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Sustainability indicators for evaluation of municipal urban water management system: the case of Volta Redonda – RJ/ Brazil

Indicadores de sustentabilidade para avaliação de sistema de gestão hídrica municipal: o caso de Volta Redonda – RJ/Brasil

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ABSTRACT: The risks of scarcity have forced several countries to change their water resources management. In Brazil, the Paraíba do Sul River has a great importance as it supplies water for many cities of the Southeast region. Thus, the management of water and wastewater systems demands a more sustainable and efficient scenario. The study's objective was to evaluate, through sustainability indicators, the urban water management system in Volta Redonda (Rio de Janeiro state, Brazil). The selection of sustainability indicators was done through Delphi technique: a group of eight specialists selected the indicators used to evaluate sustainability, its dimension and level of importance. The six criteria for the classification of indicators according to the dimensions of sustainability were: (1) Environmental / Ecological, (2) Economic, (3) Social / Cultural, (4) Technological (5) Ethical and (6) Political / Institutional. Most of the indicators were considered "very important" or just "important". Regarding the dimension of sustainability, 93% of indicators contemplated more than three dimensions. However, 13 indicators contemplated all the six dimensions as they were multidimensional indicators, analyzed according to the municipal data. The chosen method for the indicator's selection was considered quite satisfactory, since they were able to generate a set of key indicators to show the current municipal water and wastewater scenario. The city has shown satisfactory conditions regarding fresh water supply index. However, some indicators pointed

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a not sustainable system due to the low wastewater treatment index, precarious state of the river's life and divergences between the basin plan and the municipal director plan.

Keywords: water resources; sustainability assessment; sustainability indicators; Delphi technique.

RESUMO: Os riscos de escassez hídrica forçaram diversos países a modificar sua gestão de recursos hídricos. No Brasil, o rio Paraíba do Sul tem uma grande importância no abastecimento de vários municípios da Região Sudeste. Dessa forma, a gestão do Sistema de abastecimento hídrico e esgotamento sanitário exige um cenário mais sustentável e eficiente. O objetivo do estudo foi avaliar, por meio de indicadores de sustentabilidade, o sistema de gestão das águas urbanas em Volta Redonda (estado do Rio de Janeiro-Brasil), usando indicadores de sustentabilidade. A seleção dos indicadores de sustentabilidade foi realizada através da Técnica Delphi: um grupo de oito especialistas selecionaram os indicadores, suas dimensões e seu nível de importância. Os seis critérios de classificação dos indicadores, de acordo com as dimensões da sustentabilidade, foram: (1) Ambiental / Ecológico; (2) Econômico; (3) Social / Cultural; (4) Tecnológico; (5) Ético; e (6) Político / Institucional. A maioria dos indicadores foram considerados "muito importante" ou "importante". Sobre as dimensões da sustentabilidade, 93% dos indicadores contemplaram mais de três dimensões. Porém, 13 indicadores contemplaram todas as seis dimensões e, por serem indicadores multidimensionais, foram analisados de acordo com os dados municipais. O método escolhido para a seleção do indicador foi considerado bastante satisfatório, uma vez que foram capazes de gerar um conjunto de indicadores-chave para mostrar o cenário atual de água e esgoto municipal. O município apresentou condições satisfatórias quanto ao índice de abastecimento hídrico. No entanto, alguns indicadores apontaram um sistema insustentável devido ao baixo índice de tratamento do esgoto sanitário, às precárias condições de saúde do rio e a algumas divergências entre o plano de bacia e o plano diretor municipal.

Palavras-chave: recursos hídricos; avaliação da Sustentabilidade; indicadores de sustentabilidade; técnica Delphi.

1. Introduction

In urban areas, freshwater bodies are exposed to several risks such as impermeability, population density, habitat fragmentation and degradation (such as rectification and channeling of water bodies) in addition to low water quality. Due to this gradual loss of quality and the scarcity of resources, the concept of sustainability has been strengthened and several development models have been proposed in order to guarantee environmental quality, highlighting the use of future generations (Lacerda & Cândido, 2013; Thornhil *et al.*, 2017).

The Paraíba do Sul River in Brazil was identified by the National Water Agency (ANA, 2015) as a vulnerable area due to the high-water demand and the large amount of organic load released in the river. The role of Paraíba do Sul River is crucial for local water supply (about 80% of the population of Rio de Janeiro state). Therefore, quality control and consistent management are important issues for Rio de Janeiro state, including the municipality of Volta Redonda, which is the focus of this study (Coelho, 2012).

The municipality of Volta Redonda is located in the Southeastern Region of the state of Rio de Janeiro, Brazil (Figure 1). The territorial area of the municipality is 182,483 km² and the population estimated for 2018 by Brazilian Institute of Geography and Statistics (IBGE, 2019) is of 271,998

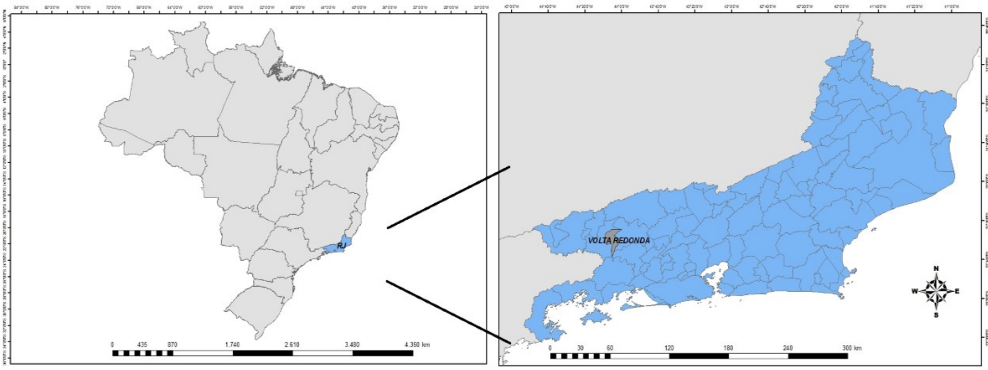

FIGURE 1 – Location of the municipality of Volta Redonda-RJ made from ARCGIS.
SOURCE: The authors.

inhabitants. The municipality is also located in the Middle Paraíba do Sul region (IBGE, 2015a). The main uses of the Middle Paraíba basin are, respectively, industrial use (63%) and human supply (25%), according to Committee for the Integration of the Paraíba do Sul River Basin (CEIVAP, 2016).

The municipal GDP (Gross Domestic Product) is currently based on services and industry, emphasizing the phases of strengthening trade and the beginning of Brazilian industrialization (IBGE, 2015a). According to local administration (PMVR, 2014), the territory has 49.5% of its area characterized by pasture areas while the urban area takes 26.4% of the city.

In the beginning of 20th century, industrialization became the main land use activity in the region. At this stage, Brazilian Steel Company (CSN, in Portuguese) was installed. CSN was the first integrated steel mill in the country, a milestone in the history of Brazilian industrialization. The quality of the Paraíba do Sul River was decisive for locating an industrial center in its basin, despite so many damages caused by organic pollution in its basin (Coelho, 2012).

This historic Volta Redonda scenario and its basin is similar to several other cities in the world. The urban occupation and the industrialization impact strongly the water resources. Thus, sustainable development was searched as a long-term policy that look for a middle term in environmental, economic and social ambitions from a holistic approach. In order to ensure quantity and quality of water resources for future generations, it is necessary to study and measure how its current use may affect their availability in the future (Bluszcz, 2016; Pellicer-Martínez & Martínez-Paz, 2016; Pupphachai & Zuidema, 2017; Rantala *et al.*, 2018).

The need to evaluate the sustainability of the system from a holistic perspective, which seeks an integral understanding of the entire process analyzed, has led to several studies with proposed multidimensional indicators. They can be applied to measure sustainability efforts within the context of products and organizational processes (Park &

Kremer, 2017).

The relationship between sustainability and water resources management becomes, from a regional perspective, an outlook of extreme importance. Thus, the establishment of indicators that may offer a diagnosis of municipal water resources management enables the identification and choice of measures to improve the system. The optimization of natural resources for human use makes the system more sustainable.

