v. 4, n. 6, 2024

Journal of
Engineering
Research

METHODOLOGY FOR ASSESSMENT AND ANALYSIS OF THE QUALITY PERFORMANCE OF DRINKING WATER PRODUCED BY SAA.

Rodrigo Antonio Pinto de Melo
Chemical Engineer by: Universidade Federal de Pernambuco (UFPE). Master in Chemical and Biochemical Process Development (UFPE). Regulatory Analyst of``*Agência de Regulação dos Serviços Públicos Delegados do Estado de Pernambuco*`` (Arpe).

Cícero Henrique Macêdo Soares
Chemical Engineer by: Universidade Federal de Pernambuco (UFPE). PhD in Catalytic processes and Chemical Reactors (UFPE). Regulatory Analyst ``*Agência de Regulação dos Serviços Públicos Delegados do Estado de Pernambuco*`` (Arpe).

João Paulo Barbosa da Costa
Civil Engineering by: Universidade Federal de Pernambuco (UFPE). Master in Civil Engineering (UFPE). Regulatory Analyst ``*Agência de Regulação dos Serviços Públicos Delegados do Estado de Pernambuco*`` (Arpe).

Emanuele Ferreira Gomes
Civil Engineering at: Universidade Federal de Campina Grande (UFCG). Master in Civil and Environmental Engineering (UFCG). Regulatory Analyst of ``*Agência de Regulação dos Serviços Públicos Delegados do Estado de Pernambuco*`` (Arpe).

Abstract: The present work aims to show the application of a system of performance indicators to evaluate the quality of drinking water distributed by Water Supply Systems (SAA) and its functionality in relation to the technical regulation of the basic sanitation service provider. Four parameters were chosen to systematically evaluate water quality for the SAA, they are: Turbidity, Free Residual Chlorine, Total Coliforms and Escherichia coli. Indicators of non-conformity of samples analyzed for the selected parameters were established and aim to verify the standards established by Annex XX of Consolidation Ordinance, number: 5 of the Ministry of Health, and an indicator that aims to summarize the information of all others in a single, called the Drinking Water Quality Index (IQAP). The measurement of indicators was carried out at the treatment outlet (st) and in the distribution network, allowing the assessment of the quality of drinking water in both positions independently, providing better identification and location of problems. In terms of the indicator's spatial coverage, the calculation was carried out first in its smallest dimensions, then expanded through the sum of data or averages for larger dimensions. As a result, it was possible to investigate the deficiencies and performance of the SAA, helping the agency in decision-making and action through regulation by exposure, providing interchangeability and dynamism of the Public Entities responsible for guaranteeing the quality of drinking water supplied by the SAA.
Keywords: Potability Standards. Quality. Performance indicators. Regulation by Exposure.

INTRODUCTION

Establishing a brief historical context about the quality of water for human consumption in Brazil, we can already see the concern of public health authorities about the quality of drinking water through the creation of the National Department of Public Health (DNSP), created by law number: 3,987 in the 1920s. In mid-1961, the Federal Government published Decree, number: 49,974/1961 regulating Law, number: 2,314/1954, adding new devices for health and environmental surveillance (Alves et al., 2023). The legal framework for more efficient and effective management in relation to the quality of drinking water began with the publication of Federal Decree nº 79,367 of March 9, 1977, which gives the Ministry of Health the responsibility to define standards, produce regulations and monitor compliance, with the aim of implementing the management of water potability for human consumption. That same year, the Ministry of Health published Ordinance, number: 56/BSB of March 14, 1977, the first provision on water quality for human consumption (Bastos, 2023). Over the years, the Ordinance underwent some revisions and in 2017, the Ministry of Health grouped its various standards into Consolidation Ordinance, number: 5 and Ordinance 2,914/2011 is incorporated as Annex XX. The next review took place in 2020 and the result was the publication of Ordinance GM/MS, number: 888, of May 4, 2021, which is the current standard on the quality of water for human consumption.

