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THE LACK OF STANDARD DEFINITION OF INTERMITTENT WATER SUPPLY SYSTEM: AN OVERVIEW OF THE USED DEFINITIONS IN THE LITERATURE AND BY BRAZILIAN REGULATORY AGENCIES

A ausência de uma definição padrão para sistemas intermitentes de abastecimento de água: Panorama das definições utilizadas na literatura e pelas Agências Reguladoras Brasileiras

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ABSTRACT

There are over 1 billion consumers around the world supplied by intermittent water service, whose operation is hazardous to the public health, can generate inequity in water supply, can reduce infrastructure lifetime, increases the consumers' costs and reduces efficiency of the system. The drawbacks are well-known and despite considerable negative impacts shown before such operation is carrying by several water companies. There is still a considerable gap in the literature that needs to be filled in order to identify a standard definition of intermittent water supply. This paper focus on the identification of how the literature and the Brazilian regulatory agencies are dealing with the lack of a standard definition. A procedure used was a systematic review of definition related to intermittency in the literature and a manual searching process on Brazilian regulatory agencies policies. Our analysis indicated that a missing standard definition of intermittency in water supply results in a wide variety of terms and definitions that are inefficient in the characterization of the problem and are often divergent. We recognize the need for a standard definition of intermittent water supply systems to improve the quality of water services.

Keywords: Discontinuity, Stoppage, water supply, Regulatory Agencies, Brazil.

RESUMO

Mais de 1 bilhão de consumidores ao redor do mundo são abastecidos intermitentemente pelos sistemas de abastecimento de água apesar de sua operação ser prejudicial à saúde pública, gerar inequidade na distribuição de água, reduzir a vida útil da infraestrutura, aumentar os custos repassados aos usuários e reduzir a eficiência do sistema. As desvantagens descritas anteriormente são bem conhecidas, entretanto, diversas companhias de água ainda utilizam essa operação. Em se tratando da literatura relacionada, identifica-se a ausência de uma definição padrão para sistemas intermitentes de abastecimento de água sendo, portanto, o objetivo deste trabalho levantar o problema sobre a indefinição de como a literatura e as agências reguladoras brasileiras lidam com a falta da definição padrão. A metodologia utilizada foi a revisão sistemática da literatura, sobre as definições de intermitência, como também o processo de pesquisa manual das definições documentadas pelas agências reguladoras. Identificou-se neste trabalho que a ausência de uma definição padrão resulta em uma ampla variedade de termos e definições ineficientes e geralmente divergentes para a caracterização do problema. Há, portanto, a necessidade de uma padronização na descrição e na abordagem da intermitência a fim de que os serviços de abastecimento sejam melhorados.

Palavras-chave: Intermitência, descontinuidade, abastecimento de água, Agências reguladoras, Brasil.

1. INTRODUCTION

According to the United Nations Committee on Economic, Social and Cultural Rights (UNITED NATIONS, 2002), "the human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses"(UNITED NATION, 2002, p. 1). The United Nations Water (2018) defines sufficiency as a right to access water any time of day or night and in sufficient quantity, therefore, as a guarantee of the human right, continuous operation of water supply system is more appropriate than intermittent operation.

Intermittent water supply (IWS) has some disadvantages, such as the related to the lack of supply guarantees, and some consequences of the operation, e.g. increase of peak demand flow, reduced lifetime of hydraulic components, reduced pressure (ILAYA-AYZA et al, 2016a), consumers' coping costs, water contamination, inequitable water distribution, malfunctioning of water meter (TOTSUKA; TRIFUNOVIC; VAIRAVAMOORTHY, 2004) and development of air pockets in the pipes (NELSON; ERICKSON, 2017).

Despite the well-known drawbacks of IWS, World Health Organization and United Nations Children's Fund (2000) estimated that more than half of Asian systems, and one-third of African and Latin-American water supply systems (WSS) are operated intermittently. Recent estimative of Bivins et al. (2017) shows that approximately one billion people were exposed to IWS in 2015, from which most of them were in Asia, Africa, and Latin-America.