These indicators can provide a sustainability assessment in a municipality. This tool has a role to inform the political managers, and also the community, about strong and weak points, highlighting priority aspects and measuring progress towards sustainable development goals. Besides that, it is important that indicators be understandable and accessible to all those involved in the decision-making process (Braulio-Gonzalo *et al.*, 2015; Tran, 2016; Pupphachai & Zuidema, 2017; Verma & Raghubanshi, 2018).

It is a fact that there is still no theoretical or empirical consensus as to which model of hydro-environmental indicator systems should be followed, it is certain, however, that new proposals are being developed and applied in river basins (Carvalho *et al.*, 2013).

The evaluation of sustainability of public services is important, especially at local level, taking into account the central role of local governments as the main public employers and service providers. Analyzing water management from a smaller territorial perspective, such as a municipality or watersheds may facilitate the understanding of factors. The municipal context becomes management less complex from a spatial and temporal point of view (Domingues *et al.*, 2015; Carvalho *et al.*, 2015).

Summarizing, the present study has its research problem based on the following question: how sustainable is the water resources management in the municipality of Volta Redonda? The objective was to evaluate, through a qualitative selection and classification method of sustainability indicators, the urban water management system in Volta Redonda (Rio de Janeiro state, Brazil). The sustainability of the municipal water and wastewater systems was also qualitatively evaluated.

2. Methodology

A bibliographic survey was carried out on the national and international literature and147 sustainability indicators about water resources management were established.69.4% (102 SI) of the 147 indicators found are Brazilians while 26.5% (39 SI) are internationals, 4.09% (6 SI) are repeated in national and international researches. The Delphi technique was used to select the most suitable indicators to the municipal reality. Experts received a spreadsheet with all the indicators found in literature. From this list, they should select those indicators that best fit features of this municipality, identifying its “degree of importance” and “dimension of sustainability”.

The options of sustainability dimensions were presented according to literature: *Environmental/Ecological, Economic, Social/Cultural, Technological, Ethical* and *Political/Institutional*. The degrees of importance were divided into: *Very Important, Important, Less Important, Irrelevant* and *Not Sure* (UN, 2007; Nascimento, 2012; Cruz & Ferrer, 2015; Machado *et al.*, 2015; Hake *et al.*, 2016; Silvestre, 2016; Spiller, 2016; Rantala *et al.*, 2018).

2.1. Delphi technique

Formulated by Dalkey & Helmer (1963), Delphi technique is based on an interactive questionnaire applied several times to a group of experts. They participate anonymously and do not communicate with each other. Each new round, the answers from the previous round are exposed to the experts. Then, aware of the previous answers given by other experts, there is a checking. This process is repeated until disagreement is reduced to a satisfactory level in order to achieve a more consensual opinion (Rozados, 2015; Meijering *et al.*, 2018)[1].

However, each one of the main features has advantages and disadvantages. Anonymity, for example, encourages greater spontaneity of responses by preventing one expert from influencing the other's opinion, but it may fail the discussion since, alone, a person who answers may not remember all the aspects he would like to address when selecting one indicator. The advantage of consulting experts is that you may form reliable concepts and opinions on sustainability indicators, however, to reach consensus too quickly is a weak point that deserves to be highlighted. Interactivity and feedback are positive points, since they allow to share the responses of the whole group without hierarchy and to exclude aspects out of context, but also it contradicts the benefit of obtaining more elaborate responses. Finally, the consensus provides a synergy of opinions among the specialists, also allowing the resolution of divergences. However, there is a risk of creating an artificial consensus since there is no standard for that (Oliveira *et al.*, 2008)[2].

Thus, like all methodologies, the Delphi technique also has its limitations. However, it is a legitimate method, validated in the literature in several scientific researches such as in Mapar *et al.* (2017) that used Delphi technique to select indicators concerning health, safety and environment in the megacities of Iran. In their work, two rounds of answers were done in order to choose the best indicators. In addition, Musa *et al.* (2015) also used this technique to develop environmental well-being indicators in order to evaluate the urban sustainability in Malaysia.

The Delphi method is a rich method that allows the exploration of opinions, the promotion of consensus and the identification of topics of disagreement. This technique is widely used by different knowledge areas but still little used in Brazil (Marques & Freitas, 2018).

Thus, the technique is widely known and applied, being useful in the selection and validation of indicators as corroborated by Haq & Boz (2018) who emphasized that participating expert framework is essential for an efficient performance in the validation and selection of qualitative and quantitative indicators.

In this work, the Delphi technique was chosen because it allows a dialogical approach through anonymity among specialists, eliminating the va-

[1] The Delphi technique has fundamental characteristics such as: i - the anonymity of the specialists; ii - consultation with specialists; iii - the application of interactive rounds with feedback and iv - the search for consensus (Oliveira *et al.*, 2008; Rozados, 2015).

[2] There are other ways (forms) of Sustainability assessment such as focus group, multi-criteria analysis technique, analytical hierarchy process (AHP), planning-oriented sustainability assessment framework (POSAF) and framework of drivers, pressures, states, impacts, and responses (DPSIR) (Nanninga *et al.*, 2012; Starkl *et al.*, 2013).

riables of influence, conflicts and slants. The use of different specialists can gradually form a varied and multidimensional set of indicators as well, through independent opinions. Besides that, the results obtained through Delphi Technique allow greater clarity and objectivity, offering a shared space for discussion between different actors of the same system, and yet, it presents greater flexibility for each person who answers the questions (Rozados, 2015).

In addition, this method seeks a selection of non-biased indicators based on the opinion of a group related to the theme of sustainability indicators or to the reality of the Volta Redonda water and wastewater systems as well. The criterion used for experts' selection was fundamental to ensure the evaluation system construction with indicators that serve the Volta Redonda peculiarities. It is important that evaluate system consider the local features.

Therefore, the selection of specialists was based on their areas of knowledge and experience in order to enable a list of indicators structured in the municipal water reality. Consequently, the indicators were selected according to their adequacy and importance to the city. Eight experts were selected due to their performance in the area of water resources management, indicators of sustainability and basic sanitation. Seven experts are familiar with the reality of Volta Redonda city and/or the Middle Paraíba Basin and one expert developed research on sustainability indicators for water resources management (Table 1)[3].

The spreadsheet sent to the specialists was composed of 4 columns, the first brought the list of 147 indicators surveyed in the literature, the second column was intended for marking if the respective indicator was selected by the specialist, the third column corresponded to the dimensionality of the chosen indicator, and the fourth column to show the degree of importance of the selected indicator. In addition to this information, the specialists also received instructions and data about the hydrographic basin of the Middle Paraíba do Sul and the municipality of Volta Redonda, the dimensions of sustainability placed as alternatives were also explained.

The specialists also received instructions for filling out the spreadsheet with explanations about the six dimensions presented. The environmental, economic and social dimensions remain in all consulted literature (Miranda & Teixeira, 2004; UN, 2007; Nascimento, 2012; Visvaldis *et al.*, 2013; Cruz & Ferrer, 2015; IBGE, 2015b; Machado *et al.*, 2015; Hake *et al.*, 2016; Silvestre, 2016; Spiller, 2016; Rantala *et al.*, 2018), however, some authors combine them with each other or with other dimensions as in Miranda & Teixeira (2004) with the socioeconomic and political-cultural dimensions or in Spiller (2016) with the socio-cultural dimension. It is also important to highlight the technological and institutional dimensions. The ethical dimension was only proposed by Machado *et al.*, (2015). From the intersections of these dimensions / criteria, from the literature, there are six dimensions:

1 - Environmental / Ecological: It is the most popular and known dimension, from this dimension

[3] According to Wright & Giovinazzo (2000), this number of specialists may vary a lot from a minimum of three to more than one hundred participants.

TABLE 1 – Expert panel, their respective roles and the justification for participating in the Delphi Technique.

