

**The springs in the Barra Mansa Municipality and its uses: reflection for the  
development of environmental awareness and water governance**

**Uso de nascentes no Município de Barra Mansa: reflexão para o desenvolvimento de  
consciência ambiental governança hídrica**

**Uso de mananciales en el Municipio de Barra Mansa: reflexión para el desarrollo de la  
conciencia ambiental gobernanza del agua**

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**Abstract**

Groundwater is an excellent alternative to meet public water supply demands, especially in the face of the water crisis and pollution of surface water bodies. Many municipalities throughout the national territory use water from springs for urban water supply. Barra Mansa, a city located in the southern Fluminense region, is an example of this. The aim of this study was to evaluate the water quality of three springs located in the city of Barra Mansa, in order to verify its water potential. The results obtained showed the water potential of the Municipality, revealing, however, the state of degradation and the risk of contamination of

groundwater, imposing the need to develop measures to preserve, prevent and mitigate anthropic impacts on the water sources. In this way, the questions proposed here may contribute to a reflection about the exploration of the sources and the implications inherent to its use.

**Keywords:** Socio-environmental relationship; Water resources; Sustainability.

### **Resumo**

As águas subterrâneas constituem uma excelente alternativa para suprir as demandas de abastecimento público, principalmente frente à crise hídrica e poluição dos corpos d'água superficiais. Muitos municípios em todo o território nacional utilizam águas provenientes de nascentes para o abastecimento hídrico urbano. Barra Mansa, cidade localizada na região Sul Fluminense, é um exemplo destes. Assim, o presente estudo teve como objetivo avaliar a qualidade hídrica de três nascentes localizadas no município de Barra Mansa, com intuito de verificar seu potencial hídrico. Os resultados aqui obtidos comprovaram o potencial hídrico do Município revelando, porém, o estado de degradação e o risco de contaminação das águas subterrâneas, impondo a necessidade de desenvolvimento de medidas de preservação, prevenção, e mitigação de impactos antrópicos sobre os mananciais. Desse modo, as questões aqui propostas poderão contribuir para uma reflexão acerca da exploração das nascentes e as implicações inerentes ao seu uso.

**Palavras-chave:** Relações socioambientais; Recursos hídricos; Sustentabilidade.

### **Resumen**

Las aguas subterráneas son una excelente alternativa para suplir las demandas del suministro público, especialmente ante la crisis del agua y la contaminación de los cuerpos de agua superficiales. Muchos municipios de todo el territorio nacional utilizan agua de manantiales para el abastecimiento hídrico en las ciudades. Barra Mansa, una ciudad ubicada en la región sur del Estado de Rio de Janeiro, es un ejemplo de esto. Así, el presente estudio tuvo como objetivo evaluar la calidad del agua de tres manantiales ubicados en la ciudad de Barra Mansa, con el fin de verificar su potencial hídrico. Los resultados aquí obtenidos han demostrado el potencial hídrico del Municipio, revelando, sin embargo, el estado de degradación y el riesgo de contaminación de las aguas subterráneas, imponiendo la necesidad de desarrollar medidas de preservación, prevención y mitigación de impactos humanos en los manantiales. Por tanto, las cuestiones aquí propuestas pueden contribuir a una reflexión sobre la explotación de los manantiales y las implicaciones inherentes a su uso.

**Palabras clave:** Relaciones socioambientales; Recursos hídricos; Sustentabilidad.

## 1. Introduction

The globalized world, in which consumption has increased exponentially, and therefore generates the need for more products, has brought negative consequences for the natural environment, especially water resources.

In this context are the springs, which are water outcrops of water that emerge from the surface and can be an excellent resource to meet local demands.

This text aims to study the springs of the Barra Mansa. In this municipality - located in the Middle Paraíba Fluminense region – there are several springs that places in comfortable situation, considering the times of water crisis (Bertolo, Hirata & Aly, 2015). According to the Brazilian Forest Code (Law n. 12.651/2012, art. 3, XVII), the concept of spring comprises "natural outcrop of the water table that presents continuity and begins a water course" (Lei n. 12.651, 2012).

It is, therefore, a possible resource in the attendance of demands. On the other hand, state that groundwater does not represent the solution to the water crisis, but are an important source, mainly for public supply and human consumption.

The Water Supply and Sewage Service of Barra Mansa (SAAE/BM) is a municipal authority responsible for the collection, treatment and distribution of water, maintenance and studies to expand the physical supply network, and is also responsible for sewage and solid waste services. According to the Brazilian Institute of Geography and Statistics (IBGE) (2015) the population of Barra Mansa is approximately 170,000 inhabitants and according to Table 1 its municipality's drinking water supply system consists of six water treatment station and five deep wells. The SAAE/BM reveals that an average of 12 million cubic meters of water per year was treated to serve the municipality. This water comes from the abstraction that occurs in the Paraíba do Sul, Bananal and Barra Mansa rivers, dams located in the neighborhood Vista Alegre and in artesian wells in the districts of Amparo, Rialto and Santa Rita de Cássia (Serviço Autônomo de Água e Esgoto de Barra Mansa [SAAE/BM], 2017).

However, in addition to the abstraction carried out by the SAAE/BM, part of the population makes direct and daily use of water collected from springs, since surface water degradation and climate changes tend to increase groundwater extraction (Agência Nacional de Águas [ANA], 2015). Compared with surface waters, groundwater has some properties that make its use more advantageous in relation to river waters, whereas they are naturally

filtered and purified through percolation, most of which presents excellent quality, without previous treatments.

**Table 1.** Barra Mansa supply system.

System	Source/Receiving System	Nominal flow	Treatment processes
ETA Nova	Paraíba do Sul river	400 L.s <sup>-1</sup>	Complete
ETA São Sebastião	Paraíba do Sul river	180 L.s <sup>-1</sup>	Complete
ETA Vista Alegre	Vista Alegre weir	25 L.s <sup>-1</sup>	Complete
ETA Colônia	Bananal river	20 L.s <sup>-1</sup>	Complete
ETA Floriano	Paraíba do Sul river	6 L.s <sup>-1</sup>	Complete
ETA Antonio Rocha	Barra Mansa river	2 L.s <sup>-1</sup>	Complete
AE Amparo	Underground	4,4 L.s <sup>-1</sup>	Simple
AE Moinho de Vento	Underground	2 L.s <sup>-1</sup>	Simple
AE Rialto	Underground	6 L.s <sup>-1</sup>	Simple
AE Santa Rita	Underground	1,3 L.s <sup>-1</sup>	Simple
AE Vila dos Remédios	Underground	6 L.s <sup>-1</sup>	Simple

*Note.* AW – artesian well  
Source: SAAE/BM (2011).

According to Bernardo & Zee (2014), from the second half of the twentieth century, water came to have its integrity threatened, due to the increasing pressure of overuse and misuse, besides the lack of adequate treatment. As a consequence of these factors, the gradual change in the composition of dissolved and / or dispersed elements in natural water bodies has been observed. Added to this fact is the disordered urban growth and the increase of public demands, motivated by the demographic concentration, that can negatively impact the water used for the public supply in the contributions of this resource, as is the case of Barra Mansa.