Analyzing Ordinance GM/MS, number: 888, two basic activities are established to guarantee drinking water quality standards: water control and surveillance. Control activity is the responsibility of whoever operates the SAA, and surveillance is the responsibility of Public Health authorities. Subnational Regulatory Agencies do not perform a water surveillance role, their way of acting is defined by the legal framework for basic sanitation, in which it is clear that one of their main roles is as a conditioner of contractual goals or those established through Basic Sanitation Plans or Normative Instruments. Given this peculiar aspect of functionality, the use of process data to develop service provider performance assessment techniques for subsequent comparison with targets, reference values or benchmarking techniques becomes one of the regulatory analyst's main tools.

Basic sanitation service providers, when operating Water Supply Systems, are obliged to provide water that meets the potability standards established by current legislation. Evaluating the performance of SAA in water production according to potability standards, considering all possible anomalies, involves a multitude of parameters that makes this task quite complicated due to the number of measurements and methods that must be used to measure all the main parameters involved in your evaluation. When working with performance indicators, there is a need to choose the smallest number of parameters possible, but without losing the systemic vision in their evaluation. In other words, the chosen parameters must make it possible to infer whether the water treatment was well carried out and whether residual protection against contamination is active throughout the distribution network.

The methodology of using performance indicator systems will allow the regulatory professional to assess whether the goals established for water quality have been met, in addition to allowing the performance assessment of the SAA, providing an excellent accessory in decision making, especially in actions inspections and in the construction of tools for the use of regulation by exposure, allowing better interaction between the Public Bodies responsible for monitoring basic sanitation (Regulasan, 2017).

GOALS

- Assess the quality of drinking water distributed by SAA through a system of performance indicators.
- Provide a means of aid in decision making.
- Make use of regulation by exposure, providing better interaction between interested parties, whether or not responsible for managing basic sanitation.

MATERIAL AND METHODS

Regarding methodology, when choosing indicators for performance evaluation, we opted to choose essential parameters for evaluating water treatability in a systemic way. Regarding bacteriological quality, according to (WHO, 2005) cited by (MINISTÉRIO DA SAÚDE, 2006), Total Coliforms constitute a satisfactory indicator for evaluating the efficiency of treatment as they present a decay rate similar to or higher than that of thermotolerant coliforms. and Escherichia coli; but for bacteriological contamination, the most accurate indicator is Escherichia coli. Regarding virological quality, the Coliform bacteriological parameter must be checked together with the Residual Chlorine parameter at the exit of the contact tank together with the contact time itself. With regard to parasitological quality, it is observed that the encapsulated forms of protozoa have high resistance to the chlorine levels used in the water disinfection process, notably Giardia cysts and Cryptosporidium oocysts, as they present high resistance to chlorination, their removal in the treatment process is strictly linked to filtration, this way, coliforms practically lose their role as an indicator and must be replaced by an indicator of removal of suspended particles through filtration, such as turbidity (MINISTRY OF HEALTH, 2006). From the above, Total Coliforms is a key parameter because it measures the efficiency of the treatment, but it must not be analyzed alone, due to the fact that there are factors that Coliforms examined alone cannot add to the information obtained through their evaluation.

Considering the parameters Turbidity, Free Residual Chlorine, Total Coliforms and Escherichia coli, as essential in evaluating the water treatability performance, Arpe chose to work with five indicators to analyze the water treatability performance distributed by the SAA operated by the service provider. Four of them are based on the incidence indicator of analyzes carried out outside the standard, which is used to measure the number of samples carried out that do not comply with the standards required by current legislation. Its assessment is based on dividing the number of analyzes performed that are outside the standard by the number of samples performed. The conjecture of these indicators must be carried out together for a more satisfactory understanding of water treatment performance in relation to bacteriological, virological and parasitological quality.