Expert/Role	Justification
Architect and City Planner/ Teacher in Higher Education.	Defended in the Ph.D. thesis about the Paraíba do Sul River and the Resende, Barra Mansa, Volta Redonda, and Barra do Piraí regions, acting in the area of Environmental and Urbanistic Preservation.
Biologist / Teacher in Higher Education.	Has experience in Watershed Management working mainly in Water Resources Management teaching discipline in this same area.
Oceanographer / Teacher in Higher Education	He has a master's degree in Civil Engineering and Water Resources, works on the theme of water quality assessment of the Paraíba do Sul River and has experience in the area of aquatic ecosystems.
Environmental Engineer / Teacher in Technical Education.	Has a master's degree in Agricultural Engineering in the area of Planning and Management of Water Resources, with experience in this area and also in water quality, coordinated the Technical Chamber of CBH-Middle Paraíba for two years. Ph.D. Student in Environment.
Graduated in Accounting / Teacher in Higher Education.	Leader of the Observatory of Management, Accounting and Sustainability (UFCG). Currently, works in research lines such as Accounting for Social and Environmental Management as well as Public Management (with emphasis on sustainability indicators).
Chemical Engineer / Teacher in Higher Education.	Operates in the areas of water pollution, sewage treatment, and basic sanitation.
Municipal autarchy manager for water and sewage services.	Civil Engineer. Has experience in municipal water and sewage services.
Municipal autarchy manager for water and sewage services.	Civil Engineer. Has experience in municipal water and sewage services

SOURCE: Prepared by the authors.

it is admitted that the advances in information allow to outline actions to minimize the impacts and pressures on the environment (Cruz & Ferrer, 2015).

2 - Economic: This dimension has the role of solving the main challenge of sustainability: reconcile the increase of income generation in an environmentally correct way and its fair distribution (Cruz & Ferrer, 2015).

3 - Social / Cultural: This is a dimension about a harmonious and integrated society, encompasses the protection of cultural diversity and the total guarantee of human rights, in addition to universal access to sanitation services (Cruz & Ferrer, 2015).

4 - Technological: This dimension is justified because technological innovations have been strongly recommended as a way of solving environmental problems presented in the context of sustainability challenges (Rantala *et al.*, 2018).

5 - Ethics: This dimension is based on the ethical foundation of sustainable development: intra and intergenerational justice (Hake *et al.*, 2016).

6 - Political / Institutional: This dimension is related to the competence and commitment invested by the government and society in order to seek changes and effective sustainable development (IBGE, 2015b).

Regarding the consensus, the variation of criteria found in the literature is large, but, whatever criterion used, it must be established before the beginning of the study (Silva & Tanaka, 1999). So, as there is no standard to establish the so-called consensus, in this word the mediator took into account those indicators selected by 60% or more of the experts. Thus, this percentage represented the majority of the people who answered based on the principle that the opinion of this majority should be prioritized. Two rounds were held in which experts had access to previous responses (feedback), including the percentages of choice for each indicator and also space was given for free comments. After two rounds, the indicators with percentages above 60% were selected to build a list of 40 indicators to be applied in Volta Redonda city.

Thus, the list with 40 indicators went through another filtering step. This time only indicators contemplating all dimensions of sustainability, according to Delphi technique, were used for the analysis of municipal water sustainability.

According to Bluszcz (2016), sustainable development is complex and multidimensional, so different methods of measuring are required for data to be able to cover all dimensions, offering a comprehensive measurement. Therefore, in order to find an evaluation that contemplates several dimensions, 13 indicators considered multidimensional were chosen for analysis within the municipal context.

According to Dale *et al.* (2018), it is important that the set of indicators should be specific to each municipality analyzed. For this reason, the set of indicators reported in this study is totally specific of this place. This study proposes a method for a convenient selection of indicators specifically for Volta Redonda city, taking into account experts who know municipal reality. The set of indicators may be customized and is not a standard list to be applied to other realities.

3. Results and discussion

3.1. Characterization of selected indicators

According to 60% or more experts, 15 (37%) indicators were classified as very important while 23 (58%) were classified as important and two indicators (5%) were considered as less important (Figure 2).

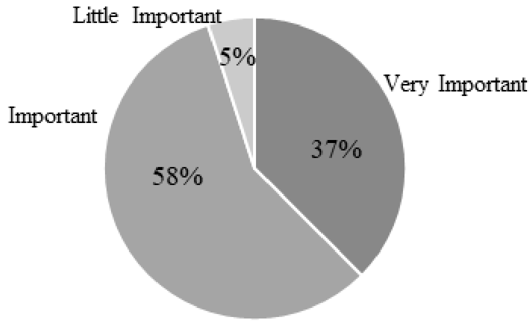

FIGURE 2 –Percentages of indicators assigned to each degree of importance by Delphi Technique.

SOURCE: Prepared by the authors.

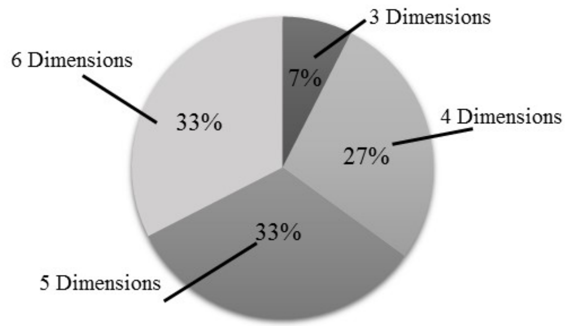

FIGURE 3 – Dimensionalities of the 40 indicators selected by the panel of experts through the Delphi technique.

SOURCE: Prepared by the authors.

Regarding the dimensionality of the indicators, 33% (13 SI) of the indicators included five dimensions, 33% (13 SI) of the indicators included six dimensions 27% (11 SI) included four dimensions while 7% (3 SI) included three dimensions (Figure 3).

In this sense, 93% were considered multidimensional because they encompassed, according to experts, more than three of the dimensions presented. Although there is a growing interest in measurement of sustainability, a majority of studies have not developed holistic indicators, that is, indicators considering all dimensions interacting with each other. Most of the researchers evaluated individual economic, environmental and social aspects. The performance of corporate sustainability is a multidimensional concept based on the original idea of sustainable development (Docekalová & Kocmanová, 2016; Molinos-Senante *et al.*, 2016).

A percentage of 93% of the indicators fulfilled great part of the dimensions, differently than Pires *et al.* (2017) who, in their research, found that 86% of indicators did not meet many of the sustainability criteria. The authors reported that indicators did not provide a holistic and multidimensional perspective. In the work of Miranda & Teixeira (2004), the analysis of indicators as a way of monitoring public policies, therefore, resulted in a very satisfactory set of indicators, being able to cover the various dimensions, showing its tendency to sustainability. Despite the difficulty in considering environmental, economic and social variables in studies of this nature, these results are satisfactory, since treating incommensurability, or even grouping information of a different nature from the indicators (Carvalho *et al.*, 2013).

When accessing how sustainable a system is, indicators should involve as many dimensions as possible. Due to the multidimensionality of sustainability, a complete and integrated evaluation is required. The fact that not all indicators have taken into account all the six dimensions should not be seen as a limitation, but as a feature to be taken into account by the managers responsible for the decision-making process (Carvalho *et al.*, 2013; Pires *et al.*, 2017).

The main dimensions (Environmental, Social and Economic) covered the largest number of indicators. They are considered the most traditional dimensions of sustainable development and should include the largest number of indicators as much as possible (UN, 2007; Cruz & Ferrer, 2015).

3.2. Analysis of multidimensional sustainability indicators in Volta Redonda city

From the Delphi Technique, 13 indicators characterized as multidimensional were selected for the analysis of sustainability in the municipal water and wastewater systems. Table 2 shows the multidimensional sustainability indicators according to the corresponding parameter. For the analysis of each indicator, the municipal data were found in the literature or / and documents such as: Middle Paraíba Basin Committee, State Environmental Institute (INEA). Some data were requested from the Autonomous Water and Sewage Service of Volta Redonda (SAAE-VR) or the Municipal Health Department of Volta Redonda.

TABLE 2 – Multidimensional indicators and their respective municipal data.

