Perception of the citizens in the city of São Mateus, Brazil, on water supply and the implications in its use

Angelo Rezende Vinturini, Rita de Cassia Feroni and Elson Silva Galvão

ABSTRACT

The perception of consumers concerning the water supplied by water supply systems (WSS) can be a valuable tool for the management of water resources. This study aims to assess the perception of the citizens of the city of São Mateus, southeast Brazil, concerning the water supplied by the local WSS, and investigating the availability of other alternative sources. A survey was given to a sample of local consumers, and the results suggest that most consumers do not have a good opinion regarding the water quality, highlighting flavor, color, and intermittent supply as the main issues, especially during periods of drought. These conditions are mainly associated with the increase of the total dissolved solids in the raw water. Using private water wells is highlighted as an available alternative source for multiple domestic uses; nevertheless, this alternative may cause some concern if the exploitation of the resource is made without control.

Key words | total dissolved solids, water alternative source, water quality perception, water volume, well water

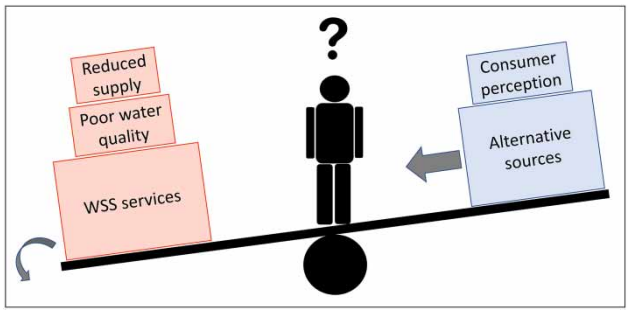
Angelo Rezende Vinturini
Rita de Cassia Feroni (corresponding author)
Departamento de Engenharias e Tecnologia,
Universidade Federal do Espírito Santo,
São Mateus, ES,
Brazil
E-mail: *rita.feroni@ufes.br*

Elson Silva Galvão
Departamento de Física,
Universidade Federal do Espírito Santo,
Vitória, ES,
Brazil

HIGHLIGHTS

- Reduced supply and poor water quality lead to seeking alternative sources.
- Dissatisfaction with WSS services are refelcted in the choice for alternative sources.
- For 71% of consumers, the water from alternative sources is good quality.
- Well water is a feasible alternative source for the residents of the city.
- The use of well water highlights the need for monitoring the potability standards.

GRAPHICAL ABSTRACT



doi: 10.2166/ws.2020.357

INTRODUCTION

The concern about consumers' satisfaction and trust regarding the quality of tap water highlights that it is necessary to have a good understanding of the consumer's perception (Doria *et al.* 2009). The consumers' feedback and complaints provide important information about their perception of water quality provided by the distribution systems (Dietrich *et al.* 2014), contributing to better management of the resource.

Surveys are useful tools to identify the main factors influencing the perception of consumers on the quality of the treated water, and they have been used in many studies around the world, as found in the studies by Doria *et al.* (2005, 2009); Levêque & Burns (2018), Al-Mefleh *et al.* (2019), and Pestana *et al.* (2019). Some works that have used questionnaire surveys to assess the perception of water consumers showed that domestic water consumption, especially drinking water, can be influenced by variables such as pollution and/or risk perception, and unpleasant organoleptic properties (Doria *et al.* 2005, 2009; Levêque & Burns 2018; Al-Mefleh *et al.* 2019; Pestana *et al.* 2019). The trust in the water supply system (WSS) can also change the perception of consumers regarding water quality (Doria *et al.* 2005, 2009). Total dissolved solids (TDS) in the water can affect its acceptance by consumers (Raich-Montiu *et al.* 2014). In the works by Marcussen *et al.* (2013) and Vingerhoeds *et al.* (2016), the relationship between chemical composition and organoleptic properties of the water showed that salty taste was strong and positively correlated to TDS, conductivity, and sodium levels. Therefore, all these variables can lead to the rejection of water by the consumers.

Intermittent water supply can change the perception and the habit of the consumers. According to Guragai *et al.* (2017), the shorter the time of water supply, the worse the consumers' perception of piped water services. According to Kumpel & Nelson (2016), the number of people affected by intermittent water supply will probably increase because of the pressure of urbanization and climate changes on water resources to meet the growing demand. These conditions may lead unsatisfied consumers to look for alternative water sources.