The fifth indicator or index aims to summarize the results of the four non-standard analysis indicators in a single number. As reported (Libânio, 2010), the dissemination of the interpretation of data and water quality parameters in a way that is intelligible to the public, although it is not exclusive to this area of knowledge in question, has been the subject of efforts by several researchers. It is often important, in terms of analysis, to reproduce in a single value the meaning of a set of data of different natures. Figure 1 reports the scheme of the indicator system.

The weighting of the IQAP indicator is carried out through a quantitative assessment of the risk that non-conformities with indicators IN076, IN075, IN084 and INp05 pose to the SAA. To characterize the risk of each parameter, we use scores for the following aspects: Severity (S), Occurrence (O) and Danger (P). Severity means the magnitude of the danger if it occurs (amount of damage that the occurring danger offers), occurrence, the frequency with which the danger is occurring in the process, that is, it is the very indicator of inference of analysis outside the standards, and danger, an adverse effect caused by a certain circumstance. A more complete methodology can be seen in (Ogata, 2011). Two aspects must be highlighted when calculating the weight w:

1) The calculated weight is dynamic: severity and danger are constant aspects for a given parameter, but the occurrence varies depending on the non-compliance indicator itself, that is, the more non-compliance there is for the parameter, the higher the calculated weight will be.

2) The weight can be redistributed: If any parameter has zero risk, it will not be included in the IQAP calculation, and the weight is redistributed among the parameters that have non-zero risk.

Table 1, below, illustrates the formulas used to calculate the indicators along with the nomenclature used.

Information regarding water quality analyzes arising from the monitoring process carried out by the Basic Sanitation Service Provider is received by the Agency monthly in Microsoft Excel® spreadsheets. A script, in Visual Basic, for reading data was developed to process the information and subsequently calculate the indicators. For visualization, three panels (dashboard) were built according to the spatial scope in which performance was to be analyzed.

The calculation of indicators is carried out for water control analyzes carried out according to the points established by current regulations, thus, the indicators are generated for two specific points of the system separately, the treatment outlet and the distribution network, allowing for better investigation the location of the problems.