Parameter	Multidimensional sustainability indicators	Reference	Municipal data (year)
System Performance in Wastewater Collection and Treatment	Collected waste water treatment index	ANZECC (2000); ONU (2007); Carvalho *et al.* (2013); Carvalho & Curi (2013); IBGE (2017); Mapar *et al.* (2017);	18.67% (2017)
	Wastewater treatment index in relation to the volume of water consumed	ANZECC (2000); ONU (2007); Carvalho *et al.* (2013); Carvalho & Curi (2013); IBGE (2017); Mapar *et al.* (2017);	16.89% (2017) 30-35% (2018)
	Number of points of release of "*in natura*" sewage in water bodies	Miranda & Teixeira (2004)	no available data
	% sanitation network by river or lake	Carvalho & Curi (2013)	75% (2018)
	% without a sanitary installation	Carvalho & Curi (2013)	3% (2018)
Performance of the System regarding Human Supply	Amount of chemicals used for the treatment per 1000m³ of treated water	Miranda & Teixeira (2004)	Aluminum sulfate: 52kg (2018)
			Polymer: 0.04kg (2018) Geocalcium: 4.2kg (2018)
			Chlorine: 2.93kg (2018)
			Fluorine: 3.2lts (2018)
	Number of cases of waterborne diseases / 1000 inhabitants	Miranda & Teixeira (2004); Carvalho *et al.* (2013); Ibrahim *et al.* (2015)	0.036765 (2017/2018)
System Performance in Qualitative and Quantitative Water Status	Nonconformities with the framing of water bodies	Miranda & Teixeira (2004)	Most parameters accordingly (2019)
	River flow for catchment	Miranda & Teixeira (2004); Vieira & Studart (2009)	37.922.565,6 m³/year (grantedflow) (2017)
	Minimum flows with a given duration and given recurrence period	Carvalho *et al.* (2013)	no available data
	Extraction of surface water versus availability	ANZECC (2000)	2250 L/s versus good availability (2018/2016)
	River health	ANZECC (2000)	Precarious / bad (2010/2012)
Management of the Basin	Does the basin have a basin plan?	Carvalho *et al.* (2013)	Yes (2018)

SOURCE: Prepared by the authors.

3.2.1. System performance in sewage collection and treatment

The indicator sewage treated in relation to water consumed shows the percentage of sewage treated. According to Treats Brazil Institute (ITB, 2017), it is better when this percentage is higher, because it means that most of sewage has been treated. Although treated sewage rate in relation to consumed water increased from 16.89%, in 2017, to 30-35%, in 2018, it is still considered low. According to the Middle Paraíba Basin Committee (CBHMPS, 2018), municipal reality differs from that established by law. The percentage of the network by river or lake represents about 75% of the sewage discharged directly into the river.

The main use of the basin water is done in dilution of sewage. This is one of the main sources of pollution of Paraíba do Sul River. This river presents a worrying state of degradation, especially in the range that crosses or touches urban areas (ANA, 2017a). In the Middle Paraíba do Sul Basin, for example, the municipality of Resende has the highest percentage of sewage treatment (72%), following by the municipality of Porto Real (67.9%), the next municipality is Volta Redonda with 18.67% of sewage treatment.

This critical scenario in many municipalities of Middle Paraíba do Sul Basin occurs mainly due to the lack of financials and technical resources. Regional hydrological studies are necessary, as well as technical management and public administrator capacitation, for example. The civil society is an important actor and must participate in discussions in order to develop empowerment about their interests in the basin. Nevertheless, the financial crisis with the lack of planning, monitoring and technical data make it more and more difficult to obtain financials resources by cities' managers (Oliveira *et al.*, 2018).

The problem of low index of wastewater treatment in Volta Redonda goes beyond the impacts caused by the discharge *"in natura"* of effluents into the water body. Furthermore, there is a recent issue which affects the global sanitation system: the dump of emerging contaminants.

The emerging contaminants are potentially toxic substances, the effects of which are still unknown and they aren't included in legislation. They are substances like dangerous chemicals products, toxic metals and biological residual capable of contaminating effluents, medicines and food. These emerging contaminants, such as hormones and medicinal drugs bring a new challenge and a new concern regarding the search for new technologies to solve this problem (Teodosiu *et al.*, 2018; Dharupaneedi *et al.*, 2019).

3.2.2. Performance of the system regarding human supply

3.2.2.1. Amount of chemicals used in treatment / 1000m³ of treated water

Aluminum sulfate ($Al_2(SO_4)_3$) is a coagulant added to water after its capture. Several studies have pointed a relation between aluminum and cases of neurodegenerative diseases. Aluminum causes a chronic neurotoxicity on human nervous system. Diseases such as Alzheimer's, Parkinson's, encephalopathies and neurological disorders may be related to human exposure to aluminum through contaminated water (Polizzi *et al.*, 2002, Banks *et al.*, 2006; Walton, 2013; Lee *et al.*, 2014; Lima-Júnior & Abreu, 2018).

There is also a concern with environmental impacts generated by intense use of these coagulants because their residues are rich in non-biodegradable metal hydroxides. The sludge generated in the treatment plants presents ecotoxicological risks due to the high concentrations of organic and inorganic substances. So, sludge must be properly disposed (Lima-Júnior & Abreu, 2018).

Therefore, there is a concern about the impact of aluminum sulphate on human health and aquatic ecosystems. So, more scientific researches are required, motivated by a search for economically viable bio coagulants. The use of substances derived from non-renewable materials may be reduced. Sustainable substances may increase the interest of sanitation services. They contribute to the reduction of the environmental impact caused by water treatment process and promote sustainability within the sanitation system.

The polymer used to help the coagulation process by the Water Treatment Station is the FLOPAM EM 230 PWG, although FLOPAM EM 230 PWG is toxic in certain concentrations, the amount used in Volta Redonda is minimal. Furthermore, the potential impacts of this coagulant on the environment were not found in the literature (SNF, 2018).

Calcium hydroxide is used to correct pH of water. The calcium hydroxide ecotoxicity was considered acute in some Chemical Safety Data Sheets, but the potential impacts of the calcium hydroxide use on the environment were not found in the literature (Anidrol, 2014; Labsynth, 2017; SAAE-VR, 2018).

Chlorine is used for disinfection due to its ability to destroy or inactivate pathogenic organisms such as viruses and bacteria, at room temperature, in a short period of time. However, the problem of the chlorine use is its reaction to natural organic matter present in the water. By-products are generated, specially trihalomethanes (THMs), which may increase risk of cancer and have adverse effects on the reproductive system. THMs are just some of the existing by-products of chlorination. Their control in public water supply may help reduce levels of other by-products such as haloacetic acids (Oliver & Ribeiro, 2014).

Chlorine is also used for the water treatment in Volta Redonda city. This is also the problem of other Brazilian supply systems, which did not replace chlorine by another substance. The chlorine use for water disinfection is more viable economically. However, strategies to reduce the generation of THMs and other by-products are required.

The water fluoridation for consumption is one of the actions with greatest impact on the prevention of dental caries and has become mandatory since 1974 (Brazil, 1974). Fluorine is toxic at certain concentrations and may cause chronic intoxication, dental fluorosis or, in more extreme cases, bone diseases such as osteosclerosis. Thus, in case of fluorine added to public water supply, the recommended levels are very low, which does not expose the population to any of its toxic effects (Garbin *et al.*, 2017; Zilbovicius *et al.*, 2017).

According to Autonomous Water and Sewage Service of Volta Redonda (SAAE-VR, 2019), the average concentration of Chlorine and Fluorine added to treated water, in 2018, were, respectively, 1.94 mg/L and 0.63 mg/L. These concentrations are below the maximum values permitted by Brazilian legislation: 2.0 and 1.5 mg/L for chorine and fluorine respectively (Brazil, 2017).

3.2.2.2. Cases of waterborne diseases / 1,000 inhabitants

The data provided by the Municipal Health Department of Volta Redonda (SMS-VR) are from the years 2017 and 2018 (Table 3). They refer to cases of the following waterborne diseases: Amebiasis; Giardiasis; Gastroenteritis; Typhoid and paratyphoid fever; Infectious hepatitis (A and E); Cholera and diseases caused by worms (Schistosomiasis, Ascariasis, Taeniasis, Rotavirus, Acute diarrheal diseases).

A total of 10 cases of waterborne diseases were reported between 271,998 inhabitants, in 2018. So, there was 0.0000367649 cases/inhabitants, or 0.0367649 cases/1000 inhabitants.