Secondary sources, such as private water wells, bottled water, or water-tank car, all including an extra charge, may be required if the services of the WSS do not satisfy the consumers' demand (Klingel 2012). Environmental issues can influence the consumption of bottled water (Doria *et al.* 2009; Levêque & Burns 2018), price, and convenience (Doria *et al.* 2009). According to Levêque & Burns (2018), the consumption of bottled water may be reduced in regions where the water quality is not an issue. Alternative water sources are more expensive than tap water. A study conducted in the city of Fortaleza, Brazil, by Pestana *et al.* (2019) revealed that during a taste and odor study in a reservoir that supplies the city, most consumers that regularly consumed tap water did so for economic reasons. According to Rocha *et al.* (2016), water wells are an alternative source in the riverine region of Colatina city, Brazil, mainly because of the mistrust of local consumers concerning the quality of the treated water so soon after the contamination of the Doce River with iron ore tailings from a mining company.

According to Döll *et al.* (2012), groundwater contributes approximately 36% of the water used by households in the world. Mattos *et al.* (2018) highlighted the need for improvements in water management, mainly in urban areas, to maintain the development of social and economic activities. However, there is some concern about the exploitation of water resources. According to Seeboonruang (2016), groundwater is an alternative water source during periods of droughts, but changes in its characteristics can occur because of industrialization, urbanization, seasonal variability, and climate changes. Climate changes can affect the availability of groundwater due to irreversible changes in the precipitation intensity, and fluctuations in groundwater recharge (Seeboonruang 2016). According to Mattos *et al.* (2018), industrial activities, inappropriate management of water, and urban waste are potential sources of groundwater contamination. Thus, the use of well water for human consumption may require previous treatment due to potential contamination.

The hydrographic basin of the São Mateus River, in the southeastern region of Brazil, has been facing some problems regarding water management. The years of 2014

and 2015 were marked by drought in southeastern Brazil (ANA 2017), which affected the hydric balance in the São Mateus River basin (historical data series) and showed a water deficit in the period, with values of evapotranspiration exceeding the precipitation along 8 months of the period (AGERH 2018). Cities that depend on the rivers in the São Mateus River basin have suffered because of shortages and problems with water quality during the last years. For instance, the city of São Mateus has been facing such shortages and problems due to low river flow and salinity of raw water (AGERH 2018).

In this context, this works aims to assess the perception of the consumers living in São Mateus of the water supplied by the WSS, and investigate alternative water sources in the region.

METHODOLOGY

The city of São Mateus is located in the Espírito Santo state, southeastern Brazil, and has an estimated population of 130,611 inhabitants and a demographic density of 56 inhabitants per km² (IBGE 2020). The municipal WSS has two main subsystems, 'São Mateus' and 'Guriri', which have a projection to supply 58% and 18%, respectively, of the fixed residents in the municipality until 2023 (PMSM 2020).

The minimum sample size (the number of surveys answered) was estimated according to the methodology proposed by Triola (2010), and a minimum of 384 surveys properly answered was necessary to achieve statistical control with a confidence level of 95% and margin of error of 5%. From the submitted online surveys, 401 inhabitants of São Mateus answered the questions, validating the minimum sample size. The online surveys were submitted between August and October 2019, a period in which no significant changes were observed in the conditions of the water supply services. The responses of the surveys were anonymous, and the collected data were stored in electronic spreadsheets for graphical and statistical analysis.

Figure 1 shows a scheme of the main variables assessed in this study. All participants answered the Level 1, in which