The United Nations World Report on Water Development (UN WWDR) points out that global water demand is strongly influenced by population growth, urbanization, food security and energy policies; macroeconomic processes such as the globalization of trade - as well as changes in diet, increased use of irrigated agriculture and increased consumption (United Nations World Report on Water Development [UN WWDR], 1992). There is also a forecast for an increase in global water demand - currently at 55% - by 2050, mainly due to the increasing demand from the industrial sector, thermoelectric power generation systems

and domestic users. By the way, water governance is being promoted, at least since the 1990s, as a normative concept to improve water resources management globally, with a focus on increased stakeholder engagement, flexibility, and less hierarchical forms of interaction between the state and society (Huo, Dang, Song, Chen & Mao, 2016; Neto, 2016; Schulz, Martin-Ortega, Glenk & Ioris, 2017).

Sustainability assessment offers a comprehensive and quantitative evaluation of the development performance of a specific region (Chen *et al.*, 2017; Huang, Yan & Wu, 2016). The shortage of water in recent years combined with the enormous waste and the great environmental impacts caused to water sources, make the subject of water resources management, the subject of discussions when it comes to sustainable development. Carli (2015) points out that the preservation of rivers and other water sources (lakes, groundwater) are even more important in these periods of crisis and drought, imposing the joint articulation of a series of instruments.

According to Freitas, Brilhante & Almeida (2001), the groundwater, besides being an economic good, is considered worldwide a source of supply for human consumption, for populations that do not have access to the public supply network or for those who, having access to a supply network, but have irregular supply often. In view of this, this important resource cannot be ignored. Santos & Silva (2018) emphasize that understanding what makes a spring water potable or non-potable provides the adoption of sustainable practices, as it helps in the systematization of preservation actions, that is, management and governance, allowing the maintenance of the integrity of the source and thus guaranteeing its potential as a possible resource for exploitation.

The Municipality of Barra Mansa has several springs and is regularly explored, making it necessary to develop research that contributes to the implementation of measures aimed at mitigating environmental impacts and that complies with what is proposed in chapter 18, topic 2 of the Agenda 21 and ratified by Agenda 30 (Organização das Nações Unidas [ONU], 2015):

Water is needed in all aspects of life. The overall objective is to ensure that adequate supply of good quality water is maintained for the entire population of the planet while preserving the hydrological, biological and chemical functions of ecosystems by adapting human activities to the limits of nature's ability and combating vectors of water-related diseases (ONU, 1992, p. 227).

Since the increase of natural resources being consumed in the process of economic development, many regions in the world have experienced a sharp conflict between sustainable economic development and the availability of resources (Abdullah, Muttaqi, & Agalgaonkar, 2015; Petrova & Nenko, 2018; Veiga & Magrini, 2013; Wu, 2014; Zhang Z., Zhang X. & Shi, 2018). By the way, urban and industrial development, associated with current climatic issues, has been identified as the responsible of impacts on underground water sources, causing a reduction in water volume, contamination and / or pollution of water sources and, in some cases, themselves (Huang, Yan and Wu, 2016; Karatas E. & Karatas A., 2016; Rantala, Ukko, Saunila, & Havukainen, 2018). New urban technology and infrastructure may also be replicable or useful in urban areas in different regions, such as historically has been the case with district heating, wastewater treatment, and public transport systems (Kes, Stefan, Lars & Lena, 2013; Panagopoulos, Duque & Dan, 2016).

Marteleira, Pinto & Niza (2014) and Wolkmer & Pimmel (2013) emphasize that the first imperative is to change the culture of waste and the understanding that water is an inexhaustible resource, emphasizing, in this context, the strategic importance of water and environmental citizenship groundwater management and collaborative management.

The present study aimed to evaluate the water quality of three springs located in the city of Barra Mansa, in order to verify their water potential and generate data that may contribute to the development of public policies, management and governance for sustainable use from water.

## **2. Materials and Methods**

Three springs located inside the Municipality of Barra Mansa, Rio de Janeiro served as our object of study. All of them are regularly used by the population to collect water for consumption. The choice of sources was made after previous visitation in 18 of them managed by the responsible agency SAAE/BM. As criteria established for the choice of the sources studied, stand out the importance of the source to attend the population, the strategic location and the improvements made for the exploration. The springs chosen were in Vila Maria, Vila Ursulino and Santa Clara neighborhood. It was carried out a characterization of the geographic space where the springs were located, as well as a survey of the interactions with the externalities of the environment. For each of the sources, water quality and socioenvironmental diagnosis were analyzed.

The collection, preservation, transport of the samples and the analyzes followed the guidelines described in the National Guide for the Collection and Preservation of Samples (Brandão, Botelho, Sato & Lamparelli, 2011) and in the Manual of Procedures for Sampling and Physical Chemical Analysis of Water (Parron, Muniz & Pereira, 2011).

To carry out the nitrate and ammonia analyzes, the samples were collected in amber glass flasks, with capacity for 1L, preserved with 2mL of sulfuric acid (H<sub>2</sub>SO<sub>4</sub>). For the analysis of the other physical-chemical parameters, the samples were collected in plastic bottles with a capacity of 2L. For bacteriological analyzes, the samples were collected in a snap-cap glass bottle, with a capacity of 125 mL, sterilized at 180°C for 1:30h. Data were collected in March 2016.

The parameters evaluated for the bacteriological and physicochemical quality of the groundwater samples were: total and faecal coliforms; ammonia; chlorides; colour; toughness; nitrate; nitrite; pH, temperature and turbidity.

The normative references were the ABNT NBR 12620 (ABNT, 1992) and the Standard Methods for the Examination of Water and Wastewater (SMEWW) (SMEWW, 2012). The pH and temperature tests were run on-site. The other analyzes were performed by AMPRO Laboratório e Engenharia Ltda.

### **3. Results and Discussion**

#### **3.1 Characterization of analyzed area**

Streams in urban areas are prone to degradation. While urbanization-induced poor water quality is a widely observed and well documented phenomenon, the mechanism to pinpoint local drivers of urban stream degradation, and their relative influence on water quality, is still lacking (Afzali, Shahedi, Roshan, Solaimani & Vahabzadeh, 2014; Ersoy & Gültekin, 2013; Thornhill *et al.*, 2017).

The characterization of the geographic space where the springs are located and the interactions with the externalities of the environment, allow to understand the several factors that influence the vulnerability of these bodies of water.

In the on-site observation of each of the sources analyzed, it was verified that the majority is in a state of degradation. O'Dwyer, Dowling and Adley (2014) and Giglio *et al.* (2016) point out that several factors may compromise groundwater quality: the final destination of domestic and industrial sewage in septic tanks and septic tanks, the inadequate

disposal of urban and industrial solid waste, gas stations and washing stations modernization of agriculture. This demonstrates the contribution of anthropic actions to the degradation of the underground water body, so that educational measures and integrated management of effluents, waste and economic activities should be considered in the actions of groundwater governance to promote conscious, sustainable and, above all, responsible.