The cases of waterborne diseases in Volta Redonda have been low in the last two years, this low number of cases may be explained by the high total drinking water supply (99%). The water quality monitoring provided by SAAE-VR, in 2018, showed that all samples were in accordance with the potability standards (SAAE-VR, 2019). Thus, Volta Redonda does not present major problems with waterborne diseases which could be associated with ingestion of contaminated water by pathogenic organisms.

TABLE 3 – Cases of waterborne diseases in the years 2017 and 2018.

Diseases	Number of cases	
	2017	**2018**
Hepatitis A	0	1
Schistosomiasis	4	5
Typhoidfever	0	0
Cholera	0	0
Rotavirus	0	0

SOURCE: SMS-VR, 2018.

3.2.3. System performance in qualitative and quantitative water status

3.2.3.1. Nonconformities with the framing of water bodies

According to National Water Resources Policy (Brasil, 1997), the classification of water bodies has as objective to ensure water quality compatible with its main uses. The compatible water quality reduces costs with pollution control actions by taking preventive actions. Ordinance of the Interior Ministry (1981) classify Paraíba do Sul River, in the range from Santa Branca until Campos, as type 2. This kind of river is characterized as water for human consumption after conventional treatment, protection of aquatic communities, recreation, irrigation, aquaculture and fishing (CONAMA, 2005).

According to the SAAE of Volta Redonda (2019), raw water samples are in compliance with the parameters established by Resolution Nº 357/2005 of CONAMA for freshwater type 2. The Water Quality Report 2018 (SAAE-VR, 2019) evaluated that most of analyzed parameters were in accordance with the resolution. Thus, the water can be distributed to the population after an appropriate treatment.

Therefore, nonconformities about raw water in relation to the water body framing standards were not observed. However, criticisms about the current Brazilian framework model should be considered.

The water framework directive methodology is used by the European Union, as an alternative to water resources management with emphasis on aquatic ecosystems. This methodology encompasses geological, hydrological, chemical and biological features, establishing an ecological standard in order to evaluate the state of a water body (Silva *et al.*, 2015).

3.2.3.2. River health

From 2002 to 2012, the INEA carried out a study about the environmental evaluation in the range Funil / Santa Cecília of Paraíba do Sul River. Endangered species and / or rare species were found in Paraíba do Sul River and some species suffered drastic reduction in a certain part of the water body. In addition, concerning bioaccumulation of mercury and methylmercury, in extreme climatic events such as during a drought occurred in 2014, the concentration of these contaminants increased in most of fish species (Azevedo *et al.*, 2018).

The intense local population and its industrial development, together with the construction of dams and the dredging of the riverbed, affected the ichthyological fauna of Paraíba do Sul River. This human interference in environment degrades the ichthyological fauna refuge, reproduction and food areas. However, in relation to the water quality, the Paraíba do Sul River has been in good condition, mainly due to its self-purification ability (Coelho, 2012).

Even with a high pollution load that Paraíba do Sul River receives from the neighbor state of São Paulo, the pollutant load does not reach the river mouth so intensively. This is due to the ability of biological, chemical and physical self-purification, besides the process of dilution by the water supply of its effluents. Although this is a positive result, there is still a need to minimize the impacts caused by pollution and to improve the sewage treatment index of the basin (Nunes *et al.*, 2014).

Nevertheless, the sanitary conditions of the Paraíba do Sul River are considered precarious and/or bad due to the fact that status of its environmental quality is poor. However, the water quality is classified as "acceptable" due to its self-purification (INEA, 2012).

3.2.3.3. Surface water extraction versus availability and river flow for catchment

The efficient water resources management should include, among other information, availability of water sources for different uses and a balance between its demand versus its availability. The hydrographic Region III, Middle Paraíba do Sul, presented high values of current consumption versus availability (INEA, 2014).

Volta Redonda city presented one of the largest levels of water consumption taken from the basin in 2010. The urban consumption flow was 0.18 m^3/s. However, the projection for future years (2030) practically remained with a flow rate of 0.19 m^3/s in both projected scenarios (CEIVAP, 2013).

In addition, Volta Redonda city presents a significant water demand regarding the general consumption and the municipality of Resende as well, in the Middle Paraíba. The CSN industry, in Volta Redonda, is the main water consumer of Paraíba do Sul in the Middle Paraíba, with almost 63%. The water supply represents 25% of the basin consumption (CEIVAP, 2016).

The coverage area of the Middle Paraíba do Sul also suffers a demand for transposition to the Guandu River, responsible for the water supply of the metropolitan region of Rio de Janeiro. The water availability of the Middle Paraíba do Sul was qualitatively evaluated, having been considered good for the future, but insufficient to meet the Guandu River transposition demands (CEIVAP, 2016).

The Middle Paraíba do Sul basin requires greater attention due to its probable transposition to Guandu River, even though Volta Redonda city presents a sufficient flow rate until 2030 (INEA, 2014). Nevertheless, there is no alternative of water supply for Volta Redonda city, in case its water is driven into Guandu River. So, the environmental education is necessary for a more rational use of water.

Regarding the river flow for abstraction, the data is the abstraction flow granted to Volta Redonda in 2017, which was 37,922,565.6 m³ / year (ANA, 2017b). The bestowal is made based on the assessment of water availability with the analysis of the minimum reference flows. From these flows, the maximum percentage to be allocated for the different uses of the basin is determined. Thus, the calculation performed to determine the flow granted provides the water security, so that, even at minimum flows, users or priority uses maintain their water withdrawals (ANA, 2011).

Even though water availability of the Middle Paraíba basin is considered good, this fact is taken for granted only in periods of water abundance or even during the rainy season. In periods of water shortage, it is important to drive water use to the priority uses determined by law. In the case of Autonomous Water and Sewage Service (SAAE-VR), the use for public supply is a priority in situations of scarcity (Ambrosio *et al.*, 2017).

3.2.4. Management

3.2.4.1. Does the basin have a basin plan?

The Hydrographic Basin Plans (PBHs) are important because they act as a reference tool for water resources management. They outline and guide the actions that must be considered in order to maintain water availability and quality, besides establishing actions that aim the water protection and conservation (ANA, 2013).

In addition, the Hydrographic Basin Plans can be used as a guide to the Municipal Management Plans. They point out guidelines for land use and occupation, integrating sanitation, urban growth and other sectors. Thus, the Hydrographic Basin Plans act as a strategic tool for articulation between water resources management and urban management (Peres & Silva, 2013).

However, the Basin Plan of the Hydrographic Region of the Middle Paraíba has not yet been elaborated. The Water Resources Plan of CEIVAP (Committee for the Integration of the Paraíba do Sul River Basin) is the guiding document for the application of financial resources from the collection for the use of water (CBHMPS, 2019). The Middle Paraíba do Sul stock book is part of the CEIVAP Basin Plan, made in 2006.This document presents the features of the municipalities, such as land use and occupation data, situation of basic sanitation systems, water uses and demands, classification of water in types of use and others.

The Master Plan of Volta Redonda city (PM-

VR, 2008) contemplates some guidelines that are connected with the acting strategies of the Basin Plan (2006). Although the Master Plan did not address the participative and integrated management of water resources and did not define the concept of water basin, the river basin should be adopted as an ideal unit for implementation of the National Water Resources Policy. Both plans require a revision as they are more than ten years old. In addition, they should guide more specific and integrated strategies in the municipal context and also in the basin river. The water-related approaches in the Master Plan, for example, only indicates general guidelines for the protection of water sources. In spite of the fact that they involve marginal areas and water pollution control, they do not contain guidelines neither practical tools of intervention nor control of land use (Peres & Silva, 2013).

4. Final considerations

Some important critical points characterized an unsustainable water supply and sewage system in Volta Redonda. Initially, the low rates of wastewater treatment contributed strongly to the deterioration of the water body. A new wastewater treatment plant should be implemented in order to increase the capacity of the existing stations. The committee deliberates about strategic action plans in which the financial resources from the water use will be allocated. Thus, investments done by the committee itself are important.

The river health also deserves greater attention. Although Paraíba do Sul River has a good self-purification capacity, impacts suffered by the aquatic fauna are significant. Thus, a more integrated management of the river basin is recommended, with a greater effective action to be taken by the committee. Control measures should be taken, such as an inspection in the institutions of state and their responsibility of water users.