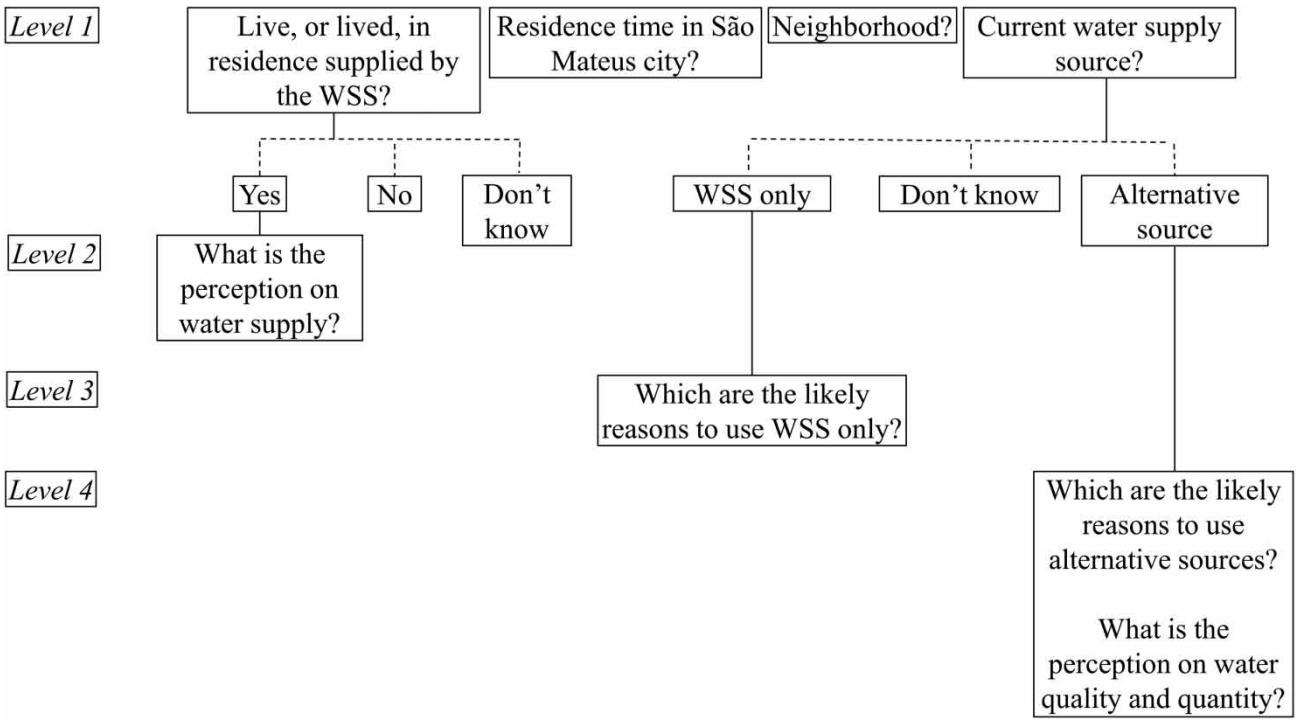


Figure 1 | Methodology applied to the survey structure.

questions were aimed at the characterization of the population and served as filters for the next levels. Level 2 questions assessed the perception of consumers who live, or lived, in residences whose water supply services were supplied by the WSS. If the consumer answered that they were supplied only with treated water from the WSS, Level 3 questions were applied to detail the likely reasons for the use of the WSS service only. The variables of Level 4 identified whether the consumer had some alternative water source, the motives to use these alternative sources, and to understand the perception of the consumers about this resource.

The survey data was graphically processed in two steps, firstly the variables associated with Level 2, and second the variables associated with Levels 3 and 4. Principal component analysis (PCA) was performed to check the correlation between the variables of Level 2.

Qualitative and quantitative data of the raw water, as TDS, were collected from the State Water Resources Agency of Espírito Santo (AGERH 2020); socioeconomic data were collected from the Brazilian Institute of Geography and Statistics (IBGE 2010, 2020); and water supply data of the São Mateus city were collected from the Brazilian National Sanitation Information System (SNIS 2020) and IBGE (2010).

RESULTS AND DISCUSSION

General considerations of consumers' perception of water supply in São Mateus city

According to the State Water Resources Agency of Espírito Santo (AGERH 2018), the average precipitation in the São Mateus River basin is approximately 1,150 mm/year, a value slightly lower than the average precipitation of the state (1,219 mm/year). The annual precipitation in São Mateus city was 1,112 mm, 797 mm, and 823 mm, respectively for 2014, 2015, and 2016 (INMET 2020), showing a period of drought between 2015 and 2016. According to AGERH (2018), high salinity in the São Mateus River has been recorded during the last years, mainly due to the low flow of the river at the mouth, which is associated with the advancing of the tide. The change of water quality can be associated with the TDS levels in the raw water.

Figure 2 shows the mean value of TDS at two monitoring sites close to the water collection point used by the WSS of São Mateus city (subsystem 'São Mateus'). The dotted line is the average TDS level and the dashed line is the Brazilian federal reference threshold of 500 mg/L for the classification of the body as water for human consumption after treatment (CONAMA 2005). According to Devesa & Dietrich (2018), consumers vary in their preference and liking according to the levels of mineralization of drinking water, and it seems they prefer water with TDS content lower than 500 mg/L. Drinking water becomes unpalatable if the TDS level is greater than 1,000 mg/L (WHO 2017). Figure 2 shows that TDS levels were greater than 500 mg/L during 17% of the monitoring period. During 2016, 100% of the monitoring data showed TDS levels higher than 500 mg/L. According to the city hall of São Mateus (PMSM 2020), salinity in the river water has occurred in both 'São Mateus' and 'Guriri' subsystems, mainly during periods of drought. To minimize this problem, both 'Guriri' and 'São Mateus' subsystems were supplemented with water from a well drilled by the WSS company (PMSM 2020).