Federal Law n. 9.433/1997, in its Article 1, Section IV, establishes a Hydrographic Basin as a management unit, implying new challenges for public administration and for civil society and emphasize the need to consolidate deliberative spaces for the strengthening of a democratic, integrated and shared management (Lei 9.433, 1997).

### ***3.1.1 The spring of Vila Maria neighbourhood – spring A***

The spring of Vila Maria features two water abstraction points, the first located on Antônio Graciano da Rocha Street, the main access road to the neighborhood. The other point is on the banks of the railway line, being about 300 meters after the first one. It has constant flow.

In situ observation, it was verified that the water comes from a hill near the abstraction points. There is little cover vegetation on the hill. The surroundings of the springs are surrounded by residences, a health station and a Municipal Nursery. Generally, users make use of the point located on the main road, because it is a place of better access, it is near a bus stop and due to improvements. These are summarized in a faucet that is fixed on the wall of a corner residence, the place has a ceramic coating and a drain through which the water seeps.

According to the 2010 census, the population of the Vila Maria neighborhood was 5016 inhabitants (IBGE, 2010). The exploitation of water from this source is not restricted to its dwellers. During the data collection the presence of other districts residents such as Centro, Saudade, Vista Alegre and Vila Nova was identified.

### ***3.1.2 The spring of Santa Clara neighbourhood – spring B***

Santa Clara is a neighborhood that presents more than one spring, according to SAAE data. The spring investigated is located at Délio Sampaio street number 5. It presents a surprising and constant volume of water. The flow impresses and calls attention by the lack of strategy of capture by the public power, since all water not captured goes to rainwater. The

water as in the other sources analyzed comes from a nearby hill, in this case covered by vegetation.

Délio Sampaio street is an important neighbourhood road access road. The catchment point is located close to residences, shopping facilities, sports court and bus stop. There is much movement to capture water and people from different place use this source. The presence of residents of the Center, Saudade, Goiabal, Vista Alegre, Vila Principal, Nova Esperança, Jardim América, Morja do Granja I, São Francisco, Morro do Cruzeiro and São Pedro was identified, in addition to the residents of Santa Clara.

Users of the neighborhood Ponte Alta, Municipality of Volta Redonda have also been found. In general, people who seek water from this source are attracted by their large water volume, supplying large quantities of containers.

The catchment point has a roof with a roof and the pipe is at a height that further the filling of water gallons. The floor is cemented and has a large drain, for drainage to the rainwater network.

Due to its easy access and physical space, some users use the spring to wash their cars. This fact, occasionally, creates conflicts with users who come in search of water for consumption.

A recurrent observed aspect in all the sources was the user demand in water abstraction. This information establishes the importance of groundwater in meeting the population needs, but at the same time, indicates that consumption is continuous, with little importance attached to the value of this resource. This data corroborates with the opinion of the National Water Agency (ANA) that treats groundwater as fundamental for public water supply in Brazil (ANA, 2010).

### ***3.1.3 The spring of Vila Ursulino neighbourhood – spring C***

The spring of the Vila Ursulino neighborhood is located on street F, next to a Health Post. The water that arrives at the faucet comes from an outcrop present on a hill and is stored in a reception box. The pickup point has a good structure, having two faucets to facilitate users. The hill has a good vegetation cover and presents some native species of the Atlantic Forest, characteristic biome of the Region. It is located in an easily accessible location. According to the report of the users presents average flow during the day and greater during the night.

In addition to the Health Post, there are residences in its surroundings. Residents make regular use of the spring and it is not restricted to local users. During the visit, residents of other neighborhood were identified, such as Centro, Santa Maria I and Vila Nova. During the on-site observation, there was an affective relationship of residents living near the source.

The Vila Ursulino spring in the last demographic sense had a population of 1684 inhabitants (IBGE, 2010).

### **3.2 Reflection on direct consumption**

A relevant data was the direct consumption of the springs, showing the degree of confidence in the quality of the water in nature. This fact is extremely important, given the culture that water springs, because they are crystalline, do not pose a health risk. Polluting microorganisms are not always perceived. Many of them do not cause a change in the colour, fragrance or even taste of the water, and may constitute a silent and imperceptible danger; hence the need for quality assessment on a regular basis. Villar (2016) corroborates the idea that the belief in superior groundwater quality discourages users from conducting water quality analyzes or restricting fecal coliform tests. Rebouças (2006) points out that groundwater also presents quality problems, whether due to anthropogenic, biological or natural contamination (from rock and water interaction). Therefore, your intake can lead to public health problems. Beliefs, concepts and prejudices are relevant and explain behaviors, habits and customs.

However, when they result in the dissimulation of shares which are harmful to public health, should be addressed. This treatment involves socio-educational measures, which may occur formally within educational institutions or even within the informal sphere through other institutions, such as association of residents, churches, media, newsletters, among others.

### **3.3 Results regarding the potability of springs**

According to Brazilian Ministry of Health (MS) the evaluation of the quality of a water must be done in an integrated way, considering all physical, chemical and biological information. In addition, the author emphasizes that some parameters are evaluation instruments that can be grouped to contemplate the most relevant characteristics of the natural

water quality. Thus, the analysis of potable water sources obtained results were grouped in blocks for better data exploitation (Ministério da Saúde [MS], 2006).

Celligoi (1999) considers groundwater chemical analyzes to be "important because the chemical analysis of groundwater is very important, since the identification parameters are required", since it allows identifying the type of water and for which activity it can be employed.

Table 2 presents obtained data for hardness, chloride and pH of the nascent water analysed samples. The hardness indicates the concentration of multivalent cations in solution in the water. The most frequently associated with hardness cations are calcium and magnesium ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ) and, to a lesser extent, iron ( $\text{Fe}^{2+}$ ), manganese ( $\text{Mn}^{2+}$ ), strontium ( $\text{Sr}^{2+}$ ) and aluminium ( $\text{Al}^{3+}$ ) (MS, 2006).

**Table 2.** Hardness, chloride and pH data.

Parameters	Spring A	Spring B	Spring C
Hardness ( $\text{mg.L}^{-1}$ )	67.79	<0.02	16.50
Chloride ( $\text{mg.L}^{-1}$ )	7.63	7.63	4.36
pH a 25°C	6.21	7.63	6.10

Source: Authors.

Hardness values for spring A give it a moderate hardness rating (between  $50\text{mg.L}^{-1}$  and  $150\text{mg.L}^{-1}\text{CaCO}_3$ ). For springs B and C, the obtained values require them to be classified as soft or soft because they are within the limits established for this category ( $<50\text{mg.L}^{-1}$  of  $\text{CaCO}_3$ ). The hardness value is a data that attracts attention, because it presents higher values in the source A than in the others. This fact may be related to the proximity of the local steel mill and to the soil type, but this fact requires further investigation.

