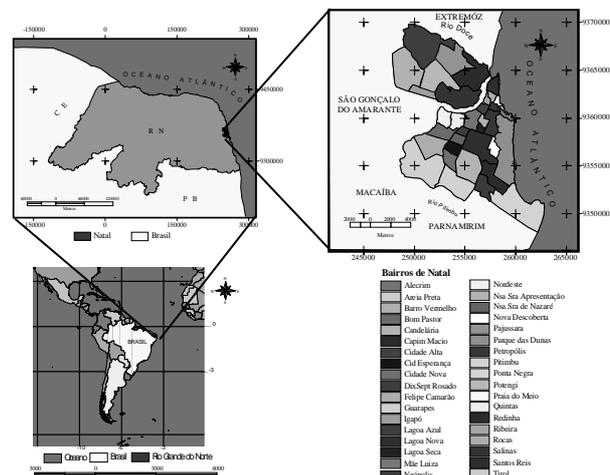


**Fig. 01** - The Water Management System GIS is composed for five main themes: which include IBGE data (1.1); System of Public and Private Provisioning (1.2); Water Quality (1.3); Cemeteries, Industrial Districts, Ponds, Flooded and Garbage (1.4); Data from Municipal General Office of Health (1.5).

The elaboration of a "Water Quality System" (WQS), allowed to identify and to characterize the different pollution sources (industrial and maidservant) that influence direct or indirectly in the quality of the underground waters and of surface (ponds) in the area of Natal and, it will make possible hereafter to accomplish the monitoring and the administration of the quality of the water in this area. This WQS offers the opportunity to model integrally in only one platform, the main problems causes of pollution of the aquifer that integrates the basin of Natal, to the future readiness of hydro resources, and the administration relational/spatial of the diseases of hydro vehicular system (diarrhea, hepatitis, leptospirose, primness, cholera and other) once the employed methodologies for the analysis of the possible risks to the health are associated to its consumption.

## 2- Location of the Area

The Municipal district of Natal, capital of the Rio Grande do Norte State – RN (NE Brazil), locates in the Oriental Coastal Area of RN, in sub-zone of Natal, which is limited to West with the Municipal district of São Gonçalo do Amarante; to the North, with Extremoz; to the South, with Parnamirim; and to East, with Atlantic ocean (**Fig 02**).



**Fig. 2** - Location of the study area.

### 3- Methodology

The works accomplished by Federal University of Rio Grande do Norte (UFRN) in partnership with the Company of Waters and Sewers of Rio Grande do Norte (CAERN) allowed to identify the main focuses of contamination of superficial and underground waters in the area of Natal. They are: (i) The sewages and drains (consequences of the lack of basic sanitation in the whole city); (ii) infiltration Ponds (current of the clandestine connections of sewer in the net of pluvial waters); (iii) Old wells transformed at sewages (they contaminate the underground water directly); (iv) Wells badly built (elaborated without appropriate technical criteria); (v) City Garbage (built on the dunes, that are very permeable); (vi) industrial Sewers (transferred for infiltration ponds or spilled directly in the Potengi, Jiqui and Jundiá Rivers); (vii) Gas stations (leaks of fuel of the tanks buried in the land and no-treatment of the served waters); (viii) Creations of animals (bovine, swine and birds) in the margins of the rivers and ponds and (ix) Deforestations of the ciliary forests and indiscriminate occupation of the areas of recharge of the aquifer.

Our main objective went to lift the location and the space distribution of these pollutant sources (**Table 1**), elaborating thematic maps of several focuses and related to database that allowed to evaluate and to quantify their several influences in the quality of the water.

**Table 1** - Points registered as bases of this research.

NAME OF CADASTER POINTS	Number of Cadaster
Administrative Sector of CAERN	38
Water Control Stations	22
Reservoirs	26
Public System Wells	215
Rivers and Drainages	05
Main flooded Areas	05
Cemeteries	10
Industrial Districts	12
Ponds (Capt. Pluvial. And Sewages.)	60
Garbages	05
Particular Wells	202
<b>Total of Cadastres</b>	<b>600</b>

**Natural Resources:** The map of Natal in the scale of 1:2.000 were obtained on the CAERN. For the mapping of the hydro resources composed by rivers, streams, dams, ponds, dams, wells, publics and matters, images of Ikonos and Spot satellite were used. The composed data in this theme were: geological, geomorphologic, land use, physical environment, areas of environmental protection, and infrastructure & topographical maps.