The surveys show that 85% of the consumers live, or lived, in a residence supplied by the WSS of São Mateus city, and 76% of the consumers lived in São Mateus for at least 5 years. This information is important because the problems regarding water supply in the city are old and recurring, mainly during periods of severe drought.

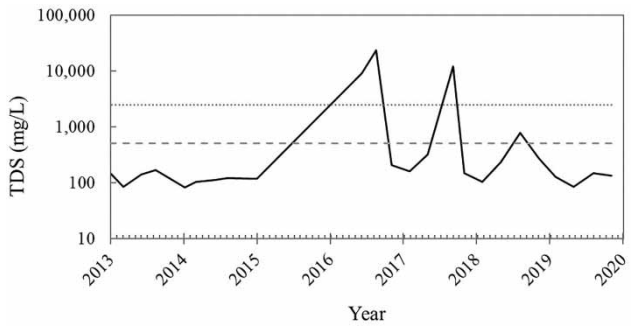


Figure 2 | TDS time series in the São Mateus River. Adapted from AGERH (2020). Dotted line is the average TDS level; dashed line is the Federal reference threshold (500 mg/L).

Figure 3 shows the consumers' perception regarding the WSS water quality, in which 19% of the consumers rated the water as 'good', 55% as 'regular', and 26% as 'bad'. Concerning the organoleptic aspects, the odor, flavor, and color were the most perceived characteristics. Concerning the complaints, 35% of consumers complained about the odor and 50% about the flavor and color, while 24% of the consumers did not noticed any relevant aspect of the water. As free opinion (optional questions in the survey), approximately 7% of the consumers reported aspects regarding the salinity of the water. The works by Doria *et al.* (2005, 2009) and Pestana *et al.* (2019) show that the perception of changes in water quality is strongly influenced by flavor. Taking into account the quantity of water provided by the WSS, for 60% of the consumers the water supply shortages were mainly associated with periods of droughts. According to AGERH (2018), during recent years, the city of São Mateus has been facing problems in providing good quality water for the population living in some neighborhoods. The city does not have advanced treatment processes to remove salinity, and thus, occasionally, the supply of water may have high levels of salinization or could even be discontinued because of interruptions of the WSS services (AGERH 2018).

According to the PCA analysis (Figure 4), the consumers who live (or lived) for less than 2 years in São Mateus city have a different perception from those who have lived longer in the city. Figure 4 shows a strong correlation between these consumers and the non-perception of unpleasant characteristics of the water, which probably induced the perception and rating of the water quality as 'good'.

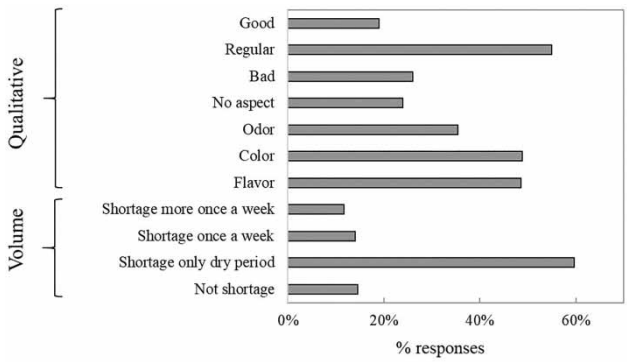


Figure 3 | Perception of quality and quantitative aspects of treated water.

