Health Risk Evaluation for Fluoride and Nitrate and A Baseline Study of Uranium in Hard Rock Aquifers of Northern Karnataka, India

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Research Article

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Abstract

Water is essential for life to exist on this planet.The increasing demand for clean water on one hand and the decreasing availability and deteriorating quality on the other hand has serious concern in India. Consumption of contaminated water can cause health risks. This study tries to find the impact of contamination in groundwater due fluoride and nitrate and its health risk in the Raichur district of Karnataka. And in addition to this a baseline study on presence of uranium in groundwater has also been done using laser fluorimeter instrument. For this study various literature, secondary groundwater quality data, thematic maps were collected and analyzed based on the gathered information 54 wells were chosen and samples were collected and analysed to understand the physiochemical characteristics and analytical data were compared to irrigation suitability standards and BIS drinking water standards.

In the health risk assessment, we have computed the values for total hazard index and hazard quotient based on the United States Environmental Protection Agency (USEPA) guidelines.

1. Introduction

When assessing groundwater resources, the quality of the water is just as important as the quantity. Groundwater is never completely free of dissolved solids, and the kind and concentration of these dissolved solids varies depending on the source, surface and subsurface environment, and volume of groundwater movement. The chemical quality of groundwater is determined by the recharge water's quality as well as the interactions that occur along its flow path, notably between the flowing fluid and geologic elements. The solubility of amount of dissolved carbon dioxide, minerals present and residence period all influence the quantities of various chemical compounds in groundwater. Anthropogenic activities such as sewage disposal, agricultural practises, industrial pollution, and others, in addition to natural changes, play a substantial role in groundwater quality changes.

2. Study Area

Location

Raichur district is located in Karnataka's north-eastern region. It is located between 15º 33’- 16º 34’ North latitudes and 76º 14’- 77º 36’ East longitudes in the Northern Maidan region. It is situated between the Krishna and the Tungabhadra, two significant rivers. Figure 1 depicts the study areas and sampling locations.

Geomorphology

The northern half of Raichur district is part of the Krishna catchment, whereas the southern part is part of the Lower Tungabhadra catchment. The Krishna and the Tungabhadra are two prominent rivers in the district, which form the district's northern and southern boundaries, respectively, and are perennial in nature. The river Bhima is a major tributary of the Krishna. The drainage pattern is quite dendritic. The irrigation techniques in the area indicated in Figure.2 have changed the drainage pattern in the area.

Climate

Raichur district is located in Karnataka's northern maidan region, which is prone to drought and lies inside the desert tract. The district's climate ranges from mild to severe, with pleasant winters and scorching summers. The coldest month is December, with a mean daily minimum temperature of 17. 7º C, while the hottest month is May, with a mean daily high temperature of 39.8º C. In May, the daytime temperature frequently reaches 45.0º C.

Geology

The district's principal rock formations are granites, gneisses, and Dharwarschists. These formations are classified as "hard rock" because they lack primary porosity. Secondary porosity, on the other hand, develops as a result of faults, fractures, joints, and weathering, improving the permeability and water yielding capability of these rocks. Ground water occurs in worn and jointed hard rock under water table conditions and in fractured rock under restricted to semi-confined conditions.

3. Review Of Literature

In [1] has done an investigation about Fluoride and nitrate poisoning in hard rock aquifers of the Shanmuganadhi River basin: a potential health risk assessment in which 61 samples were collected and physicochemical parameters were analysed and for the human health risk evaluation F^- and NO_3^- ion parameters were chosen, based on the equation given by USEPA.

In the work of [2–4] has done the hazard quotient (HQ) and total hazard index (THI) for According to USEPA recommendations, around 87 percent of the samples have non-carcinogenic risk in children and 69 percent of the samples have non-carcinogenic risk in adults (men), respectively, and lastly the human health risk assessment is done..

In [5–7] has done a work on Assessment of Uranium concentration in groundwater and its human health impact in a part of Northern Tamil Nadu, India. The study area is in the Vellore and Katpadi districts of Tamil Nadu. The samples locations were chosen by 2*2 km grid pattern and the water samples were analysed for the uranium contamination using quantalase LF2 laser fluorimeter and the computed results showed out of 54samples 7 samples were above the WHO and USEPA permissible limit which is 30ppb.