According to the Brazilian Legislation for supply water, the drinking standard sets the limit of  $500\text{mg.L}^{-1}\text{CaCO}_3$ , values usually only found in underground aquifers.

Related to chlorides, the obtained values meet the Brazilian Legislation specifications, which recommends a limit of 250mg. Higher values compromise the organoleptic quality of the water (Celligoi, 1999). The author report that:

the presence of chloride in groundwater can be attributed to the dissolution of saline deposits, discharges of chemical industry effluents, saline intrusions, etc. Chloride ions are highly mobile and are not retained in permeable rocks. In argillites, NaCl crystals or NaCl solutions can be contained in pores. Chloride ions are present at low

concentrations ( $<10\text{mg}\cdot\text{L}^{-1}$ ). High concentrations may indicate anthropogenic pollution (Celligoi, 1999, p.93).

The Brazilian Ministry of Health Ordinance (Consolidation Ordinance n. 5, 2017) recommends that the pH value of water intended for human consumption and supplied by the public supply network is in the range of 6.0 to 9.5). Although the analyzed waters come from underground resources, therefore of mineral origin, they meet this limit established as a guarantee of potability (Portaria de Consolidação n. 5, 2017).

However, the obtained values analyses verified that the samples from sources A and C presented acidified pH while that of source B, slightly alkaline. These results suggest that probably at source B it may indicate the presence of bicarbonates ( $\text{HCO}_3^-$ ), carbonates ( $\text{CO}_3^{2-}$ ) or hydroxides ( $\text{OH}^-$ ), which are the main responsible for alkalinity, requiring more detailed analysis in later research. In the samples referring to the A and C springs, the light acidity may suggest anthropogenic and / or natural causes, such as, for example, organic matter decomposition (MS, 2006).

Table 3 presents obtained data for biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in the water samples of the analyzed samples. BOD is the amount of oxygen required to oxidize organic matter by aerobic microbial decomposition to a stable inorganic form. COD is the amount of oxygen required for oxidation of organic matter by a chemical agent.

**Table 3.** BOD and COD data.

Parameters	Spring A	Spring B	Spring C
BOD ( $\text{mg}\cdot\text{L}^{-1}$ )	3.00	3.00	3.00
COD ( $\text{mg}\cdot\text{L}^{-1}$ )	$<15.00$	$<15.00$	$<15.00$

Source: Authors.

According to Environmental Company of the State of São Paulo (CETESB) the inland water quality report in the State of São Paulo infers that:

When dissolved oxygen levels tend to zero, the decomposition of organic matter occurs in an anaerobic environment, which causes the emanation of odorous volatile by-products from water bodies, causing discomfort to the population and damage to materials and flora. In an aerobic environment, on the other hand, the decomposition of carbonaceous organic matter and nitrogenous organic matter occurs, the latter being converted into nitrate. Both phosphorus and nitrate are essential nutrients for biological activity (CETESB, 2018, p.16).

Table 4 shows obtained data for nitrite ( $\text{NO}_2^-$ ), nitrate ( $\text{NO}_3^-$ ) and ammonia ( $\text{NH}_3$ ) from the analyzed sources. The nitrite, nitrate and ammonia obtained values are in accordance with those required by the Consolidation Ordinance n. 5, 2017 and ABNT NBR 1260/1992, which establishes for nitrate  $10\text{mg.L}^{-1}$ , nitrite  $1\text{mg.L}^{-1}$  and ammonia  $1.5\text{mg.L}^{-1}$  (ABNT, 1992; Portaria de Consolidação n. 5, 2017). According to the American Public Health Association (APHA) nitrate ion is one of the most commonly found in natural waters and is generally low in surface water, but in deep water it can be found in high concentrations (American Public Health Association [APHA], 1992).

**Table 4.** Nitrite, nitrate and ammonia data.

Parameters	Spring A	Spring B	Spring C
Nitrite ( $\text{mg.L}^{-1}$ )	<1.00	<1.00	<1.00
Nitrate ( $\text{mg.L}^{-1}$ )	<0.002	0.010	<0.002
Ammonia ( $\text{mg.L}^{-1}$ )	<0.010	<0.010	<0.010

Source: Authors.

Consumption of nitrate-contaminated waters result in serious health risks especially in children methemoglobinemia, causing “blue baby syndrome” as well as the potential formation of carcinogenic nitrosamines and nitrosamides (Bouchard, Williams & Surampalli, 1992; Organización Mundial de la Salud para lalcalidade del agua potable [OMS], 1995; Queiroz, 2004).

Regarding nitrite intake Batalha & Parlato (1977) emphasize that when ingested directly with drinking water, it can cause methemoglobinemia regardless of the consumer's age group and its effect is faster and more pronounced than nitrate.

Although the level of nitrogen compounds and compounds found in the samples is low in concentration and does not compromise these water bodies, it should be noted that the nitrogen series (molecular nitrogen, nitrite, nitrate and ammonium ions, among other nitrogen compounds) such as releases, domestic sewage, industrial and animal breeding, as well as the excessive use of fertilizers in water bodies, with a good indicator of contamination.

Table 5 shows obtained data for apparent colour and turbidity in water samples from the analyzed samples. To meet the potability standard, water must have an apparent colour intensity of less than five units. The data obtained are in accordance with the established.

**Table 5.** Data obtained for apparent color and turbidity in water samples from the analysed samples

Parameters	Spring A	Spring B	Spring C
Apparent color (uH)	<3.48	<3.48	<3.48
Turbidity (UNT)	<3.00	<3.00	<3.00

Source: Authors.

According to CETESB (2016), the turbidity of a sample of water constitutes the degree of attenuation of the intensity that a beam of light suffers when crossing it. This reduction occurs by absorption and scattering, since the particles that cause the turbidity in the waters are larger than the wavelengths of white light. This measurement is made with the turbid meter or nephelometer, which compares the scattering of a beam of light as it passes through the sample with that of a beam of equal intensity when passing through a standard suspension. The greater the spread, the greater the turbidity (Couto, 2016). The natural turbidity of the waters is generally in the range of 3 to 500 units.

For potability purposes, the turbidity must be less than one unit. This restriction is based on the influence of turbidity on the usual processes of disinfection, acting as a shield to the pathogenic microorganisms, thus minimizing the action of the disinfectant (MS, 2006). However, the results concerning turbidity reveal that the values found are in agreement with the expected for the natural condition of the water, considering that it is mineral water. However, outside the established limits for the treatment of water in treatment systems.

Table 6, below, shows the data obtained for *Escherichia coli* counts and total coliform counts from the analysed samples. The presence of *Escherichia coli* in water acts as the body most used as an indicator of faecal contamination. Their presence suggests that the water may have received a load of faecal contamination. This burden contributes to the deterioration of the microbiological quality of the water and can pose risks to the health of consumers.