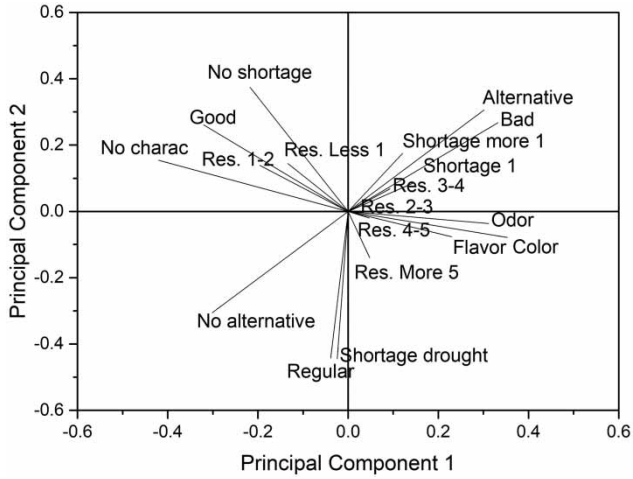


Figure 4 | PCA analysis of the variables associated with the consumers' perception and decision. Resides less than 1 year (Res. Less 1); resides between 1 and 2 years (Res. 1–2); resides between 2 and 3 years (Res. 2–3); resides between 3 and 4 years (Res. 3–4); resides between 4 and 5 years (Res. 4–5); resides more than 5 years (Res. More 5); good evaluation (Good); regular evaluation (Regular); bad evaluation (Bad); there was no shortage (no shortage); shortage during drought (Shortage drought); shortage at least once a week (Shortage 1); shortages more than once a week (Shortage more 1); flavor in water (Flavor); color in water (Color); odor in water (Odor); no relevant characteristics in water (No charac.); has alternative source (Alternative); and does not have an alternative source (No alternative).

This behavior can also be associated with the progressive drilling of water wells since 2017 by the city hall of São Mateus when searching for alternative sources during periods of high salinity levels in the São Mateus River (PMSM 2020).

Figure 4 shows that the variables 'shortage of water at least once a week' and 'shortage more than once a week', may have induced consumers to a negative perception (rating 'bad') of the water provided by the WSS, leading consumers to seek alternative sources. The link between reduced water supply and consumer perception is clearer because of the correlation between regular consumer's perception and shortages of water services during the dry season.

In Figure 4, the results suggest that the perception of organoleptic characteristics such as odor, flavor, and color seem to be more correlated with people who have lived longer in the city (over 4 years). The recent use of well water by the WSS to supply the city during periods of the inferior quality of the raw water may explain the perception of consumers. The variable 'does not have an alternative source' did not show any correlation with other variables.

Thus, the negative perception of the water quality and the quantity of water supplied by the WSS during some periods may be partly associated with a memory of the consumers, which does not rule out the possibility of the citizens to have some alternative source of water. Problems regarding water quality in the city are old and recurring, and although minimized, a definitive solution has not yet been implemented. Issues on the memories associated with health problems and water perception were addressed in previous studies (Doria *et al.* 2005, 2009).

Alternative sources of water used by the inhabitants of São Mateus city

Figure 5(a) shows the distribution of the consumers by type of water source. Approximately 52% of the consumers were supplied only by the WSS, while 25% of the consumers used only private water wells as a water source, and 15% were supplied with both sources. Only 2% of the consumers used other sources of water, for instance, WSS and tankers, WSS and cisterns, or only cistern. Approximately 4% of people who use alternative sources live in rural areas. Thus, the results suggest that well water is a feasible alternative source for the residents of the São Mateus city for domestic use.

Consumers reported the poor quality of water and the high frequency of water shortages as the major motivations for their residences not being supplied with water from the WSS (full or partially), as shown in Figure 5(b). For 5% of the consumers, their neighborhood is not supplied with water. From that 5%, most (99.4%) live in urban areas, while 0.6% live in rural areas. Consumers who answered 'others' or 'don't know' as the major motivations correspond to 28%.

It is expected that the number of consumers using alternative sources will increase in the future. Figure 5(c) shows that 67% of consumers use the WSS services as the sole source because of the high cost of alternative sources or because they live in rented houses, as well as other motivations. According to Census 2010, in the city of São Mateus, households with no income or those with monthly incomes up to two minimum wages correspond to approximately 42% (IBGE 2020). The per capita income of the population in the city has been decreasing over the years. In 2015 and 2018, the workers in the formal sector were paid the equivalent of 2.6 and 2.3 Brazilian monthly minimum wage, respectively (IBGE 2020). Only 33% of the consumers answered that they are satisfied with the water provided by the WSS. The dissatisfaction with the WSS services was reflected in the number of residences supplied by the system. Figure 6 shows an increasing trend in the number of inhabitants in São Mateus, compared to the number of residences supplied by the WSS since 2015, which dropped by 20% between 2015 to 2018. This drop can be associated with the use of alternative sources of water by local consumers. The survey showed that approximately 22% of the people living in urban areas use only alternative sources of water (Figure 5(a)).

In relation to the quality and volume of water of alternative sources, 71% of consumers reported good quality and sufficient volume. However, it is important to highlight that 29% of consumers are not satisfied with the water services for their residences.