Furthermore [8–9], by studying the spatial distribution of hydrogeochemical elements analysed the quality of groundwater in the Chithar Basin, Tamil Nadu. The groundwater is hard, fresh to brackish, and alkaline in nature, according to hydrochemical examination.

In [10–11], various hydrogeochemical experiments were carried out to determine the geochemical processes that regulate groundwater chemistry in the research area, which is located in the extreme south of Tamilnadu.

Moreover [12–13] for these study 30 wells were chosen whose long term and recent ground water quality data were used. According to the analytical results, when comparing primary and secondary groundwater quality data, primary data has higher electrical conductivity and major ion concentrations than secondary data, implying that the aquifer's solute load has increased.

4. Methodology

Data collection

Various sources have been used for the data collection about the study area, general information and statistical data were collected from the official website of the state, well inventory details and depth to water level data were collected from the central ground water board. Flowchart showing detailed methodology is shown in Figure.3

Sampling and field investigation

Groundwater samples were taken from 54 wells across the research region, including shallow dug wells in the mining area, domestic wells and irrigation wells during the month of January 2020 representing post-monsoon seasons. Basic parameters were gathered in 1-litre HDPE bottles that were rinsed three to four times with the water sample before being filled to capacity and labelled accordingly. The samples were kept at a temperature below 4^{0}C before being analysed in the lab. The conventional approaches [14-15] were followed in terms of sample collection, preservation, and analysis. The EC and pH of water samples were measured in the field using pH and EC metres immediately after the samples were collected. Table 1 lists the locations where groundwater samples were taken. The pictures of sample collection on field is shown in Figure.4

Groundwater quality analysis

The groundwater quality analyses of 54 samples were carried out by two types of procedure one is by titrimetric analysis and others were done with use of various instrumentations. A flame photometer was used to measure alkali metal ions (Na^+ and K^+). Turbidimetric technique was used for the analysis of sulphate. A UV-Visible spectrophotometer was used to measure nitrate. The SPADNS method was used to determine the fluoride content. The photographs during laboratorial analysis is shown in Figure.5

5. Results And Discussion

Table 2 shows the minimum, maximum, average, and standard deviation values of the water quality indicators obtained in January 2020.

All of the water quality metrics in the study area varied greatly in space. Groundwater contamination from anthropogenic sources such as industry, open home sewerage systems, and agricultural activities accounted for the majority of the regional variance. Furthermore, surface water resources such as tanks and rivers have an impact on water quality through groundwater recharge. The geographic variance in water quality metrics recorded over the study period is detailed further below.

pH (Hydrogen ion concentration)

It is a measurement of the concentration of Hydrogen (or) Hydroxyl ions in water. It influences the solubility of mineral matter and other anthropogenic pollutants. Hence it plays a major role in the mineralization of ground water and it is expected to increase along its flow path. The pH scale has a range of 0 to 14 on it. Water with a pH of 7 is neutral; water with a pH of greater than 7 is basic; water with a pH of less than 7 is acidic. A ten-fold difference in hydrogen-ion concentration is represented by a 1-unit change in pH..

The pH values in the study area ranged from 7.86 to 9.86, with an average of 8.27, indicating that the samples were somewhat alkaline overall. The pH of ground water is normally controlled by the equilibrium between the dissolved carbon dioxide – bicarbonate – carbonate species. As the ground water moves along its flow path, consumption of carbon dioxide shifts the equilibrium to the right side, which results in the pH to increase. In addition to the natural control, industrial pollution could also contribute the pH to increase or decrease, depending on the waste generated.

Electrical conductivity (EC)

At 25 degrees Celsius, electrical conductivity in the research region ranged from 703 to 15280 μS/cm at 25 ^{o} C. Distribution of Electrical conductivity is shown as a contour map in Figure.6. EC values showed a wide variation in space. Table 3 shows the classification of ground water based on electrical conductivity.