**Table 6.** Data obtained for *Escherichia coli* count and total coliform counts from the analysed samples.

Parameters	Spring A	Spring B	Spring C
<i>Escherichia coli</i> Count (NMP/100mL)	<1.8	<1.8	<1.8
Total Coliform Count (NMP/100mL)	<1.8	<1.8	<1.8

Source: Authors.

The presence of *E. coli* in the three sources analyzed made them unfit for direct consumption of water, imposing the need for disinfection mechanisms for human consumption, without which it could pose a health risk. It is worth mentioning that water can act as a vehicle for disease-causing agents such as diarrhea, dysentery, cholera, typhoid and hepatitis, since many users consume water directly without any post-harvest treatment. This fact is a factor of medical-sanitary relevance, requiring interference in the management of these important water resources.

The decontamination by *E. coli* for underground springs must comply with the guidelines established in art. 33 paragraphs 1.2 and 3 of MS (2017). Bertoldo *et al.* (2019) mention that in recent decades, legislation and public policies have been improved, resulting in improved management actions for contaminated areas. However, civil society and decision makers lack effective actions to improve the protection of the underground water resource

Within this perspective, it is extremely important to carry out periodic reports as well as their wide dissemination, through different means of communication, such as the internet, boards or in the media.

### 3.4 Analysis within a way management and governance perspective

The “Agenda 21” advocates that a significant part of the damage is due to the lack of knowledge or negligence of social actors regarding the capacity of ecosystems to support them. The central issue, in this case, would be the implementation of management means that, by ensuring the dissemination and absorption of knowledge, ensure sustainability.

Pagnoccheschi (2016) and Al Saidi (2017) emphasizes that the major challenges to be faced in the coming years regarding water resources governance are related to the articulations that will be needed with the sectors that use water resources, generally subject to specific public policies, which corroborates the idea proposed here of the need for local policy development that addresses the municipality of Barra Mansa and involves all its social actors

(users, public and private management) in order to establish a more efficient and sustainable mechanism for the use of groundwater in the County.

Victorino (2007), Patil *et al.* (2013) and Ashiyani *et al.* (2015) points out that widespread scarcity, gradual destruction and worsening pollution of water sources in many regions of the world require awareness and changes in attitudes towards water. Such changes will only occur through a re-education or an education aimed at the environment. Gadotti (2000) states that "to educate is to know how to read the world, to know it to transform it and to transform it, to know it".

Therefore, the understanding of the environment and the variables present in it are essential for the formation of citizens aware of their role in urban space. Lima (1998) corroborates the idea, when inferring that education is a key element in the process of changing mentalities, habits and behaviors, towards a sustainable society. Moreira (2014), bringing to an urban context, emphasizes that urban waters thus become the subject of permanent debates not only for the patrimony of supply and energy that often translate to cities, but also for the landscape and the identity character which they enter.

Groundwater cannot be disregarded as a viable alternative for urban water supply. An example of successful use of this resource is verified through the analysis of CETESB data, in 2002, 462 municipalities in the State of São Paulo (72%) were totally or partially supplied with groundwater and that 308 (47.7%) municipalities were fully supplied by this water resource, although most of these were municipalities with a small number of inhabitants (less than 10,000) (CETESB, 2004).

In 2010, the number of cities fully served by groundwater rose to 331 and those using mixed systems, 126. The State of São Paulo has excelled in public policies and strategic measures in the exploitation of groundwater, such as reports, documents and several studies produced by CETESB and other managing bodies. The State of Rio Grande do Sul presents a significant number of municipalities using groundwater. These successful examples undoubtedly demonstrate the importance of groundwater for human activities (CETESB, 2013).

Considering the above, we can affirm that the exploration and maintenance of a water supply system using only groundwater, which serve a Municipality as a whole is possible and, considering the wide employment and the multiple urban activities that water can acquire, we can infer that groundwater plays a large role in maintaining life and productive chains. Rebouças (2006) points out that 95% of São Paulo's industries use groundwater.

Machado (2004) emphasizes that social participation in the management of water resources involves both the democratic principle and the necessary awareness for the construction of a new way of managing the public good, by nature, expensive and scarce. Senthilkumar, Nithya & Babu (2014) infers that the integrated management of water resources aims to ensure their preservation, use, recovery and conservation in conditions satisfactory to their multiple users and consistent with the region's balanced and sustainable development and efficiency.

The present study does not pretend to indicate solutions to solve the problems of the use of groundwater in the Municipality of Barra Mansa, but to provoke a reflection on the subject so that new studies can be developed and with that, to provide efficient use of this important water resource.

#### **4. Conclusion**

Groundwater emerges as an alternative to meet the demands of public supply, in the face of the water crisis and pollution of surface water bodies. The municipality of Barra Mansa has an impressive underground water potential.

However, there is a lack of public policies aimed at preserving this important resource. The results obtained here reveal both the potential, the degradation status and the risk of groundwater contamination, suggesting the need for measures to preserve, prevent and mitigate anthropogenic impacts on water sources.

The potability analyzes showed that most of the parameters evaluated in the samples of the fountains are in agreement with the established by the Ministry of Health.

However, the presence of *Escherichia coli* in the samples indicates possible fecal contamination, making them unfit for human consumption.

To meet this purpose, they become necessary disinfection mechanisms. The presence of *Escherichia coli* brings this data to the area of medical health interest.

Under the socio-environmental aspect, the present study highlights the importance that the springs present for the population of Barra Mansa and reveals the network of springs spread throughout its territory. This information assists in the development of management of groundwater resources of the Municipality, since it allows the identification, mapping, verification of the qualitative and quantitative water potential for the use of these waters in human consumption and other social demands.

Thereby the groundwater use contributes to expenses reduction and sustainable measures adoption, since the treatment stages consume energy and inputs in their processes, providing significant savings to the Municipality, besides offering consumers better quality.

In such context, public policies compromised with Ambiental

In such context, the importance of developing public policies focused on management and governance, with the participation of the whole society is highlighted. Besides that, the protection of underground water bodies must be a priority, considering their peculiarities and characteristics.

Given the above, it can be inferred that further investigations are needed to support the management of water resources in the Municipality of Barra Mansa. For example, research on other springs, including those located in rural areas and in neighboring municipalities.

## References

Abdullah, M. A., Muttaqi, K. M., & Agalgaonkar, A. P. (2015). Sustainable energy system design with distributed renewable resources considering economic, environmental and uncertainty aspects. *Renewable Energy*, 78, 165-172. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0960148114008714>. doi: 10.1016/j.renene.2014.12.044

ABNT NBR 12620, de 09 de setembro de 1992. Águas - Determinação de nitrato - Métodos do ácido cromotrópico e do ácido fenoldissulfônico. Rio de Janeiro: Associação Brasileira de Normas Técnicas.