**Sanitary Districts:** The outlines of the sanitary districts of the municipal district of Natal was transcribed visually starting from the base data of IBGE, for plants in the scale of 1:10.000 and 1:2.000 obtained from IDEMA/RN and CAERN. To these sections data were associated on sanitation, provisioning and population contained in the Demographic Census of year 2.000. The layers of the sanitary exhaustion were classified by permanent private homes, general net of sewer or pluvial, septic tank, for rudimentary sewage, ditches, river, lake or sea, or other canal type, and also if had or no bathroom or sanitarium. The forms of water supply were classified in agreement with the permanent private homes under the users' of the general net total; well or nascent; another form of provisioning and no channeled (**Fig 1.1**).

**Public System and Particular water Supply:** This theme was implemented starting from digital maps in the scale 1:2.000, obeying the map base of CAERN, involving the identification of the offices, of the reservoirs, public and private wells, treatment elevator

stations, and their respective alphanumeric data, as well as photos of the referred point, locate by GPS and visualization of the scanner profiles (in the case of the wells) (**Fig. 1.2**). In this theme they were incorporate the information of analyses in the concentrations of nitrate and the layer in 3D of the no-saturated underground water level.

**Industrial districts, public and private cemeteries, ponds, flooded areas and garbages:** The used routine and scale went the same that the previous topic, the points were obtained in field through the use of GPS. The images, and the implemented alphanumeric data are referring to each point and complementally information of the same get in the field. (**Fig 1.4**).

**Governmental system of health:** In this layer were implemented the data about the incidence of diseases linked to the sanitation in the neighborhoods of the municipal district, exposing its existent situation for crossing of the data with the hydro resources, industrial districts, cemeteries and garbage. The data are willing in the theme in several ways, all regarding the years from 1998 to 2001 (**Fig 1.5**).

**Quality of the water:** Data were associated with the acceptable pattern in agreement with the world patterns as World Health Organization (WHO), and Brazilian patterns as CONAMA, CAERN and SERHID, in the sense that each point has it located space positioning and plotted as permanent point of monitoring in chart with scale 1:2.000 supplying the maps of CAERN (**Fig. 1.3**).

### 3- Analysis of the resulted dates

The spatial analysis of the distribution of the pollutant sources and their relationships with the public health had as main objective to identify areas and the populations submitted to risk, using the environmental and social-demographic criteria, and being of vital importance to support the analysis process using the elaborated system.

The **Table 2** identifies examples of possible populations and areas submitted to risk according to the mentioned criteria. The data were tabulated starting from the data of the census 2.000 that identifies a population of 712.317 inhabitants for the city of Natal and of WHO and CONAMA, and the areas of each region were calculated directly in WQS.

To better facilitate the identification of the several information, the variables were grouped in classes, which varied from 4 to 6 depending on the case. The areas of occurrence of the diseases facts were classified respectively, of the largest for to smallest category, using on the map, tones ash darker to the clearings intermixed with hachure. The respective illustrations (figures) regarding each one of the explored themes and analyzed through the system, are presented below.

(i) The areas of larger number of residents, according to the census of 2.000 that has declared not to be supplied by general net of water supply (**Fig. 5**).

(ii) The areas of larger concentration in septic and/or rudimentary tanks and larger number of wells were marked on the map, and depending of the growing population of these districts it is possible that there a strict relation with the contamination of the aquifer. These were identified in agreement with the base of data of the census section that has answered to this criterion (**Fig. 6**).

(iii) The areas nearly of the wells with concentration of the ion Nitrate that present tenors above 40 mg/l., superior to the acceptable index for CONAMA and WHO. The tenors were located through buffers of 0,5 km surrounding the arches that represent the whole net of water provisioning for each well (**Fig 7**).