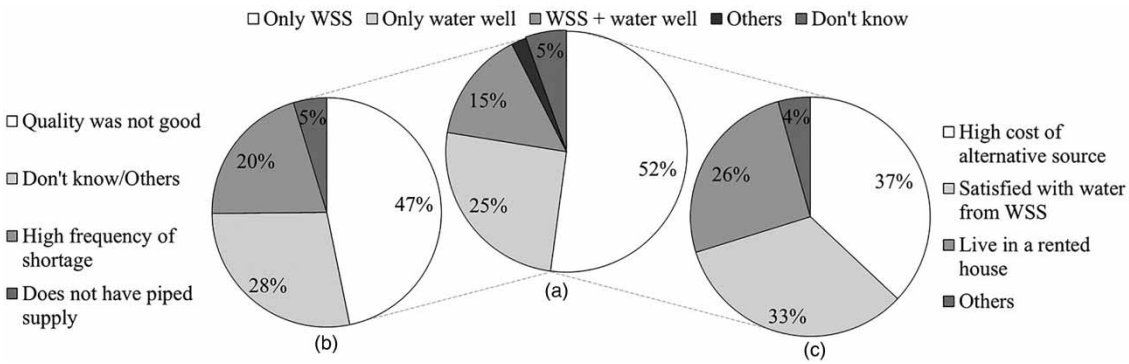


Figure 5 | (a) Water source of inhabitants of São Mateus city; (b) reasons for using an alternative source; (c) reasons for not using an alternative source.

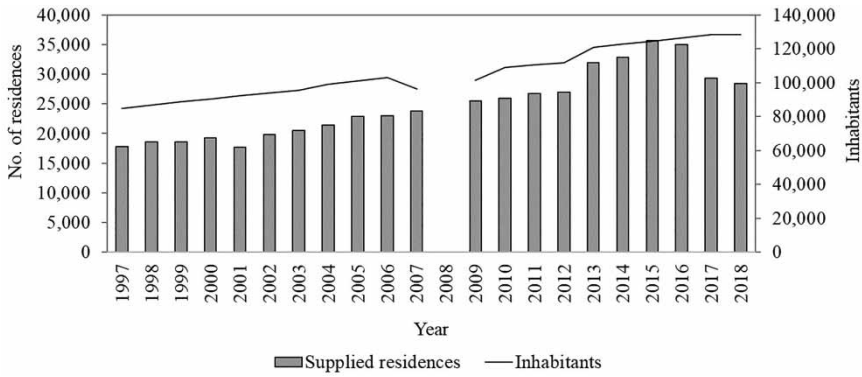


Figure 6 | Residences supplied by the WSS and estimated population in the São Mateus city. Source: Adapted from SNIS (2020).

The result of the survey can serve as an alert to municipal water resource managers. According to AGERH (2018), the number of well water consumers is increasing in the city of São Mateus, mainly driven by the high salinity of the São Mateus River. The salinity of the river may be aggravated because of excessive pumping of the groundwater, and the consequent advance of seawater (AGERH 2018). There are also some conflicts regarding the use of the basin of the São Mateus River, such as the opening of wells in areas of permanent protection, construction of dams, and capture of water resources for irregular irrigation, irregularities that have intensified since 2015 (AGERH 2018). Between 2011 and 2016, at least 191 environmental crimes associated with water misuse were registered, with 141 cases only in the period 2015–2016 (AGERH 2018). State Water Resources Council (CERH 2015) determined that permanent buildings in urban areas can only have individual sources for human consumption in the absence of public water supply network. The results suggest that a fraction of the water wells in the urban area of São Mateus may be clandestine.

The responses of the survey were compared with water supply data of the São Mateus city, reported in the Census 2010 (IBGE 2010), which covers 86% of permanent private households in the city. The region 'sub-district of São Mateus' covers the downtown area, and the region 'sub-district of Barra Nova' covers Guriri Beach, an important tourist region of the São Mateus city. According to Census 2010, 9% of the residents in the 'sub-district of São Mateus' and 26% of the residents in the 'sub-district of Barra Nova' are consumers of alternative sources of water. However, considering the responses of the survey, 24% of the residents in the 'sub-district São Mateus' and 67% of the residents in the 'sub-district of Barra Nova' are consumers of alternative sources, an increase of approximately 2.5 times. This is worrying information because consumers may not monitor the potability aspects of the water prior to consumption.