The studied system cannot be considered sustainable yet due to the aspects mentioned above, but positive aspects, such as the low occurrence of waterborne diseases despite the high rate of total water supply service were observed.

Thus, actions to make the municipal water resources management more sustainable are required. These actions need to attend all sustainability dimensions, including environmental preservation, social justice and economic viability.

This work faced difficulties to classify the data, since the literature does not establish sustainability standards due to the specificities of each system. Everything depends on the specific features of each municipality / company or basin to be evaluated. It is important to consider that the list of indicators is not closed and may be modified in the future. The development of indicators is a continuous process.

Thus, regarding future works, the importance to evaluate the indicators not selected by the experts, including those related to industry, is highlighted. In this research only the indicators considered multidimensional, according to the panel of experts, were analyzed. In addition, an approach about the ethical principles applied to the management of water resources, questioning their application in the context of this basin, is recommended.

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References

Ambrosio, L. L.; Placido, D. T.; Formiga-Johnsson, R. M. Outorga de direito de uso da água no rio Paraíba Do Sul. *In: Anais do Simpósio Brasileiro de Recursos Hídricos*. Florianópolis, 26 nov., 2017.

ANA – Agência Nacional de Águas. *Cadernos de capacitação em recursos hídricos- Outorga de direito de uso de recursos hídricos*, 2011. Available at: <https://arquivos.ana.gov.br/institucional/sge/CEDOC/Catalogo/2012/OutorgaDeDireitoDeUsoDeRecursosHidricos.pdf>. Access in: dec. 2018.

ANA – Agência Nacional de Águas. *Acervo Educacional sobre Água - Lei das Águas: Instrumentos da Política Nacional de Recursos Hídricos*, 2013. Available at: < https://capacitacao.ana.gov.br/conhecerh/handle/ana/3198?mode=full>. Access in: dec. 2018.

ANA – Agência Nacional de Águas. *Sala de situação - Paraíba do Sul*, 2017a. Available at: <https://www.ana.gov.br/sala-de-situacao/paraiba-do-sul/saiba-mais>. Access in: mar. 2018.

ANA – Agência Nacional de Águas. *Cadastro de usuários federais na Bacia do Rio Paraíba do Sul*, 2017b. Available at: <http://www.ceivap.org.br/cadastro-usuario-outorga.php>. Access in: dec. 2018.

Anidrol. *FISPQ - Ficha de informações de segurança de produtos químicos* - Hidróxido de Cálcio, 2014. Available at: <http://www.anidrol.com.br/Produto/id/793>. Access in: jun. 2019.

ANZECC – Australian and New Zealand Environment and Conservation Council. *Core environmental indicators for reporting on the state of the environment*, 2000. Available at: <https://www.environment.gov.au/system/files/pages/a94a73f8-79db-4347-8a7a-f03ecdc48074/files/core-indicators.pdf>. Access in: jun. 2019.

Azevedo, L. S.; Pestana, I.; Rocha, A. R. M.; Meneguelli-Souza, A. C. Drought promotes increases in total mercury and methylmercury concentrations in fish from the lower Paraiba do Sul River, southeastern Brazil. *Chemosphere*, 202, 483-490, 2018. doi:10.1016/j.chemosphere.2018.03.059

Banks, W. A.; Niehoff, M. L.; Drago, D.; Zatta, P. Aluminum complexing enhances amyloid β protein penetration of blood–brain barrier. *Brain Research*, 1116, 215-221, 2006. doi: 10.1016/j.brainres.2006.07.112

Bluszcz, A. A comparative analysis of selected synthetic indicators of sustainability. *Procedia - Social and Behavioral*, 220, 40-50, 2016. doi: 10.1016/j.sbspro.2016.05.467

Brasil. *Lei n.º 6.050, de 24 de maio de 1974*. Dispõe sobre a fluoretação da água em sistemas de abastecimento quando existir estação de tratamento. Brasília: DOU de 27/05/1974.

Brasil. *Lei n.º 9.433, 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. Brasília: DOU de 9/01/1997.

Brasil. Ministério da Saúde. *Portaria de Consolidação n.º* 5, de 28 de setembro de 2017. Consolidação das normas sobre as ações e os serviços de saúde do Sistema Único de Saúde. Brasília: DOU de 03/10/2017.

Brasil. Ministério do Interior. *Portaria n.º 86, de 4 de junho de 1981*. Enquadra os cursos d'água da Bacia Hidrográfica do Rio Paraíba do Sul. Brasília: DOU de 05/06/1981.

Braulio-Gonzalo, M.; Bovea, M. D.; Ruá, M. J. Sustainability on the urban scale: proposal of a structure of indicators for the Spanish context. *Environmental Impact Assessment Review*, 53, 16-30, 2015. doi: 10.1016/j.eiar.2015.03.002

Carvalho, J. R. M.; Cândido, G. A.; Lira, W. S. Análise da sustentabilidade hidroambiental de municípios da região da sub-bacia do alto Piranhas, PB. *Holos*, 6, 13-31, 2015. doi: 10.15628/holos.2015.2093

Carvalho, J. R. M.; Curi, W. F. Construção de um índice de sustentabilidade hidroambiental através da análise multicritério: estudo em municípios paraibanos. *Sociedade e Natureza*, 25, 91-106, 2013. doi: 10.1590/S1982-45132013000100008

Carvalho, J. R. M.; Curi, W. F.; Lira, W. S. Processo participativo na construção de indicadores hidroambientais para bacias hidrográficas. *In*: Lira, W. S.; Cândido, G. A. (Orgs.). *Gestão sustentável dos recursos naturais*: *uma abordagem participativa*. Campina Grande: EDUEPB, p. 30-80, 2013.

CBHMPS – Comitê da Bacia Hidrográfica do Médio Paraíba do Sul. *Atlas região hidrográfica Rio Paraíba do Sul*, 2016. Available at: <http://www.cbhmedioparaiba.org.br/conteudo/atlas-CBH-MPS.pdf>. Access in: jan. 2018.

CBHMPS – Comitê da Bacia Hidrográfica do Médio Paraíba do Sul. *Resolução CBH-MPS n.º 75/2017 de 28 de fevereiro de 2018*. Aprova o Relatório da Oficina do Raio-X do Esgotamento Sanitário do Comitê Médio Paraíba do Sul, 2018.

CBHMPS – Comitê da Bacia Hidrográfica do Médio Paraíba Do Sul. *Plano de Bacia*, 2019. Available at: <http://www.cbhmedioparaiba.org.br/plano-de-bacia.php>. Access in: jan. 2019.

CEIVAP – Comitê de Integração da Bacia do rio Paraíba do Sul. *Plano de bacia*, 2006. Available at: <http://www.ceivap.org.br/planobacia.php>. Access in: jun. 2019.

CEIVAP – Comitê de Integração da Bacia do rio Paraíba do Sul. *Avaliação dos impactos das novas transposições de vazão no rio Paraíba do Sul. R4- Demandas de uso de água consuntivos e não-consuntivos*, 2013. Available at: <http://ceivap.org.br/conteudo/r4-demandas-de-uso-versao-final.pdf>. Access in: jun. 2019.

CEIVAP – Comitê de Integração da Bacia do rio Paraíba do Sul. *Plano integrado de recursos hídricos – PIRH da Bacia Hidrográfica do Rio Paraíba do Sul e planos de ação de recursos hídricos – PARH das Bacias Afluentes*, 2016. Available at: <http://ceivap.org.br/conteudo/REL-Produto-C-versao-final-dez16.pdf>. Access in: jun. 2019.

Coelho, V. *Paraíba do Sul* - um rio estratégico. Rio de Janeiro: Casa da Palavra, 2012.

CONAMA – Conselho Nacional do Meio Ambiente. *Resolução n.º* 357, de 17 de março de 2005. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências. Brasília: DOU de 18/03/2005.