Total dissolved solids (TDS)

Total cations and total anions are added together to calculate TDS. Ionic species such as Na, K, Ca, Mg, CO_3, HCO_3, Cl, SO_4, NO_3 and other trace elements are included in this. Major cations and anions, on the other hand, typically made up more than 90% of the TDS. Table 4 shows groundwater classifications based on TDS as determined by [4]. In the absence of other sources, the desirable level is 500 mg/L and the highest allowable limit is 2000 mg/L, according to the Bureau of Indian Standards' drinking water specification. Table 5 shows the TDS-based suitability of groundwater for drinking.

Total hardness, Calcium and Magnesium

The presence of alkaline earth metals and other polyvalent cations in water causes it to be hard. Calcium and magnesium ions are abundant in the majority of groundwater. The following classification in (Table 6) characterizes the soft & hard water. The bulk of groundwater samples fell into the hard water category, according to total hardness categorization. With respect to the classification of Table 7, about 76.0 % of the samples are categorized as very hard water. The details of samples compared with BIS drinking water standard is given in Table 8.

Chloride

In groundwater, chloride is one of the most common anions. Chloride ions are present in water due to the rapid mobility of the ion and the high solubility of chloride salts. About 15% of the samples were above the permissible limit of 1000 mg/L.

Sulphate

Sulphate is one of the principal anions found in groundwater, and due to solubility controls, its concentration levels are generally lower than those of chloride and bicarbonate. The concentration of sulphate ranged between 18 and 1850 mg/L, with mean value of 294 mg/L. Figure 7 depicts the regional distribution of sulphate.

Nitrate

One of the most important markers of pollution from anthropogenic sources is nitrate. Its persistent nature and transit through the ground water flow path are aided by its negative charge and high mobility. The spatial distribution contour of nitrate (Figure.8) is parallel to electrical conductivity contour, which indicates that the source is same. It is also noticed that the concentration of nitrate is more in irrigation wells than that of domestic wells.

Assessment for Nitrate

The presence of nitrate content in groundwater can be mainly through two sources either geogenic or anthropogenic activities. Because nitrogen is one of the most important components of fertilizer; agricultural operations are a major source of nitrate leaching into groundwater. [11]. The poisoning of agricultural land by leaching of nitrate is a major problem in India, since seventy percent of the population relies on horticultural activities [14].Table 9showing THI values for nitrate calculated using both oral and dermal HQ.

Health risk assessment for Fluoride

Fluorine is a prevalent element in the earth's crust, accounting for around 0.32 percent of the total (WHO 2017) and in some lithological compositions, higher levels are found. Table 10 showing THI values for fluoride calculated using both oral and dermal HQ.

6. Conclusion

The investigation is being conducted to examine health risks and determine the presence of uranium in groundwater. The study area has mainly gneissic and schistose rocks with fractures and joints, which act as aquifers in this region. A total of 54 samples were taken from dug wells and bore wells, and physicochemical parameters were determined.

In the study area, the pH value ranged from 7.86 to 9.86 with the average value of 8.27 indicating alkaline nature of the ground water. No pattern of variation was observed among the wells located in the industrial areas, waste disposal sites, surface water bodies and unpolluted areas. This indicates that the anthropogenic sources of pollution had minimal effect on pH. The variation may be due to the buffering capacity of dissolved CO_2 and bicarbonate ions.

Electrical conductivity ranged between 703 to 15280 µS/cm at 25^o C. EC values showed a wide variation in space. Classification of ground water based on electrical conductivity reveals that in 55% of the samples, EC varied between 751 and 2250 mS/cm, and in 9% of samples, it varied between 2251 and 3000 ms/cm. This indicates that the ground water is slightly mineralized. Artificial groundwater recharge techniques, such as rainwater collecting, can be used to improve groundwater quality in the research area's northern section, where increased fluoride concentrations were discovered. It is also essential to keep a view on the groundwater quality in this area to see how it affects human health.

Declarations

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Non-financial interests: none.

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Tables

Due to technical limitations, table 1-10 is only available as a download in the Supplemental Files section.