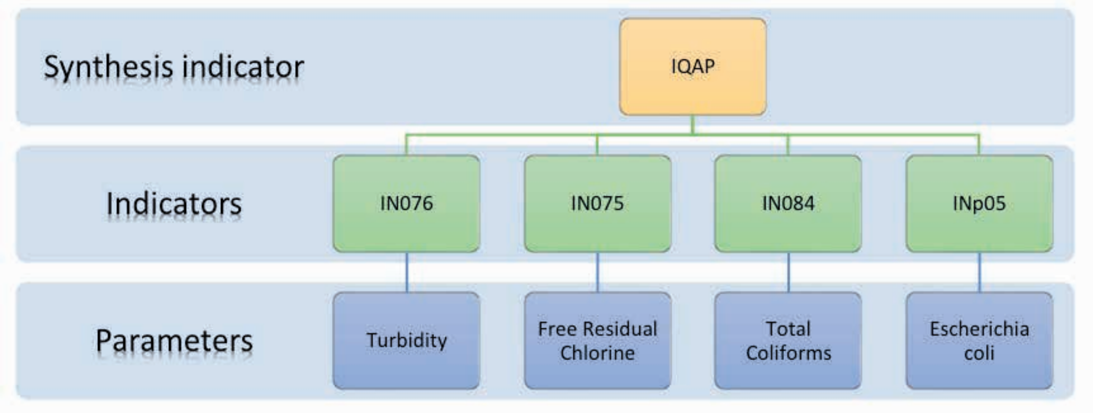

Figure 1 – System of indicators for assessing water treatability

Source: Sanitation and Solid Waste Coordination -Arpe, 2023

Indicator	Description	Origin	Calculation formula
IN075	*Incidence of non-standard residual chlorine analyzes*	SNIS	$$IN075 = \left(\frac{QD007}{QD006}\right) \times 100$$ QD007 -- Number of samples for non-standard residual chlorine (analyzed) QD006 - Number of samples for residual chlorine (analyzed)
IN076	*Incidence of non-standard turbidity analyzes*	SNIS	$$IN076 = \left(\frac{QD009}{QD008}\right) \times 100$$ QD009 - Number of samples for non-standard turbidity (analyzed) QD008 - Number of samples for turbidity (analyzed)
IN084	*Incidence of non-standard total coliform analyzes*	SNIS	$$IN084 = \left(\frac{QD027}{QD026}\right) \times 100$$ QD027 - Number of samples for non-standard total coliforms (analyzed) QD026 - Number of samples for total coliforms (analyzed)
INp05	*Incidence of non-standard E. coli analyzes*	Arpe	$$IN_P05 = \left(\frac{QD_P009}{QD_P010}\right) \times 100$$ QD_p009 - Number of samples for non-standard E. coli (analyzed) QD_p010 - Number of samples for E. coli (analyzed)

Journal of Engineering Research ISSN 2764-1317 DOI: https://doi.org/10.22533/at.ed.3174624230210

IQAP	*Drinking water quality index*	Arpe	$$IQA_p = \sum_{i=1}^{n}[(1-q_i) * w_i]$$ $$\sum_{i=1}^{n} w_i = 1$$ $$R_i = Severity\ (S)\ x\ Occurrence(O)\ x\ Danger(D)$$ $$R_{total} = \sum_{i=1}^{n} R_i\ .:\ w_i = \frac{R_i}{R_{total}}$$ where.: n - number of water quality parameters evaluated locally at SAA i - parameter evaluated q_i - Incidence of non-standard analyzes of parameter i w_i - Weight assigned to parameter i R_i - Risk that parameter i offers