(iv) The areas of larger incidence, for all of the cases of morbidity, in tones ash darkness. In this case it was associated to the probable hydro net. The areas were identified through the base of data of Districtal Public Health dates (**Fig. 8**).

The **Table 2** presents the criteria that were used, in way to allow the identification of partner-space groups subject to risks to the health associated to the resources of provisioning of sanitation. The use of alternative sources of water supply through small local springs (criterion 1) in the **Figure 5**, or the use of wells or nascent in areas of larger concentration in septic tanks and/or rudimentary (criterion 2) visualized in the **Figure 6**, they can present risks for significant portions of the population (about 35%), located in the areas North and South of the municipal district and concentrate the most several economical classes. The tenors in the concentrations of nitrate are distributed by the whole municipal district, as display the data of all of the wells (**Figure 7**). They were associated with those tenors (criterion 3) for the cases of mortality in stomach and intestinal cancer and it can be observed that the population under risk (less than 2%), is concentrate at the South area and East (**Figure 8**).

The location of the resident population and risk area for the incidences of the cases of morbidity (criterion 4) according to obtained data of the Secretary Municipal of Health they can be visualized in the figure 8. It includes a great part of the population under risk, acting more than 30% of the residents' total population in the municipal district. The areas of incidences of the cases of morbidity are concentrated in the surround area of the Potengi River, Rio Doce and Pond of Extremoz and outlying of the North and West Area, which represent a mesh diversified hydro.

**Table 2** - Location, resident population and risk area, in agreement with the criteria of quality of the water and morbidity.

	Risk Criterion	Pop number of residents.	Area (km <sup>2</sup> )	Location (Districts)
1.	Use of alternative sources of H <sub>2</sub> O	1.272	11,35	North Zone – Nsa Sra da Apresentação followed by Felipe Camarão, Zona Oeste with 593 residences.
2.	Use of wells or nascent sources	247.440	70,01	South Zone – Ponta Negra, Capim Macio, Candelária e Lagoa Nova. North Zone – Pajussara, Lagoa Azul e Nsa Sra da Apresentação. followed by Redinha e Potengi – Zona Norte, Petrópolis, Alecrim e Tirol – Zona Leste, Felipe Camarão – West Zone, Nova Descoberta, Extremoz e Neópolis – Zone South.
3	Water Contamination (Nitrate)	6.434	4,19	South Zone – Neópolis e, East Zone – Praia do Meio. followed by Lagoa Azul e Igapó – North Zone - Alecrim –East and South Zones – Lagoa Nova, Nova Descoberta e Pitimbu.
4	incidence of cases in morbidity	236.707	105	North and West Zone. spill Rio Potengi, Rio Doce Complex, Lagoa de Extremoz and outlying..

#### 4- Conclusions

With this research it was intended to implement a digital hydro-cartographic base of the area of Natal, with reliable data and that could rescued the largest number of possible

information, because only a extensive and systematic monitoring, settling down techniques of control of the pollutant sources and the identification of the risks to the human health related to the non service of the pattern of potability of the water, it will allow precautions to be taken and settle down politics of control of the patterns of the quality of the waters.