Figures

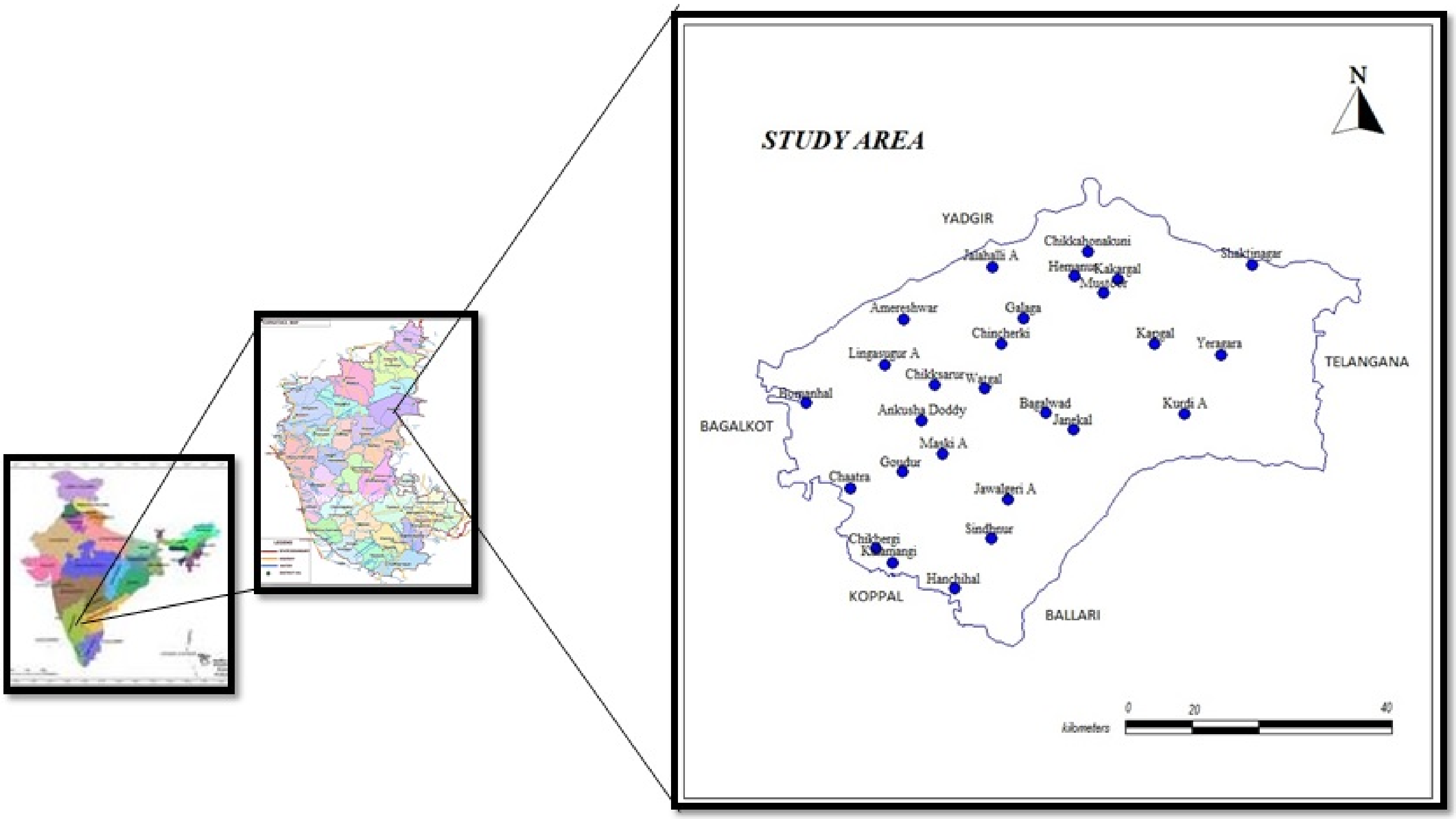

Figure 1

Location map of the study area showing sampling sites

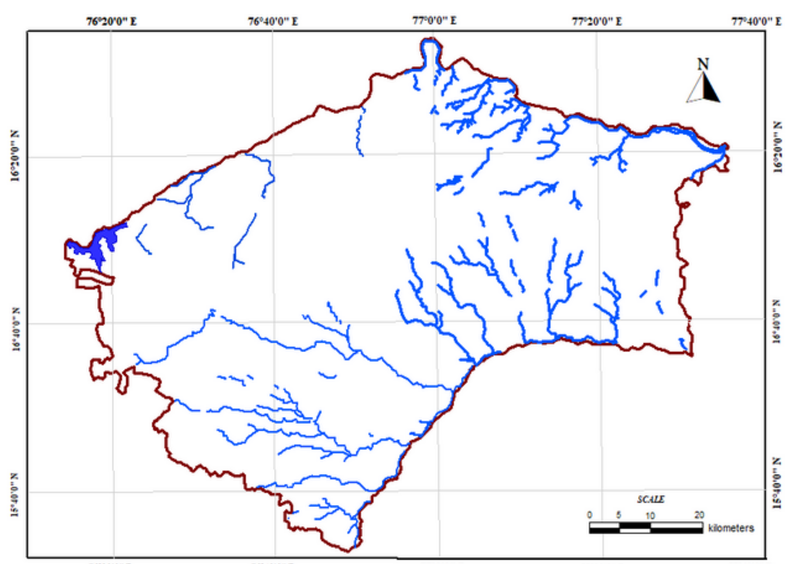