Urban areas have a great demand for water, which can promote potential for deterioration of these resources (Mattos *et al.* 2018). Fachetti *et al.* (2017) assessed the use of groundwater in the neighborhood of Guriri in a study including 36 water wells. The results showed that only one of the 36 wells complied with the national potability standards, and half of the wells exceeded the microbiological standard, probably because of the proximity to cesspits. In these cases, consumers were asked to treat raw water before consumption. During periods of salinization of the river, the city of São Mateus has an intermittent water supply, which may lead to individual water stock by the consumers. According to Klingel (2012), individual water stocks, stagnation of water in the piping due to pressure deficiency, and intermittent operation of the WSS can cause contamination of the water by pathogens. In the city of São Mateus, hospitalization rates for inhabitants for diarrhea and gastroenteritis increased by 219% between 2014 and 2019 (DATASUS 2020). Thus, a detailed investigation of the probable reasons is needed.

CONCLUSION

The results suggest that consumers' perception regarding the treated water provided by the WSS has influenced the

increase in using alternative water sources by residents of the city of São Mateus. Most consumers do not consider the water from the WSS as good quality, a perception driven mainly by the flavor and color of the water. Consumers also reported intermittent supply, which occurs mainly in periods of drought and high salinity of raw water.

The availability of alternative water sources is important for the consumers to decide whether or not to use water from the WSS. In this case, consumer memory seems to be an important factor because a significant percentage of the survey participants would like to have an alternative source of water.

Private water wells were reported by residents of São Mateus city as a feasible alternative source for multiple domestic uses. Private water wells have been used as permanent supply source because water supply problems in the region are recurrening. However, the exploitation of these resources with no control may compromise the water supply system. The consumers of alternative sources of water may consume contaminated water if no previous treatment is made or if there is inadequate water storage. Municipal water resources managers should therefore pay special attention to these issues in the region.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Institutional Scientific Initiation Program of the Federal University of Espírito Santo (UFES) and to the Group of Applied Physics of the UFES for the support.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES

AGERH 2018 *Diagnóstico e o prognóstico das condições de uso da água na bacia hidrográfica do Rio São Mateus (Diagnosis and Prognosis of Water use Conditions in the São Mateus River Basin)*. State Water Resources Agency. Available from: www.agerh.es.gov.br (accessed 19 April 2020). Portuguese.

AGERH 2020 *Dados de Qualidade das Águas Interiores (Water Quality Data)*. State Water Resources Agency. Available from: www.agerh.es.gov.br (accessed 19 April 2020). Portuguese.

Al-Mefleh, N. K., AlAyyash, S. M. & Bani Khaled, F. A. 2019 Water management problems and solutions in a residential community of Al-Mafraq city, Jordan. *Water Supply* **19** (5), 1371–1380.

ANA 2017 *Conjuntura dos recursos hídricos no Brasil 2017 (Conjuncture of Water Resources in Brazil 2017)*. Brazilian National Water Agency. Available from: www.ana.gov.br (accessed 21 March 2020). Portuguese.

CERH 2015 *Resolução CERH n° 07 de 16 de dezembro de 2015 (Resolution CERH n° 07 of 16 December 2015)*. State Water Resources Council. Available from: www.cbhdoce.org.br/wp-content/uploads/2016/01/resolucao-cerh-n%C2%B0-007.pdf (accessed 21 March 2020). Portuguese.

CONAMA 2005 *Resolução CONAMA n° 357 de 17 de março de 2005 (Resolution CONAMA n° 357 of 17 March 2005)*. National Environment Council. Available from: www2.mma.gov.br (accessed 21 May 2020). Portuguese.

DATASUS 2020 *Department of Informatics of the Unified Health System*. Available from: www.datasus.saude.gov.br (accessed 18 May 2020). Portuguese.

Devesa, R. & Dietrich, A. M. 2018 Guidance for optimizing drinking water taste by adjusting mineralization as measured by total dissolved solids (TDS). *Desalination* **439**, 147–154.

Dietrich, A. M., Phetxumphou, K. & Gallagher, D. L. 2014 Systematic tracking, visualizing, and interpreting of consumer feedback for drinking water quality. *Water Research* **66**, 63–74.

Döll, P., Hoffmann-Dobrev, H., Portmann, F. T., Siebert, S., Eicker, A., Rodell, M., Strassberg, G. & Scanlon, B. R. 2012 Impact of water withdrawals from groundwater and surface water on continental water storage variations. *Journal of Geodynamics* **59–60**, 143–156.

Doria, M. F., Pidgeon, N. & Hunter, P. 2005 Perception of tap water risks and quality: a structural equation model approach. *Water Science and Technology* **52** (8), 143–149.