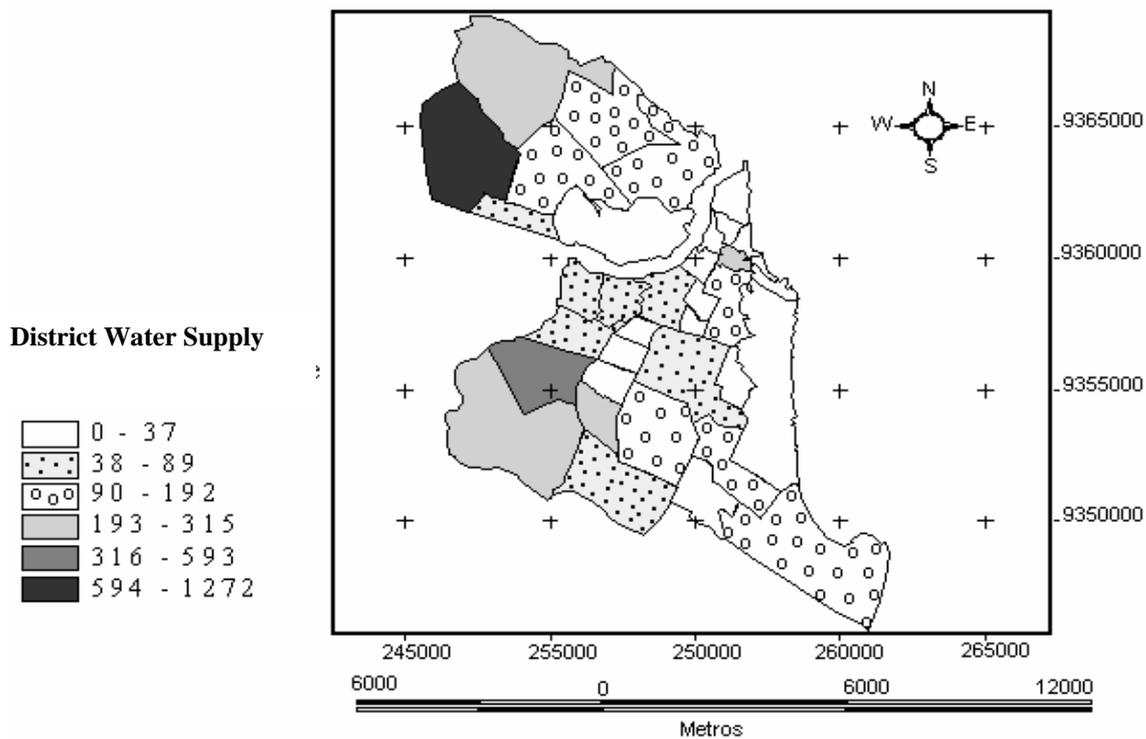
All the wells of the public system of provisioning were registered, besides the closed and the one that are not in operation, as well as the water stations and the reservoirs. Also the ponds of reception of pluvial waters and of treatment of sewers considered important its maintenance in the existent place due to the intrusion of the saline wedge in the underground water. On this sense the WQS GIS gives opportunity to model integrally in only one platform, the main problems causes of pollution of the Dunas/Barreiras aquifer, with focus to the problems of the binomial "water & health", as well as of creating simulations seeking to identify risk areas, as well as evaluating the relationships of quality of the water with the public health, to generate of new maps thematic identification of problematic areas with epidemic focuses, that can notice problems related to the bad quality of the water.

The main sources of pollutants were registered, be through sewers, industrial dejections or sewages. Also as final product in agreement with the data already existent, a map was produced in 3-D (three dimensions) of the profile of the aquifer in sub-surface, starting from the crossing of the data of the static level of each well added to the topographical data, making possible to visualize the level no saturated and it recharge relationship with the lease of the main potential sources of contamination of the aquifer, through rivers, streams, reservoirs, ponds of stabilization that receive industrial dejections among other, wells, garbage, cemeteries, finally, resources that interact with the Duna/Barreiras aquifer system.