Afzali, A., Shahedi, K., Roshan, M. H. N., Solaimani, K., & Vahabzadeh, G. (2014). Groundwater Quality Assessment in Haraz Alluvial Fan, Iran. *International Journal of Scientific Research in Environmental Sciences*, 2(10), 346-360. Recovered from [https://www.researchgate.net/publication/273221678\\_Groundwater\\_Quality\\_Assessment\\_in\\_Haraz\\_Alluvial\\_Fan\\_Iran](https://www.researchgate.net/publication/273221678_Groundwater_Quality_Assessment_in_Haraz_Alluvial_Fan_Iran). doi: 10.12983/ijres-2014-p0346-0360

Agência Nacional de Águas. (2015). *Índice de qualidade das águas (IQA)*. from <http://portalpnqa.ana.gov.br/indicadores-indice-aguas.aspx>

Agência Nacional de Águas. (2010). *Abastecimento Urbano de Água: Panorama Nacional*. Brasília: ANA/Engecorps. Retrieved jan. 16, 2015, from <http://atlas.ana.gov.br/Atlas/downloads/atlas/Resumo%20Executivo/Atlas%20Brasil%20-%20Volume%201%20-%20Panorama%20Nacional.pdf>

Al-Saidi, M. (2017). Conflicts and security in integrated water resources management. *Environmental Science and Policy*, 73, 38-44. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S1462901116301071>. doi: 10.1016/j.envsci.2017.03.015

American Public Health Association. (1992). *Standard methods for the examination of water and wastewater* (17a ed.), 4-75/ 4-93. Washington: APHA.

Ashiyani, N., Parekh, F., & Suryanarayana, T. M. V. (2015). Analysis of Physico-Chemical Properties of Groundwater. *International Journal of Innovative Research in Science, Engineering and Technology*, 4(3), 1094-1098. Recovered from [http://www.ijirset.com/upload/2015/march/61\\_Analysis.pdf](http://www.ijirset.com/upload/2015/march/61_Analysis.pdf). doi:10.15680/ijirset.2015.0403061

Batalha, B. H. L. & Parlatore, A. C. (1977) *Controle da qualidade da água para consumo humano: bases conceituais e operacionais*. São Paulo, CETESB.

Bernardo, C., & Zee, D. (2014) *Meio ambiente urbano: desafios e soluções* (1a ed.). Rio de Janeiro: Letra Capital.

Bertolo, R. A., Hirata, R., & Aly J. (2019). Método de Valoração da Água Subterrânea Impactada por Atividades Contaminantes no Estado de São Paulo. *Revista Águas Subterrâneas*, 33(3), 303-313.

Bertolo, R., Hirata, R., Conicelli, B., Simonato, M., Pinhatti, A., & Fernandes, A. (2015). Água subterrânea para abastecimento público na Região Metropolitana de São Paulo: é possível utilizá-la em larga escala? *Revista DAE*, 63, 6-18. Recovered from <http://revistadae.com.br/site/artigo/1602-Aamp769gua-subterraamp770nea-para-abastecimento-puamp769blico-na-Regiaamp771o-Metropolitana-de-Saamp771o-Paulo-amp769-possiaamp769vel-utilizaamp769-la-em-larga-escala>. doi: 10.4322/dae.2014.148

Bouchard, D. C., Willians, M. K., & Surampalli, R. Y. (1992). Nitrate contamination of ground water: sources and potencial health effects. *Journal American Water Works Association*, 84, 85-90.

Brandão, C. J., Botelho, M. J. C., Sato, M. I. Z., & Lamparelli, M. C. (2011) *Guia nacional de coleta e preservação de amostras: água, sedimento, comunidades aquáticas*. São Paulo: CETESB.

Carli, A. A. (2015) *Água é vida; eu cuido, eu poupo - para um futuro sem crise* (1ª ed.). Rio de Janeiro: Fundação Getúlio Vargas. ISBN: 978-85-225-1727-5.

Celligoi, A. (1999). Considerações sobre análises químicas de águas subterrâneas. *Geografia*, 8(1), 91-97. Retrieved jan. 06, 2017, from <http://www.uel.br/revistas/uel/index.php/geografia/article/viewFile/10207/9020>.

Companhia Ambiental do Estado de São Paulo. (2018). *Qualidade das águas interiores no estado de São Paulo*. Retrieved from <https://cetesb.sp.gov.br/aguas-interiores/wp-content/uploads/sites/12/2019/10/Relat%C3%B3rio-de-Qualidade-das-%C3%81guas-Interiores-no-Estado-de-SP-2018.pdf>

Companhia Ambiental do Estado de São Paulo. (2016). *Apêndice E: Significado Ambiental e Sanitário das Variáveis de Qualidade das Águas e dos Sedimentos e Metodologias Analíticas e de Amostragem*. 2016 Retrieved from <https://cetesb.sp.gov.br/aguas-interiores/wp-content/uploads/sites/12/2017/11/Ap%C3%AAndice-E-Significado-Ambiental-e-Sanit%C3%A1rio-das-Vari%C3%A1veis-de-Qualidade-2016.pdf>

Companhia Ambiental do Estado de São Paulo. (2013). *Qualidade das águas subterrâneas do Estado de São Paulo 2010-2012 [recurso eletrônico] / CETESB*. 2013. Retrieved from <https://cetesb.sp.gov.br/aguas-subterraneas/publicacoes-e-relatorios>

Companhia Ambiental do Estado de São Paulo. (2004). *Relatório de qualidade das águas subterrâneas do Estado de São Paulo 2001- 2003*. 2004. Retrieved from <https://cetesb.sp.gov.br/aguas-subterraneas/publicacoes-e-relatorios>

Chen, X., Chen, Y., Shimizu, T., Niu, J., Nakagami, K., Qian, X., Li, J. (2017). Water resources management in the urban agglomeration of the Lake Biwa region, Japan: An ecosystem services-based sustainability assessment. *Science of the Total Environment*, 586, 174-187. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0048969717302280>. doi: 10.1016/j.scitotenv.2017.01.197

Couto, J. L. V. *Limnologia*. Retrieved from <http://www.ufrj.br/institutos/it/de/acidentes/turb.htm>

Ersoy, A. F., & Gültekin, F. (2013). Drastic-based methodology for assessing groundwater vulnerability in the Gümüşhacıköy and Merzifon basin (Amasya, Turkey). *Earth Science Research*, 17(1), 33-40, 2013. ISSN 1794-6190.

Freitas, M. B., Brilhante, O. M., & Almeida, L. M. (2001). Importância da análise de água para a saúde pública em duas regiões do Estado do Rio de Janeiro: enfoque para coliformes fecais, nitrato e alumínio. *Caderno Saúde Pública*, 17 (3), 651-660.

Gadotti, M. (2000). *Perspectiva atuais da Educação*. Porto Alegre: Editora ArtMed. ISBN: 8573076208.