Figure 2

Drainage map of the study area

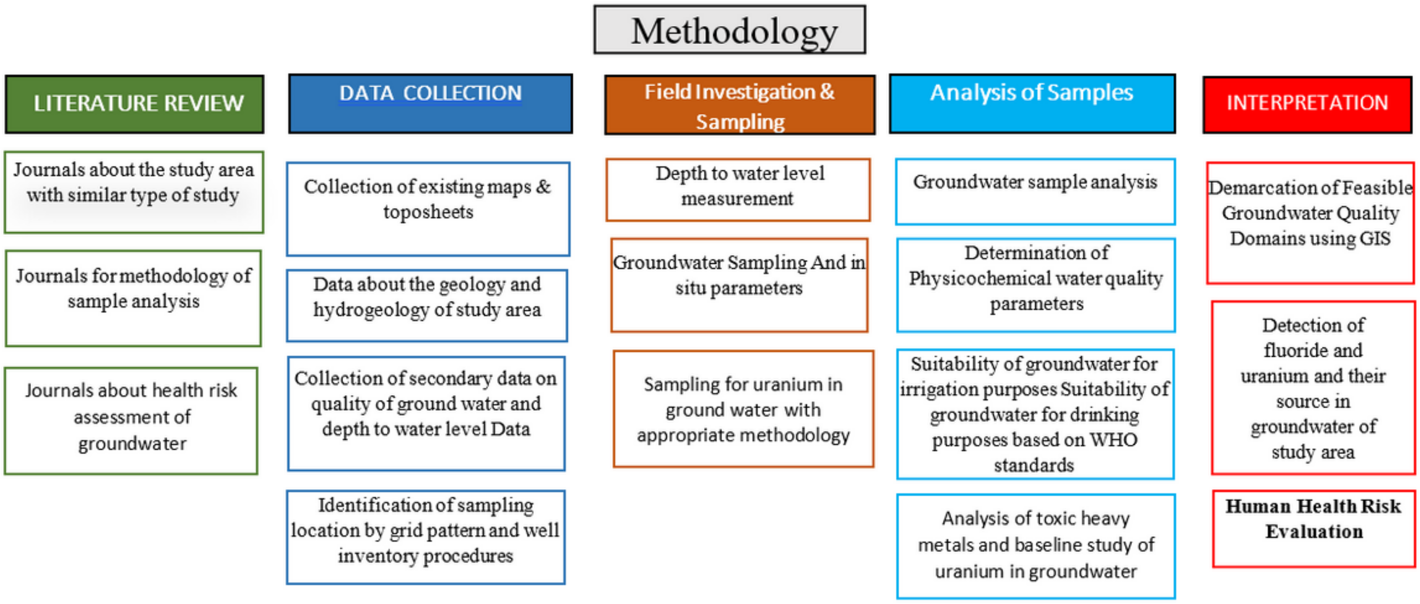

Figure 3

Flowchart showing detailed methodology

Figure 4

Pictures of sample collection on field