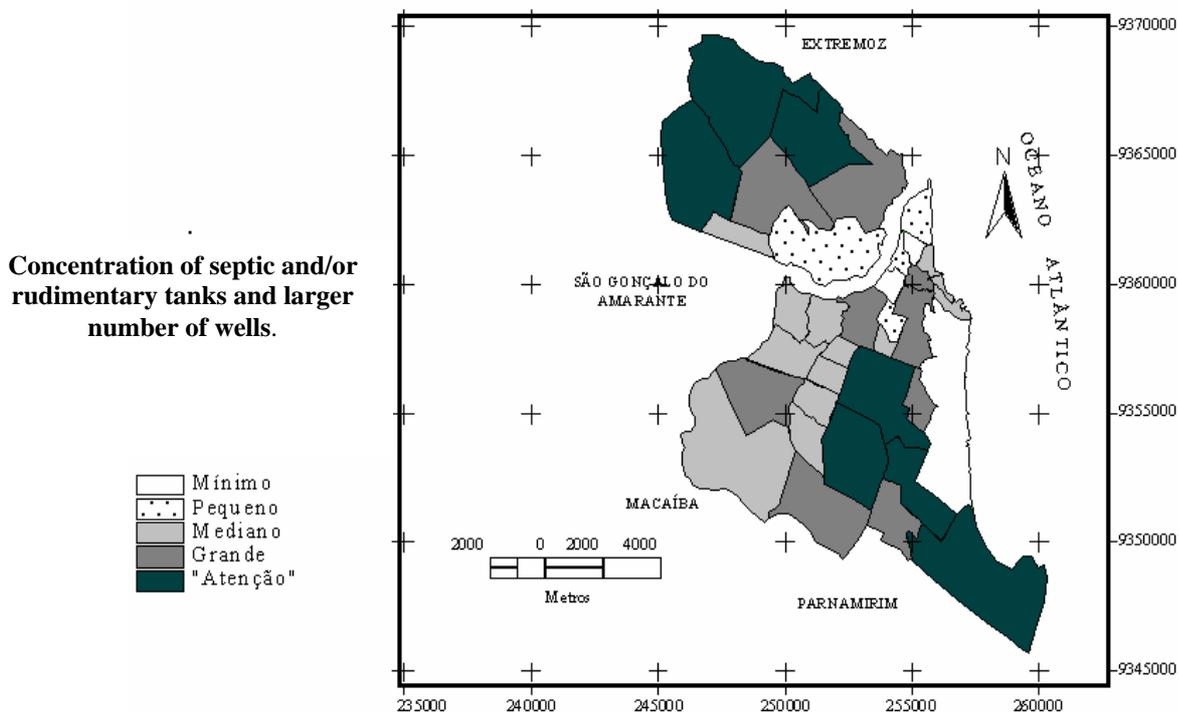
On this view point it can be evaluated that the area of Natal lacks an intensive management in a lot of areas, mainly in those located in area of recharge of the aquifer as well as, with urgency, an appropriate sanitation to avoid the pollution. It was also verified the need of an intensive politics of sanitation in vulnerable areas the pollution, where the researches should come accompanied of other actions, as the finalization of the collection system and sewer treatment in the whole city, the creation of a politics and to of laws that make possible a better recharge of the aquifer, the cadastre of the existent wells, the prohibition of the construction of new wells and, mainly, the creation of a fiscal equip for manager the use of the hydro resources

## 5- References

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**Fig. 5** - Areas in agreement with number of residents no supplied by the general net of water supply, according to the 2.000 census. Larger concentration was identified in dark hachure of gray tone.



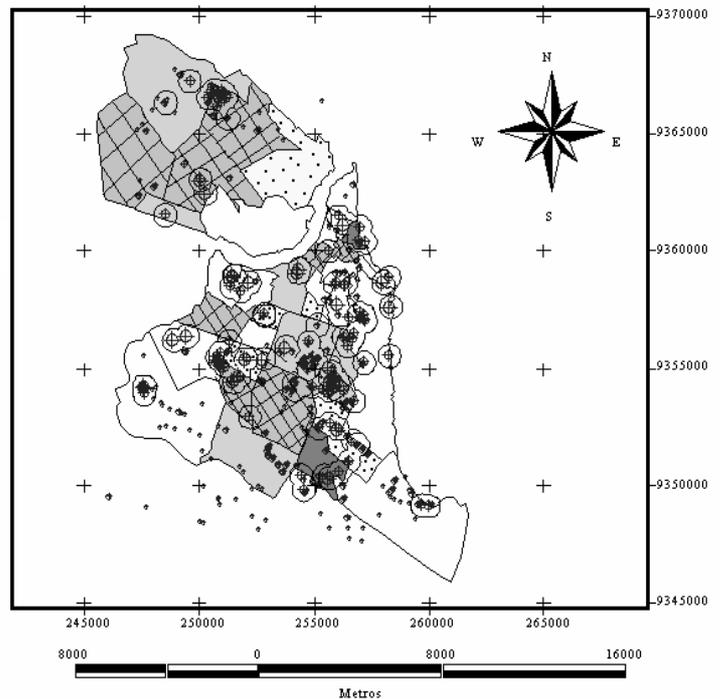
**Fig. 6** - Areas of larger concentration in septic tanks and/or rudimentary and larger number of wells. These were identified in agreement with the base of data of the census section that has answered to this criterion. The hachure of dark gray tone shows the neighborhoods under risk in relation to the quality of the water.