Table 1 – Indicator calculation scheme

Source: Sanitation and Solid Waste Coordination -Arpe, 2023

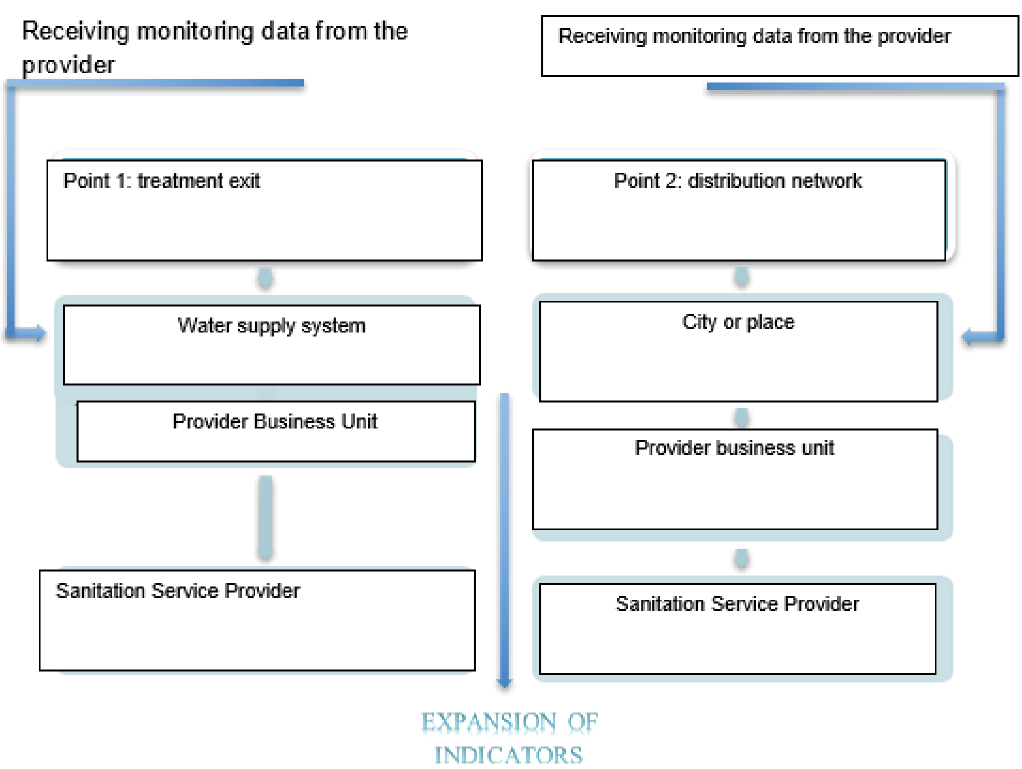

Figure 2 – calculation of indicators by spatial coverage

Source: Sanitation and Solid Waste Coordination– Arpe, 2023

Regarding the scope of the indicators, Figure 2 illustrates the unit in which we received the data and its expansion for calculation in larger territorial units, aiming for a more macro evaluation.

RESULTS/DISCUSSION

To evaluate, according to the methodology presented, the provision of basic sanitation services in terms of water treatability performance, we used some performance graphs of the IQAP index and their respective composition indicators, calculated in the annual range from 2018 to 2022 Figure 3 reports the IQAP's performance classified as regular for all years of investigation, and a negative downward trend over the years.

When observing Figure 4, it can be seen that the average IQAP for the years under analysis had a deficit of 24.28% in relation to the 100% maximum excellence and that of the set of indicators that make up the IQAP, IN076 was responsible for approximately 23.46% of the deficit, leaving 0.82% which is made up of the deficit of the indicators: IN084, IN075 and IN_p05. Therefore, the concessionaire achieved excellent performance in terms of bacteriological parameters and free residual chlorine dosage, demonstrating excellent efficiency in eliminating viruses and bacteria, given that the average IN084 deficit was 0.66%. In relation to IN076, the deficit shows a difficulty in obtaining the standard of 0.5 NTU in 95% of samples for some regions, showing that it may be exposed to problems related to this non-compliance. Figures 5 and 6 show the results of the indicators for the distribution network.

Analyzing Figure 5, it is seen that for the 5 years analyzed, service provision in terms of water treatability in the distribution network obtained an excellent rating, presenting an IQAP of 92.74% for 2018 and in the remaining years an average of around 95% excellence. As shown in Figure 6, the average deficit in the IQAP for the distribution network was 5.37%. Again, IN076 obtained the highest percentage of the deficit, but this time accounting for only 3.82%, and the remaining 1.55%, distributed among the other indicators. The concessionaire achieved an IQAP at a level of excellence in the distribution network, different from the treatment output, which presented a continuous problem in relation to the IN076 indicator.

Evaluating a smaller spatial scope, Figure 7 reports the IQAP calculation for the provider's business units, it is possible to verify that six managements had IQA classified as poor.

The explanation for a below-average performance is that, for the administrations of Alto do Capibaribe, Ipojuca, Agreste Central, Russas and Agreste Meridional, which belongs to the **northeastern agreste region, many of the springs used for water supply have collapsed or pre-collapse due to problems related to water scarcity, which often increases the turbidity of the water** significantly, making clarification difficult, especially if the treatment is not conventional.

Taking into consideration, the results of the performance assessment through the indicator systems for water treatability, Arpe opted for direct inspection for some municipalities in Mata Norte in 2023, since they had a poor IQA and had not been subject to inspection recent.

Taking a general overview in relation to the IN076 indicator in the state of Pernambuco, it is observed that Water Treatment Plants with non-conventional treatment types have difficulty reaching 0.5 uT in 95% of samples for the majority of SAA, and that, even ETAs that have complete treatment, in rainy periods, often fail to reach the standards required by Ordinance GM/MS, number: 888 for indicator IN076.