Doria, M. F., Pidgeon, N. & Hunter, P. R. 2009 Perceptions of drinking water quality and risk and its effect on behaviour: a cross-national study. *Science of the Total Environment* **407** (21), 5455–5464.

Fachetti, P., Favero, D. & Cotta, A. 2017 *Qualidade da água subterrânea do bairro Guriri, São Mateus-ES (Groundwater Quality in the Guriri Neighborhood, São Mateus-ES)*. VI ENCAQUI – Encontro Capixaba de Química – SBQ/ES.

Guragai, B., Takizawa, S., Hashimoto, T. & Oguma, K. 2017 Effects of inequality of supply hours on consumers' coping strategies and perceptions of intermittent water supply in Kathmandu

Valley, Nepal. *Science of the Total Environment* **599–600**, 431–441.

IBGE 2010 *Censo 2010 (Census 2010)*. Brazilian Institute of Geography and Statistics. Available from: www.censo2010.ibge.gov.br (accessed 11 April 2020). Portuguese.

IBGE 2020 *Brazilian Institute of Geography and Statistics*. Available from: www.ibge.gov.br (accessed 11 April 2020). Portuguese.

INMET 2020 *National Meteorological Institute of Brazil*. Available from: www.inmet.gov.br (accessed 11 March 2020). Portuguese.

Klingel, P. 2012 Technical causes and impacts of intermittent water distribution. *Water Science and Technology: Water Supply* **12** (4), 504–512.

Kumpel, E. & Nelson, K. L. 2016 Intermittent water supply: prevalence, practice, and microbial water quality. *Environmental Science and Technology* **50** (2), 542–553.

Levêque, J. G. & Burns, R. C. 2018 Drinking water in West Virginia (USA): tap water or bottled water – what is the right choice for college students? *Journal of Water and Health* **16** (5), 827–838.

Marcussen, H., Bredie, W. L. P., Stolzenbach, S., Brüsch, W., Holm, P. E. & Hansen, H. C. B. 2013 Sensory properties of Danish municipal drinking water as a function of chemical composition. *Food Research International* **54** (1), 389–396.

Mattos, J. B., Cruz, M. J. M., De Paula, F. C. F. & Sales, E. F. 2018 Natural and anthropic processes controlling groundwater hydrogeochemistry in a tourist destination in northeastern Brazil. *Environmental Monitoring and Assessment* **190**, 395.

Pestana, C. J., Neto, J. C., Barros, M. U. G., Menezes, I., Góis, A. & Santos, G. 2019 Consumer perception of water quality during an off-flavor event in Fortaleza-Brazil. *Journal of Water Supply: Research and Technology – AQUA* **68** (1), 63–73.

PMSM 2020 *São Mateus City Hall*. Available from: www.saomateus.es.gov.br (accessed 05 June 2020). Portuguese.

Raich-Montiu, J., Barios, J., Garcia, V., Medina, M. E., Valero, F., Devesa, R. & Cortina, J. L. 2014 Integrating membrane technologies and blending options in water production and distribution systems to improve organoleptic properties. The case of the Barcelona Metropolitan Area. *Journal of Cleaner Production* **69**, 250–259.

Rocha, E. M., Moraes, L. G. M., Almeida, L. V., Dalvi, L. R., Andriato, L. C., Bergamaschi, L. K., Dala-Bernardina, L. S., Pereira, W. B., Gimenez, V. G., Chiarelli-Neto, O. & Almeida, H. S. 2016 The impact of disruption of the barrage in Mariana – MG on the health of the riverside population in the city of Colatina – ES. *Tempus Actas de Saúde Coletiva* **10** (3), 31–45.

Seeboonruang, U. 2016 Impact assessment of climate change on groundwater and vulnerability to drought of areas in Eastern Thailand. *Environmental Earth Sciences* **75** (1), 1–13.

SNIS 2020 *Brazilian National Sanitation Information System*. Available from: www.snis.gov.br (accessed 05 March 2020). Portuguese.

Triola, M. F. 2010 *Elementary Statistics, (Technology Update)*. Pearson.

Vingerhoeds, M. H., Nijenhuis-de Vries, M. A., Ruepert, N., van der Laan, H., Bredie, W. L. P. & Kremer, S. 2016 Sensory quality of drinking water produced by reverse osmosis membrane filtration followed by remineralisation. *Water Research* **94**, 42–51.

WHO 2017 *Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum*. World Health Organization, Geneva.

First received 20 July 2020; accepted in revised form 22 November 2020. Available online 7 December 2020