Figure 5

Photographs during laboratorial analysis

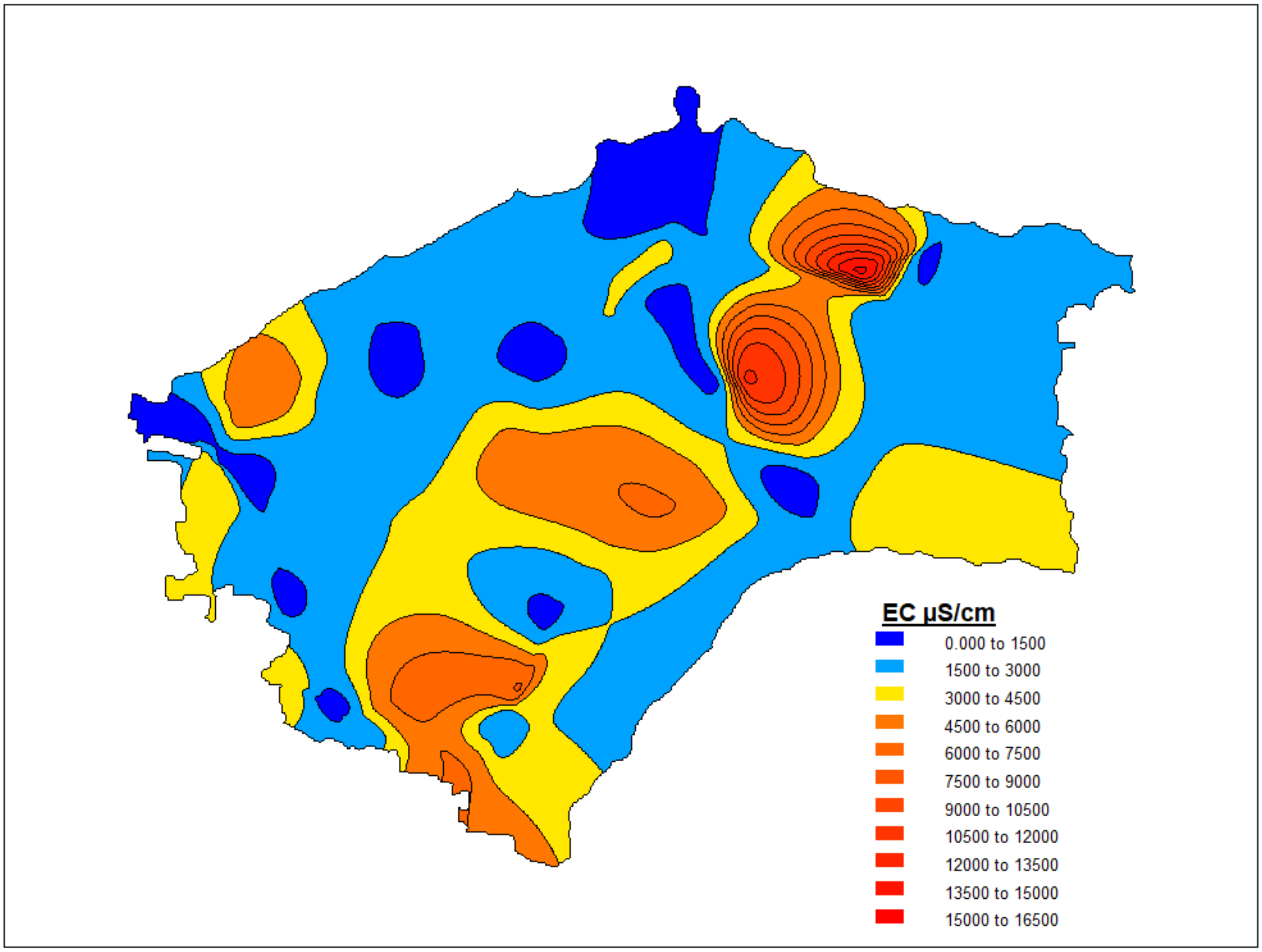

Figure 6

Spatial distribution of electrical