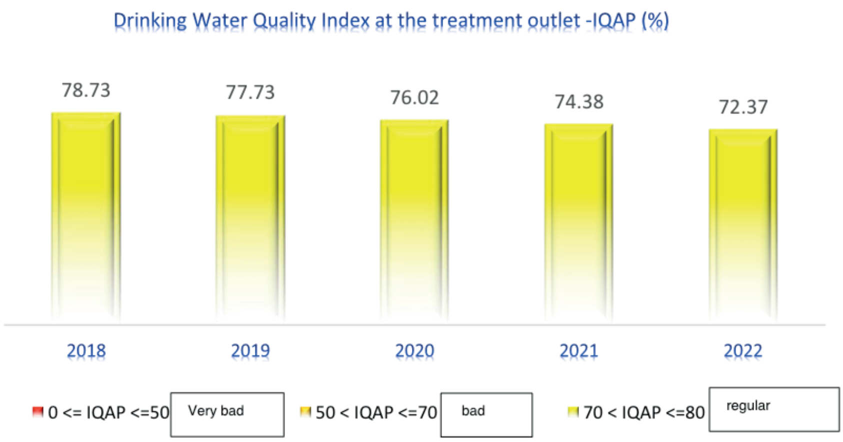

Figure 3 – IQAP (st) annual evolution graph

Source: Sanitation and Solid Waste Coordination -Arpe, 2023

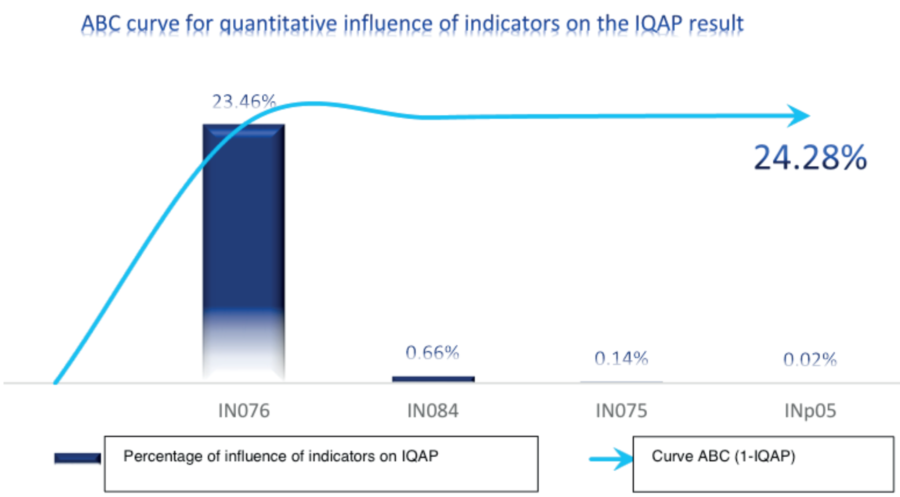

Figure 4 – ABC Curve Graph (1 – IQAP (st))