Cruz, M. P.; Ferrer, G. R. Direito, sustentabilidade e a premissa tecnológica como ampliação de seus fundamentos. *Sequência*, 71, 239-278, 2015. doi: 10.5007/2177-7055.2015v36n71p239

Dale, V. H.; Kline, K. L.; Richard, T. L.; Karlen, D. L.; Belden, W. W. Bridging biofuel sustainability indicators and ecosystem services through stakeholder engagement. *Biomass and Bioenergy*, 114, 143-156, 2018. doi: 10.1016/j.biombioe.2017.09.016

Dalkey, N.; Helmer, O. An experimental application of the Delphi method to the use of experts. *Management Science*, 9(3), 458-467, 1963. doi: 10.1287/mnsc.9.3.458

Dharupaneedi, P. S.; Nataraj, S. K.; Nadagouda, M.; Reddy, K. R.; Shukla, S. S.; Aminabhavi, T. M. Membrane-based separation of potential emerging pollutants. *Separation and Purification Technology*, 201, 850-866, 2019. doi: 10.1016/j.seppur.2018.09.003

Docekalová, M. P.; Kocmanová, A. Composite indicator for measuring corporate sustainability. *Ecological Indicators*, 61, 612-623, 2016. doi: 10.1016/j.ecolind.2015.10.012

Domingues, A. R.; Pires, S. M.; Caeiro, S.; Ramos, T. B. Defining criteria and indicators for a sustainability label of local public services. *Ecological Indicators*, 57, 452-564, 2015. doi: 10.1016/j.ecolind.2015.05.016

Garbin, C. A. S.; Santos, L. F. P.; Garbin, A. J. I.; Moimaz, S. A. S.; Saliba, O. Fluoretação da água de abastecimento público: abordagem bioética, legal e política. *Revista Bioética*, 25, 328-337, 2017. doi: 10.1590/1983-80422017252193

Hake, J. F.; Schlor, H.; Schurmann K.; Venghaus, S. Ethics, sustainability and the water, energy, food nexus approach – a new integrated assessment of urban systems. *Energy Procedia*, 88, 236-242, 2016. doi: 10.1016/j.egypro.2016.06.155

Haq, S. U.; Boz, I. Developing a set of indicators to measure sustainability of tea cultivating farms in Rize Province, Turkey. *Ecological Indicators*, 95, 219-232, 2018. doi: 10.1016/j.ecolind.2018.07.041

IBGE – Instituto Brasileiro de Geografia e Estatística. *Cidades - Volta Redonda/RJ* –infográficos economia, 2015a. Available at: <http://cidades.ibge.gov.br/painel/economia.php?lang=&codmun=330630&search=rio-de-janeiro|volta-redonda|infogr%E1ficos:-despesas-e-receitas-or%E7ament%E1rias-e-pib>. Access in: jun. 2018.

IBGE – Instituto Brasileiro de Geografia Estatística. *Indicadores de desenvolvimento sustentável* – ed. 2015. Rio de Janeiro: IBGE, 2015b.

IBGE – Instituto Brasileiro de Geografia e Estatística. *Indicadores de Desenvolvimento Sustentável- Edição 2017*. Available at: <https://sidra.ibge.gov.br/pesquisa/ids/tabelas > Access in: jun. 2018.

Ibrahim, F. I.; Omar, D.; Mohamad, N. H. N. Theoretical review on sustainable city indicators in Malaysia. *Procedia - Social and Behavioral Sciences*, 202, 322-329, 2015. doi: 10.1016/j.sbspro.2015.08.236

INEA – Instituto Estadual do Ambiente do Rio de Janeiro. *Avaliação ambiental do Rio Paraíba do Sul - trecho Funil--Santa Cecília*, 2012. Available at: <https://www.ceivap.org.br/downloads2011/REL%20INEA%20AA%20Funil.pdf>. Access in: feb. 2019.

INEA – Instituto Estadual do Ambiente do Rio de Janeiro. *Nota técnica DIGAT/INEA nº 01-A/2014¹- em 26 de março de 2014*, 2014.

ITB - Instituto Trata Brasil. *Ranking de Saneamento Básico 2017*, 2017. Available at: <http://www.tratabrasil.org.br/component/estudos/itb/ranking-do-saneamento-2017>. Access in: jun. 2018.

Labsynth. *FISPQ - Ficha de informações de segurança de produtos químicos* - Hidróxido de Cálcio, 2017. Available at: <http://downloads.labsynth.com.br/FISPQ/rv2012/FISPQ%20Hidroxido%20de%20Calcio.pdf>. Access in: jan. 2019.

Lacerda, C. S.; Cândido G. A. Modelos de indicadores de sustentabilidade para gestão de recursos hídricos. In: Lira, W. S.; Cândido, G. A. (Orgs). *Gestão sustentável dos recursos naturais*: uma abordagem participativa. Campina Grande: EDUEPB, p. 13-30, 2013.

Lee, C. S. A review on application of flocculants in wastewater treatment. *Process Safety and Environmental Protection*, 92, 489-508, 2014. doi: 10.1016/j.psep.2014.04.010

Lima-Júnior, R. N.; Abreu, F. O. M. S. Produtos naturais utilizados como coagulantes e floculantes para tratamento de águas: uma revisão sobre benefícios e potencialidades. *Revista Virtual de Química*, 10, 2018. doi: 10.21577/1984-6835.20180052

Machado, I. C.; Fagundes, L.; Henriques, M. B. Multidimensional assessment of sustainability extractivism of mangrove oyster *Crassostrea spp*. in the estuary of Cananéia, São Paulo, Brazil. *Brazilian Journal of Biology*, 75(3), 670-678, 2015. doi: 10.1590/1519-6984.20713

Mapar, M.; Jafari, M. J.; Mansouri, N.; Arjmandi, R.; Azizinejad, R.; Ramos, T. B. Sustainability indicators for municipalities of megacities: integrating health, safety and environmental performance. *Ecological Indicators*, 83, 271-291, 2017. doi: 10.1016/j.ecolind.2017.08.012

Marques, J. B. V.; Freitas, D. The Delphi method: characterization and potentialities for educational research. *Pro-posições*, 29, 389-415, 2018. doi: 10.1590/1980-6248-2015-0140

Meijering, J. V.; Tobi, H.; Kern, K. Defining and measuring urban sustainability in Europe: a Delphi study on identifying its most relevant component. *Ecological Indicators*, 90, 38-46, 2018. doi: 10.1016/j.ecolind.2018.02.055

Miranda, A. B.; Teixeira, B. A. N. Nota técnica: indicadores para o monitoramento da sustentabilidade em sistemas urbanos de abastecimento de água e esgotamento sanitário. *Engenharia Sanitária e Ambiental*, 9, 269-279, 2004. doi: 10.1590/S1413-41522004000400002

Molinos-Senante, M.; Marques, R. C.; Pérez, F.; Gómez, T.; Sala-Garrido, R.; Caballero, R. Assessing the sustainability of water companies: a synthetic indicator approach. *Ecological Indicators*, 61, 577-587, 2016. doi:10.1016/j.ecolind.2015.10.009

Musa, D. H.; Yacob, M. R.; Abdullah, A. M.; Ishak, M. Y.

Delphi method of developing environmental well-being indicators for the evaluation of urban sustainability in Malaysia. *Procedia Environmental Sciences*, 30, 244-249, 2015. doi: 10.1016/j.proenv.2015.10.044

Nanninga, T. A.; Bisschops, I.; López, E.; Martínez-Ruis J. L.; Murillo, D.; Essl L.; Stakl, M. Discussion on sustainable water technologies for peri-urban areas of Mexico City: balancing urbanization and environmental conservation. *Water*, 4, 739-758, 2012. doi: 10.3390 /w4030739

Nascimento, P. E. Trajetória da sustentabilidade: do ambiental ao social, do social ao econômico. *Estudos avançados*, 74(26), 51-64, 2012. doi: 10.1590/S0103-40142012000100005

Nunes, T. C. G.; Menezes, G. G.; Corrêa, B. S.; Francelino, F. M. A.; Oliveira, V. P. S. Abordagem da qualidade da água do Rio Paraíba do Sul na educação ambiental na UPEA, Campos dos Goytacazes, RJ. *Boletim do Observatório Ambiental Alberto Ribeiro Lamego*, 8, 2014. doi: 10.19180/2177-4560.v8n214-02

Oliveira, J. A.; Barbosa, L. G.; Magalhães, P. F. Esgotamento sanitário no Médio Paraíba do Sul: oficina RX do esgotamento. *In: Anais do III Simpósio de Recursos Hídricos da Bacia do Rio Paraíba do Sul*. Juiz de Fora, 27 ago., 2018.