conductivity during January 2020

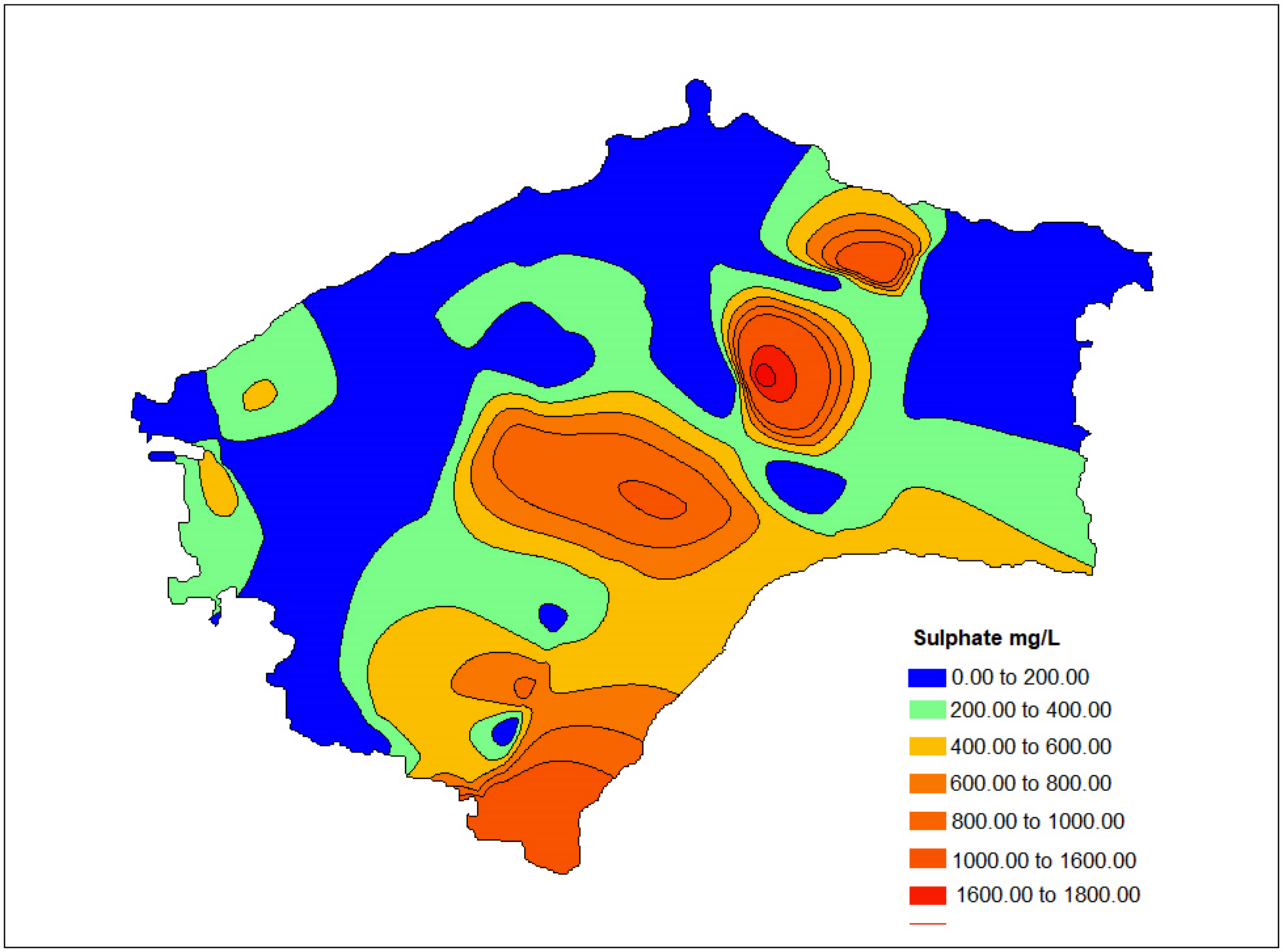

Figure 7

Spatial distribution of sulphate during January 2020

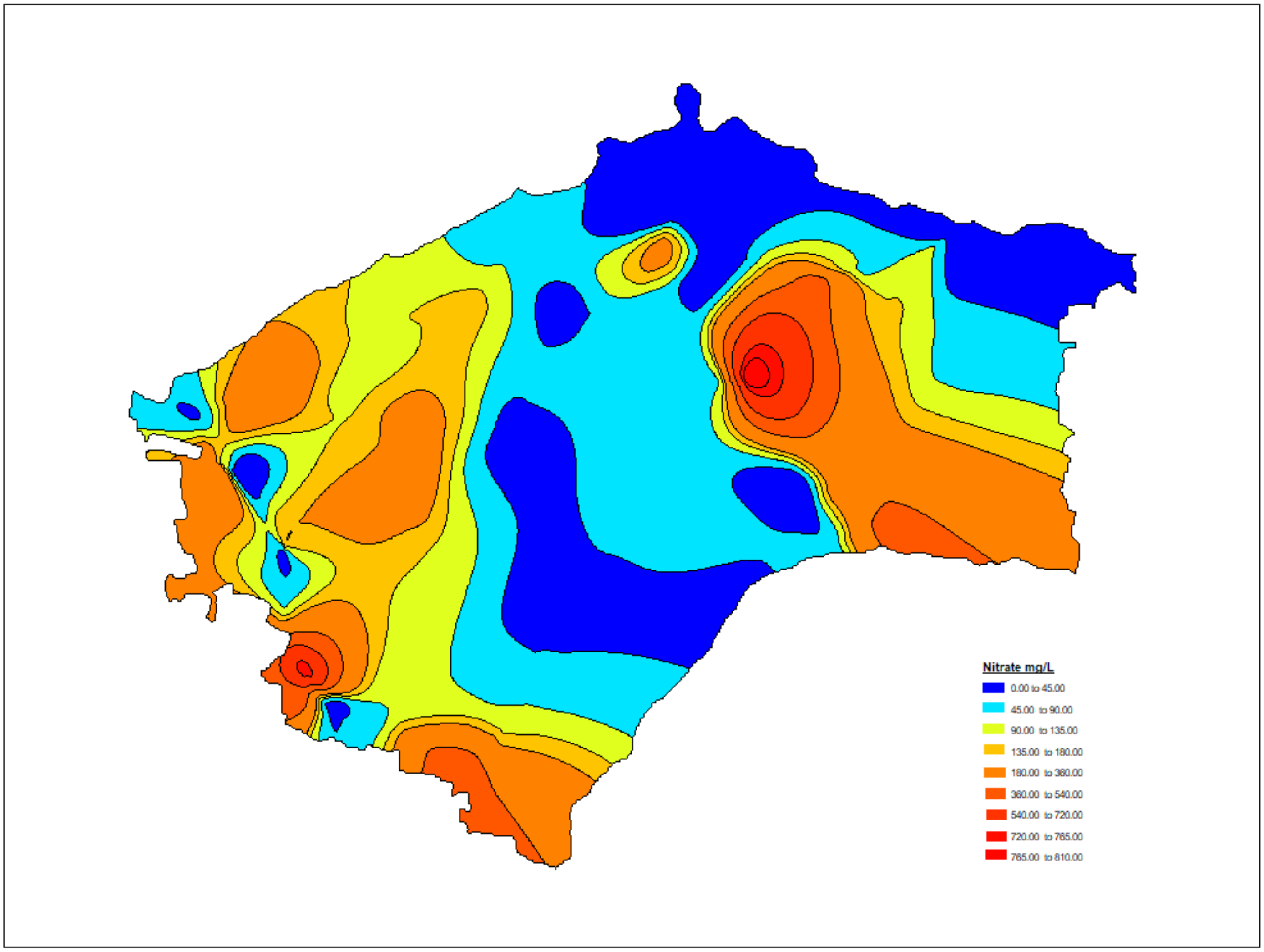

Figure 8

Spatial distribution of nitrate during January 2020

Supplementary Files

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- Tables.pdf