Source: Sanitation and Solid Waste Coordination– Arpe, 2023

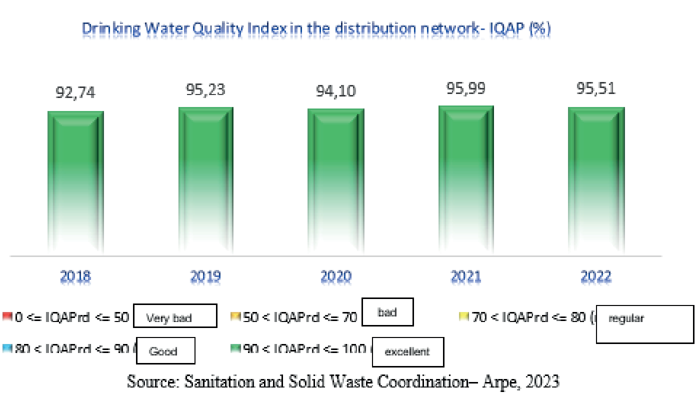

Figure 5 – IQAP annual evolution graph

Source: Sanitation and Solid Waste Coordination– Arpe, 2023

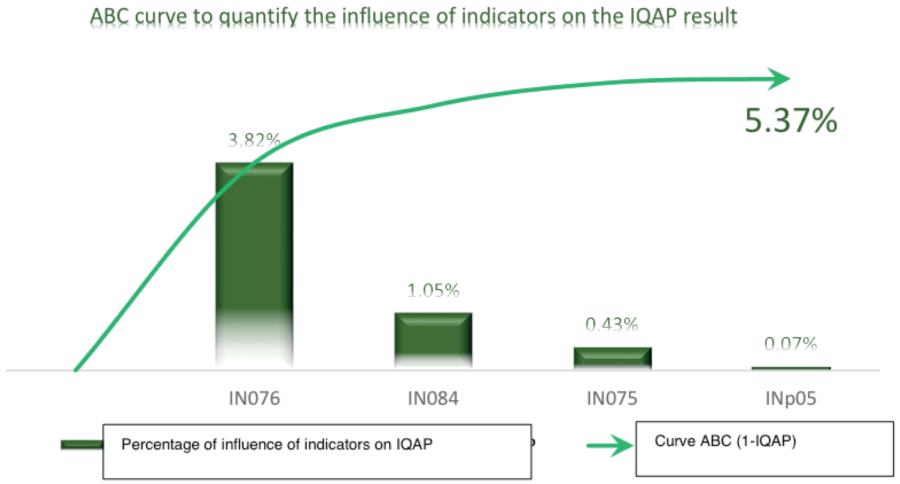

Figure 6 – ABC Curve Graph (1 – IQAP)