Giglio, O. Barbuti, G., Trerotoli, P., Brigida, S., Calabrese, A., Vittorio, G., ... Montagna, M. T. (2016). Microbiological and hydrogeological assessment of groundwater in southern Italy. *Environ Monit Assess*, 188, 638. Recovered from <https://link.springer.com/article/10.1007/s10661-016-5655-y>. doi: 10.1007/s10661-016-5655-y

Huang, L., Yan, L., & Wu, J. (2016). Assessing urban sustainability of Chinese megacities: 35 years after the economic reform and open-door policy. *Landscape and Urban Planning*, 145, 57-70. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0169204615002042>. doi: 10.1016/j.landurbplan.2015.09.005

Huo, A. D., Dang, J., Song, J. X., Chen, X. H., & Mao, H. R. (2016). Simulation modeling for water governance in basins based on surface water and groundwater. *Agricultural Water*

*Management*, 174, 22-29. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0378377416300749>. doi: 10.1016/j.agwat.2016.02.027

Instituto Brasileiro de Geografia e Estatística. *Conheça cidades e estados do Brasil*. Retrieved from <https://cidades.ibge.gov.br/brasil/rj/barra-mansa/panorama>

Karataş, E., & Karataş, A. (2016). The role of sustainable water management in protection of water resources. *Journal of Survey in Fisheries Sciences*, 2(2), 83-90. Recovered from [http://sifisheressciences.com/browse.php?a\\_id=77&slc\\_lang=en&sid=1&printcase=1&hbnr=1&hmb=1](http://sifisheressciences.com/browse.php?a_id=77&slc_lang=en&sid=1&printcase=1&hbnr=1&hmb=1). doi: 10.18331/SFS2016.2.2.7

Kes, M., Stefan, A., Lars, C., & Lena, N. (2013). Advancing sustainable urban transformation. *Journal of Cleaner Production*, 50, 1-11. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0959652613000085>. doi:10.1016/j.jclepro.2013.01.003

*Lei n. 12.651 de 25 de maio de 2012*. Dispõe sobre a proteção da vegetação nativa; altera as Leis nos 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006; revoga as Leis nos 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória no 2.166-67, de 24 de agosto de 2001; e dá outras providências. Diário Oficial [da] República Federativa do Brasil, 28 mai. 2012.

*Lei n. 9433, de 8 de janeiro de 1997*. Institui a Política Nacional de Recursos Hídricos, cria o Sistema Nacional de Gerenciamento de Recursos Hídricos, regulamenta o inciso XIX do art. 21 da Constituição Federal, e altera o art. 1º da Lei nº 8.001, de 13 de março de 1990, que modificou a Lei nº 7.990, de 28 de dezembro de 1989. Retrieved nov. 20, 2017, from [http://www.planalto.gov.br/ccivil\\_03/LEIS/L9433.html](http://www.planalto.gov.br/ccivil_03/LEIS/L9433.html)

Lima, G. F. C. (1998) Consciência Ecológica: emergência, obstáculos e desafios. *Revista Ciência & Trópicos*, 26(J), 103-122.

Machado, C. J. S. (2004). A nova aliança entre Estado e sociedade na administração da coisa pública: descentralização e participação na Política Nacional de Recursos Hídricos. In: C. J.

S. Machado, N. Miranda, & A. A. S. Pinheiro (Orgs.). *Gestão de Águas Doces* (pp.1-38). Rio de Janeiro: Interciência. ISBN-10: 8571930872.

Marteleira, R., Pinto, G., & Niza, S. (2014). Regional water flows. *Resources, Conservation & Recycling*, 82, 66-74. ISSN:0921-3449.

Ministério da Saúde. (2006). *Vigilância e controle da qualidade da água para consumo humano*. Retrieved from [http://bvsms.saude.gov.br/bvs/publicacoes/vigilanc\\_ia\\_controle\\_qualidade\\_agua.pdf](http://bvsms.saude.gov.br/bvs/publicacoes/vigilanc_ia_controle_qualidade_agua.pdf).

Moreira, A. A. (2017). *Paraíba do Sul: um rio, quatro cidades, um patrimônio socioambiental em questão* (Tese de doutorado). Faculdade de Arquitetura e Urbanismo. Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brasil. Retrieved from <https://minerva.ufrj.br/F/PDVT6JI6M4NRBXIR15IFKJGJVNMPBC9I5E42CG23Y29U7YH7L9-12447?func=shortrank&action=RANK&W01=Todos&W02=os&W03=Camos=&W04=andrea&W05=auad>

Neto, S. (2016). Water governance in an urban age. *Utilities Policy*, 43, 32-41. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0957178715300771>. doi: 10.1016/j.jup.2016.05.004

O'Dwyer, J., Dowling, A., & Adley, C.C. (2014) Microbiological assessment of private groundwater-derived potable water supplies in the mid-west region of Ireland. *Journal of Water and Health*, 2, 310–317. Recovered from [https://www.researchgate.net/publication/264636205\\_Microbiological\\_assessment\\_of\\_private\\_groundwater-derived\\_potable\\_water\\_supplies\\_in\\_the\\_Mid-West\\_Region\\_of\\_Ireland](https://www.researchgate.net/publication/264636205_Microbiological_assessment_of_private_groundwater-derived_potable_water_supplies_in_the_Mid-West_Region_of_Ireland). doi: 10.2166/wh.2014.178

Organización Mundial de la Salud. Guías para lcalidad del agua potable. (1995) V. 1: *Recomendaciones* (2a ed.). Ginebra: OMS.

Organização das Nações Unidas (2015). *Transformando Nosso Mundo: A Agenda 2030 para o Desenvolvimento Sustentável*. Retrieved from [http://www.itamaraty.gov.br/images/ed\\_devsust/Agenda2030-completo-site.pdf](http://www.itamaraty.gov.br/images/ed_devsust/Agenda2030-completo-site.pdf)

Organização das Nações Unidas (1992). *Conferência das Nações Unidas sobre o Meio Ambiente e Desenvolvimento: Agenda 21*. Retrieved from <https://www.senado.gov.br/noticias/Jornal/emdiscussao/rio20/a-rio20/conferencia-rio-92-sobre-o-meio-ambiente-do-planeta-desenvolvimento-sustentavel-dos-paises.aspx>.

Pagnoccheschi, B. (2016). Governabilidade e governança das águas no Brasil. In: A. M. M. Moura (Org). *Governança ambiental no Brasil: instituições, atores e políticas públicas* (Cap.7, pp.175-199). Brasília: Ipea. ISBN: 978-85-7811-275-2. Retrieved from <http://repositorio.ipea.gov.br/bitstream/11058/9270/1/Governabilidade.pdf>.

Panagopoulus, T., Duque, J. A. G., & Dan, M. B. (2008). Urban planning with respect to environmental quality and human well-being. *Environmental Pollution*, 208, 137-144. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0269749115003711>. doi:10.1016/j.envpol.2015.07.038

Parron, L. M., Muniz, D. H. F., & Pereira C. M. (2011). *Manual de procedimentos de amostragem e análise físico química da água*. Brasília: EMBRAPA. ISSN 1980-3958. 2011. Retrieved from <https://www.embrapa.br/busca-de-publicacoes/-/publicacao/921050/manual-de-procedimentos-de-amostragem-e-analise-fisico-quimica-de-agua>.