**Area of Influence (500m) WHO, CONAMA**

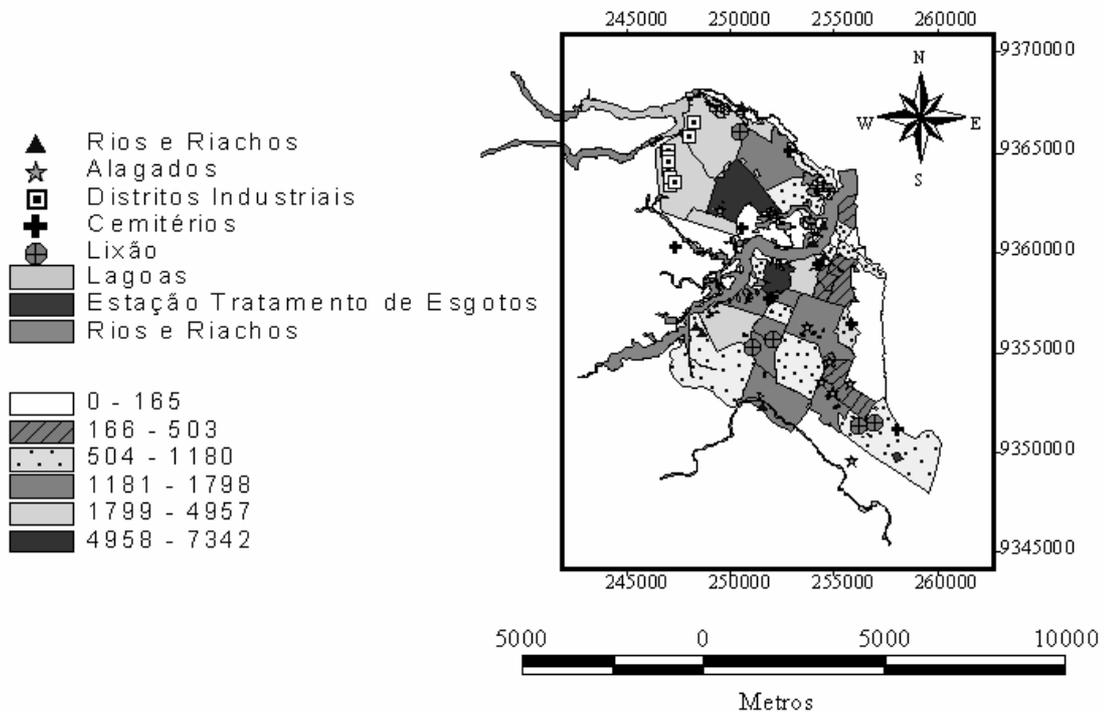
- Nº3 - CONAMA/OMS/EPA\*
- Pontos não contaminados
  - ⊕ Pontos pouco contaminados
  - ⊗ Pontos contaminados
  - ⊗⊗ Pontos muito contaminados

**Total stomach and intestinal cancers**

- 0 - 1
- ▨ 2 - 3
- ▤ 4 - 5
- ▥ 6 - 8
- ▧ 9 - 11



**Fig. 7 -** Contamination for nitrate in the public and private wells in Natal. The space analysis used the technique of buffers in a ray of 500 m starting from the positions of the wells with tenors of nitrate above the acceptable levels for the organs CONAMA/WHO. Those data were crossed with the mortality data in stomach and intestinal cancers.



**Fig. 8 -** Areas of larger incidence of the cases of morbidity, for all of the studied cases, in hachure of dark gray tone. In this case it has associated the hydro net information's.