Source: Sanitation and Solid Waste Coordination– Arpe, 2023

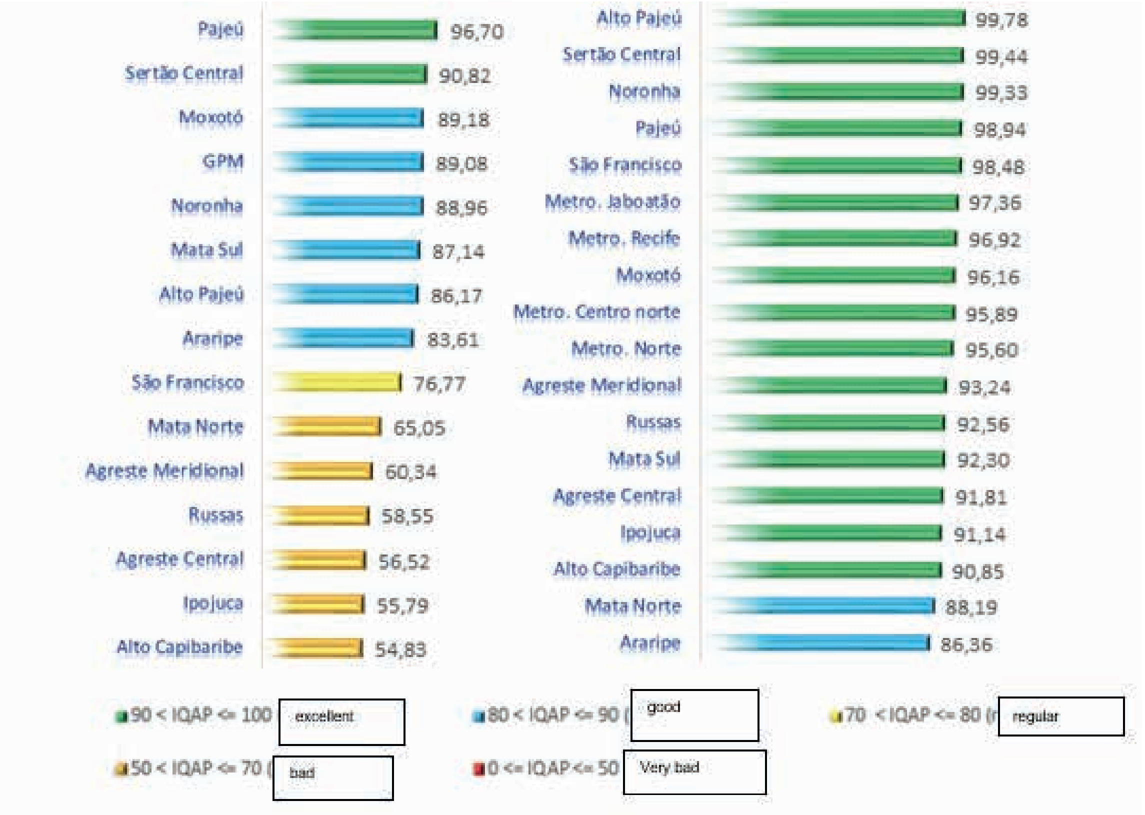

Figure 7- Average IQA (2018 – 2022) calculated to cover business units

Source: Sanitation and Solid Waste Coordination – Arpe, 2023

CONCLUSION

As it was seen through the graphs, the average percentage (2018-2022) of non-conformities for indicators IN084, IN075 and INp05 that impacted the IQAP were respectively 0.66%, 0.14% and 0.02% for treatment exit and 1.05%, 0.43% and 0.07% in the distribution network, highlighting specific problems in relation to water treatment, but it can be inferred that, in general, the SAA presented a good performance in relation to elimination of viruses and bacteria in the water distributed to the population. A systemic problem was verified for indicator IN076, which can be used as an indicator of efficiency in parasitological removal to exit treatment. IN076 was responsible for an average deficiency of 23.46% for the IQAP at the end of treatment, totaling practically the entire deficit obtained.

The use of a system of performance indicators to evaluate the quality of drinking water produced by a SAA proved to be a very useful tool for the type of work carried out by the regulator in basic sanitation. The capacity of the system of indicators to allow the evaluation of performance in terms of water treatability provides several work and analysis instruments, which guarantees the analyst a gain in decision-making, as well as better procedures and supervisory actions, given that deficiencies can be pointed out, reducing the asymmetry of information at the time of inspection, allowing selection and focus on the universe of SAA in worse conditions of production and maintenance of the quality of drinking water. Furthermore, the management of the sanitation sector is quite complex, often requiring joint action from various public sector stakeholders, who are often not aligned with their internal work, much less with other institutions. The preparation of performance reports, their dissemination and availability are interesting elements to narrow the gaps that exist between bodies and provide more efficient and globalized management.

REFERENCES

Libânio, M. (2010). **Fundamentos de qualidade e tratabilidade de água (3ª ed.)**. Campinas, SP.

Ogata, I. S. Avaliação de risco da Qualidade da Água Potável do Sistema de Abastecimento da Cidade de Campina Grande (PB). Trabalho de Conclusão de Curso. Universidade estadual da Paraíba. Campina Grande (2011)

Regulasan. **Curso de avaliação da qualidade, desempenho dos serviços, indicadores e sistemas de informação**. Projeto REGULASAN. Curso III (produto VIII.3). Campinas (2017)

Ministério da Saúde. (2006). **Vigilância e Controle da Qualidade da Água para Consumo Humano**. Brasília, DF. Acesso em 08 de 09 de 2023, disponível em https://bvsms.saude.gov.br/bvs/publicacoes/vigilancia_controle_qualidade_agua.pdf

Alves, A. G., Formaggia, D. M., Fernandes, M. L., Machado, P. A., Souza, R. M. **Padrão de potabilidade: Contexto histórico das portarias de potabilidade, dúvidas, indagações, considerações e preocupações da nova Portaria GM/MS n° 888/21.** Acesso em 06 de julho de 2023, disponível em https://tratamentodeagua.com.br/artigo/padrao-potabilidade-nova-portaria-gm-ms-888-21/

Bastos, R. K. **A norma brasileira de qualidade da água para consumo humano em revisão – um convite à reflexão sob a ótica dos direitos**. Acesso em 05 de julho de 2023, disponível em https://ondasbrasil.org/wp-content/uploads/2020/05/A-norma-brasileira-de-qualidade-da %C3%A1gua-para-consumo-humano-em-revis%C3%A3o-%E2%80%93-um-convite-%C3%A0 reflex%C3%A3o-sob-a-%C3%B3tica-dos-direitos-.pdf