Patil, C., Narayanakar, S., & Virupakshi, A. (2013). Assessment of Groundwater Quality Around Solid Waste Landfill Area - A Case Study. *International Journal of Innovative Research in Science, Engineering and Technology*, 2(7). ISSN: 2319-8753.

Petrova, M., & Nenko, A. (2018). Urban emptiness as a resource for sustainable urban development. *Management of Environmental Quality*, 29(3), 388-405. Recovered from [https://www.researchgate.net/publication/323432226\\_Urban\\_Emptiness\\_as\\_a\\_Resource\\_for\\_Sustainable\\_Urban\\_Development](https://www.researchgate.net/publication/323432226_Urban_Emptiness_as_a_Resource_for_Sustainable_Urban_Development). doi: 10.1108/MEQ-01-2018-0004

*Portaria de Consolidação No. 5, de 28 de setembro de 2017*. Dispõe sobre os procedimentos de controle e de vigilância da qualidade da água para consumo humano e seu padrão de potabilidade. Retrieved from [http://bvsms.saude.gov.br/bvs/saudelegis/gm/2017/prc0005\\_03\\_10\\_2017.html](http://bvsms.saude.gov.br/bvs/saudelegis/gm/2017/prc0005_03_10_2017.html)

Queiroz, E. T. (2004). *Águas minerais do Brasil: distribuição, classificação e importância econômica*. Brasília: DF. Retrieved from <http://www.dnrm.gov.br/dnrm/publicacoes-economia-mineral/arquivos/aguas-minerais-do-brasil-distribuicao-classificacao-e-importancia-economica>.

Rantala, T., Ukko, J., Saunila, M., & Havukainen, J. (2018). The effect of sustainability in the adoption of technological, service, and business model innovations. *Journal of Cleaner Production*, 172, 46-55. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0959652617322977>. doi: 0.1016/j.jclepro.2017.10.009

Rebouças, A. C. (2006). Águas Subterrâneas. In: A. C. Rebouças, B. Braga, J. G. Tundisi (Orgs). *Águas doces no Brasil: Capital ecológico, uso e conservação*. São Paulo: Escrituras Editora. ISBN: 85-86303-41-0.

Serviço Autônomo de Água e Esgoto de Barra Mansa - RJ. (2011). *Plano Municipal de Saneamento Básico*. Retrieved from [https://pmsbguanabara.files.wordpress.com/2018/12/pmsb\\_barra-mansa.pdf](https://pmsbguanabara.files.wordpress.com/2018/12/pmsb_barra-mansa.pdf)

*Serviço Autônomo de Água e Esgoto de Barra Mansa*. (2017). Retrieved from [http://saaebm.rj.gov.br/pagina/1864\\_Qualidade-da-Agua.html](http://saaebm.rj.gov.br/pagina/1864_Qualidade-da-Agua.html).

Santos, D. C. R. M., & Silva, C. M. (2018). Saneamento básico dentro da perspectiva das águas subterrâneas. In: J. R. M. Leite, C. E. Peralta, & A. A. Carli (Orgs.), *Agua y saneamiento básico en el siglo XXI: Brasil y Costa Rica (1a ed., Cap III, pp.73-94)*. San Jose: Universidad de Costa Rica. ISBN:9789968619882.

Schulz, C., Martin-Ortega, J., Glenk, K., & Ioris, A. R. (2017). The Value Base of Water Governance: A Multi-Disciplinary Perspective. *Ecological Economics*, 131, 241-249. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0921800915303967>. doi: 10.1016/j.ecolecon.2016.09.009

Senthilkumar, P., Nithya, J., & Babu S. S. (2014). Assessment of Groundwater Vulnerability in Krishnagiri District, Tamil Nadu, India Using DRASTIC Approach. *International Journal of Innovative Research in Science, Engineering and Technology*, 3 (3). Recovered from

<https://link.springer.com/article/10.1007/s12594-019-1326-2>. doi: 10.1007/s12594-019-1326-2

*Standard Methods for the Examination of Water and Wastewater* (2nd.ed). (2012). Washington: American Public Health Association.

Thornhill, I., Ho, J. G., Zhang, Y., Li, H., Ho, K. C., Miguel-Chinchilla, L., & Loiselle, S. A. (2017). Prioritising local action for the water quality improvement using citizen science: a study across three major metropolitan areas of China. *Science of the Total Environment*, 584, 1268-1281. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0048969717302255>. doi: 10.1016/j.scitotenv.2017.01.200

United Nations Educational, Scientific, and Cultural Organization. (1992). *Relatório Mundial das Nações Unidas sobre Desenvolvimento dos Recursos Hídricos - Água para um mundo sustentável*. Retrieved from [http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/images/WWDR2015ExecutiveSummary\\_POR\\_web.pdf](http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/images/WWDR2015ExecutiveSummary_POR_web.pdf).

Veiga, L. E., & Magrini, A. (2013). The Brazilian Water Resources Management Policy: Fifteen Years of Success and Challenges. *Water Resources Management*, 27, 2287-2302. Recovered from <https://link.springer.com/article/10.1007/s11269-013-0288>. doi: 10.1007/s11269-013-0288-1

Victorino, C. J. A. (2007). *Planeta água morrendo de sede: uma visão analítica na metodologia do uso e abuso dos recursos hídricos*. Porto Alegre: Editora PUCRS. ISBN 978-85-7430-661-2.

Villar, P. C. (2016). As águas subterrâneas e o direito à água em um contexto de crise. *Revista Ambiente & Sociedade*, 19(1), 83-102. Retrieved from [http://www.scielo.br/pdf/asoc/v19n1/pt\\_1809-4422-asoc-19-01-00085.pdf](http://www.scielo.br/pdf/asoc/v19n1/pt_1809-4422-asoc-19-01-00085.pdf).

Wolkmer, M. F. S., & Pimmel, N. F. (2013). Política Nacional de Recursos Hídricos: governança da água e cidadania ambiental. *Sequência (Florianópolis)*, 67, 165-198. Recovered from [https://www.scielo.br/scielo.php?script=sci\\_abstract&pid=S2177-70552013000200007&lng=pt&nrm=iso&tlng=pt](https://www.scielo.br/scielo.php?script=sci_abstract&pid=S2177-70552013000200007&lng=pt&nrm=iso&tlng=pt). doi: 0.5007/2177-7055.2013v34n67p165

Wu, J. (2014). Urban ecology and sustainability: the state of the science and future directions. *Landscape and Urban Planning*, 125, 209-221. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0169204614000322>. doi:10.1016/j.landurbplan.2014.01.018

Zhang, Z., Zhang, X., & Shi, M. (2018). Urban transformation optimization model: How to evaluate industrial structure under water resource constraints? *Journal of Cleaner Production*, 195, 1497-1505. Recovered from <https://www.sciencedirect.com/science/article/abs/pii/S0959652617325969>. doi: 10.1016/j.jclepro.2017.10.291

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