Oliveira, J. S. P.; Costa, M. M.; Wille, M. F. C.; Marchiori, P. Z. *Introdução ao método Delphi*. Curitiba: Mundo Material, 2008.

Oliver, S. L.; Ribeiro, H. Variabilidade climática e qualidade da água do Reservatório Guarapiranga. *Estudos Avançados*, 28, 95-128, 2014. doi: 10.1590/S0103-40142014000300007

Park, K.; Kremer, O. E. G. Text mining-based categorization and user perspective analysis of environmental sustainability indicators for manufacturing and service systems. *Ecological Indicators*, 72, 803-820, 2017. doi: 10.1016/j.ecolind.2016.08.027

Pellicer-Martínez, F.; Martínez-Paz, J. M. The water footprint as an indicator of environmental sustainability in water use at the river basin level. *Science of the Total Environment,* 571, 561-574, 2016. doi: 10.1016/j.scitotenv.2016.07.022

Peres, R. B.; Silva, R. S. Análise das relações entre o Plano de Bacia Hidrográfica Tietê-Jacaré e os planos diretores municipais de Araraquara, Bauru e São Carlos, SP. *Sociedade e Natureza*, 25, 349-362, 2013. doi: 10.1590/S1982-45132013000200011

Pires, A.; Morato, J.; Peixoto, H.; Botero, V.; Zuluaga, L.; Figueroa, A. Sustainability assessment of indicators for integrated water. *Science of The Total Environment*, 578, 139-147, 2017. doi: 10.1016/j.scitotenv.2016.10.217

PMVR – Prefeitura Municipal de Volta Redonda. *Lei Municipal nº 4.441 de 06 de agosto de 2008*. Aprova o Plano Diretor Participativo de Desenvolvimento Urbano de Volta Redonda e dá outras providências.

PMVR - Prefeitura Municipal de Volta Redonda. *Planos municipais de saneamento básico e gestão integrada de resíduos sólidos*. Volta Redonda, 2014.

Polizzi, S.; Pira, E.; Ferrara, M.; Bugiani, M. Papaleo, A. Albera, R., Palmi, S. Neurotoxic effects of aluminium among foundry workers and alzheimer's disease. *NeuroToxicology*, 23, 761-744, 2002. doi: 10.1016/S0161-813X(02)00097-9

Pupphachai, U.; Zuidema, C. Sustainability indicators: a tool to generate learning and adaptation in sustainable urban development. *Ecological Indicators*, 72, 784-793, 2017. doi: 10.1016/j.ecolind.2016.09.016

Rantala, T.; Ukko, J.; Saunila, M.; Havukainen, J. The effect of sustainability in the adoption of technological, service, and business model innovations. *Journal Cleaner Production*, 172, 46-55, 2018. doi: 10.1016/j.jclepro.2017.10.009

Rozados, H. B. F. O uso da técnica Delphi como alternativa metodológica para a área da ciência da informação. *Em questão*, 21, 64-86, 2015. doi: 10.19132/1808-5245213.64-86

SAAE-VR – Serviço Autônomo de Água e Esgoto de Volta Redonda. *Dados municipais referentes ao sistema de água e esgoto de Volta Redonda*. Volta Redonda, 2018.

SAAE-VR – Serviço Autônomo de Água e Esgoto de Volta Redonda. *Relatório qualidade da* água *2018*, Volta Redonda, 2019.

Silva, S. C.; Mariani, C. F.; Pompêo, M. Análise crítica da Resolução CONAMA n° 357 à luz da diretiva quadro da água da União Europeia: estudo de caso (Represa do Guarapiranga - São Paulo, Brasil). *In*: Pompeo, M.; Moschini-Carlos, V.; Nishimura, P. Y.; Silva, S. C.; Doval, J. C. L. (Orgs.). *Ecologia de reservatórios e interfaces.* São Paulo: E-Publising Inc., p. 367-375, 2015.

Silva, U. F.; Tanaka. O. Y. Técnica Delphi: identificando as competências gerais do médico e do enfermeiro que atuam em atenção primária de saúde. *Rcv. Esc. Enf.* 33, 207-216, 1999. doi: 10.1590/S0080-62341999000300001

Silvestre, B. Sustainable supply chain management: current debate and future directions. *Gestão e Produção*, 23(2), 235-249, 2016. doi: 10.1590/0104-530x2202-16

SMS-VR – Secretaria Municipal de Saúde de Volta Redonda. *Dados referentes às doenças de veiculação hídrica em Volta Redonda em 2017 e 2018*, 2018.

SNF – Health Safety Environment. *FISPQ - Ficha de informações de segurança de produto químico FLOPAM EM 230 PWG*, 2018. Available at: <https://www.snf.com/products-category/flocculants/>. Access in: jun. 2019.

Spiller, M. Adaptive capacity indicators to assess sustainability of urban water systems – Current application. *Science of the Total Environment*, 569-570, 751-761, 2016. doi: 10.1016 / j.scitotenv.2016.06.088

Starkl, M.; Brunner, N.; López, E.; Martínez-Ruiz, J. L. A planning-oriented sustainability assessment framework for peri-urban water management in developing countries. *Water Research*, 47(20), 7175-7183, 2013. doi: 10.1016 / j.watres.2013.10.037

Teodosiu, C.; Gilca, A. F.; Barjoveanu, G.; Fiore, S. Emerging pollutants removal through advanced drinking water treatment: a review on processes and environmental performances assessment. *Journal of Cleaner Production,* 197, 1210-1221, 2018. doi: 10.1016/j.jclepro.2018.06.247

Thornhil, I.; Jonathan G. H.; Zhang Y.; Li H.; Ho, K. C.; Miguel-Chinchilla L.; Loiselle S. A. Prioritising local action for water quality improvement using citizen science; a study across three major metropolitan areas of China. *Science of the Total Environment*, 584-585, 1268–1281, 2017. doi: 10.1016/j.scitotenv.2017.01.200

Tran, L. An interactive method to select a set of sustainable urban development indicators. *Ecological Indicators*, 61, 418-427, 2016. doi: 10.1016/j.ecolind.2015.09.043

UN – United Nations. *Sustainable development indicators*: guidelines and methodologies. New York: UN, 2007.

Verma, P.; Raghubanshi, A. S. Urban sustainability indicators: challenges and opportunities. *Ecological Indicators*, 93, 282-291, 2018. doi: 10.1016/j.ecolind.2018.05.007

Vieira, P. M. S.; Studart, T. M. C. Proposta metodológica para o desenvolvimento de um índice de sustentabilidade hidro-ambiental de áreas serranas no semiárido brasileiro - estudo de caso: Maciço de Baturité, Ceará. *Revista Brasileira de Recursos Hídricos*, 14, 125-136, 2009. doi: 10.21168/rbrh.v14n4.p125-136

Visvaldis, V.; Ainhoa, G.; Ralfs, P. Selecting indicators for sustainable development of small towns: the case of Valmiera municipality. *Procedia Computer Science*, 26, 21-32, 2013. doi: 10.1016/j.procs.2013.12.004

Walton, J. R. Aluminum's involvement in the progression of alzheimer's disease. *Journal of Alzheimer's Disease*, 35, 7-43, 2013. doi: 10.3233/JAD-121909

Wright, J. T. C.; Giovinazzo, R.A. Delphi - uma ferramenta de apoio ao planejamento prospectivo. *Cadernos de Pesquisas em Administração*, 2000(1), 54-55. Available at: https://docplayer.com.br/19266368-Delphi-uma-ferramenta-de--apoio-ao-planejamento-prospectivo.html

Zilbovicius, C.; Ferreira, R. G. L. A.; Narvai, P. C. Água e saúde: fluoretação e revogação da lei federal n. 6.050/1974. *Revista de Direito Sanitário*, 18, 104-124, 2017. doi: 10.11606/issn.2316-9044.v18i3p104-124