Although IWS is still a reality for many countries, its reference in the literature is limited when compared to the extensive literature of the continuous operation. It is possible to classify the IWS references according to their research focus: hydraulic modelling, optimization model to WSS, hydraulic properties, water quality, management of WSS and social aspects. Lieb, Rycroft and Wilkening (2016) analysed hydraulic modelling of transient flow in IWS, while Cabrera-Bejar and Tzatchkov (2009) and Shrestha (2012) focused on hydraulic modelling of network's filling and emptying process. Optimization models were developed to improve equity in supply, resiliency and mechanical reliability of water distribution networks (SOLGI et al., 2016) and to identify some optimal supply schedule (ILAYA-AYZA et al., 2016b), network design (CHANDAPILLAI; SUDHEER; SASEENDRAN, 2012) and rehabilitation scheduling (SHIRZAD; TABESH; ATAYIKIA, 2017). Some hydraulic properties as the variation of Hazen-Williams coefficient and the relation between leakages and IWS were studied by Sashikumar, Mohankumar and Sridharan (2003) and Al-Ghamdi (2011), Shirzad et al. (2013) respectively. In water quality topic, Goyal and Patel (2015) developed a methodology to compute the residual chlorine at critical nodes of WSS, Kumpel and Nelson (2013) tested water samples of IWS and continuous supply for contamination and physical-chemical properties, and Bivins et al. (2017) and Caprara et al. (2009) explored the relationship between IWS and waterborne diseases. Risk analysis of water supply (ALAYOUBI, 2015), design parameters (VAIRAVAMOORTHY; GORANTIWAR; MOHAN, 2007) and conceptual approach for transforming IWS in continuous (KLINGEL; NESTMANN, 2014) are some researches about management of IWS. Britto, Johnsson and Carneiro (2016) discussed the hydro-social scarcity.

When we analyse cases of IWS it is clear that each of them is a result of different conjuncture and has differences in dimension, frequency, intensity, and consequences. In spite of that, few researchers have addressed the question of a more detailed definition and classification of IWS, resulting in a superficial definition for a complex problem. In Brazilian context, regulatory agencies of water supply systems have the same obstacle to improve the supply service and the legal aspects of regulation.

The lack of an adequate and standard definition of IWS contributes to the unawareness of the consequences caused by its operation and underestimate the need for a discussion, besides causing difficulties in identifying the existence of the problem. An adequate and standard definition of IWS is necessary for a better understanding of the issue besides helping to overcome the problem. A satisfactory definition promotes a better understanding of possible causes, consequences, and solutions for each situation. The definition should be general enough to include all the related cases, but also specific to distinguish the cases according to the main characteristics of the IWS. Identifying the

fragility of definition and classification of IWS, this paper has analysed how these issues are presented in the literature and how Brazilian regulatory agencies of water supply services describe them.

2. METHODS

The development of the survey material proceeded in two phases. First, papers about IWS were trialled adopting an explicit protocol, to find the definition of intermittency in the water supply using an international database. In the second step, we conducted a search of definitions elaborated by each of the state regulatory agencies in Brazil.

International IWS studies

The first phase was conducted by the software StArt 2.3.4 (State of the Art through Systematic Review) (FABBRI et al., 2016) and followed two main steps: planning and execution.

In the planning step, the StArt is composed by 4 topics: a protocol with the objective of the systematic review, main question related to the research scope, sources selection criteria and identification of database.

The execution phase includes studies identification, selection of accepted papers according to the planning step, and extraction of the required information which will compose this research.

To find a definition of IWS in the literature we used Science Direct, Scopus and Web of Science as search engine database, and we queried with the keyword "intermittent and water and supply". There was found 375 articles published until May 2018, from which 67 are related to intermittency in the water supply systems. From those, only 25 articles discuss the definition, and, therefore, they composed this paper.

Brazilian regulatory agencies context of IWS

In Brazilian regulatory agencies context, the "search engine" was a manual process of searching standards, resolutions, technical notes and other documents related to IWS of each state regulatory agency. During this step, we searched the information on the regulatory agencies, water companies, city hall and state government websites.

In a second step of the search, we contacted the agencies by e-mail or by the ombudsman when no information about definition and classification was available on the internet. All the required information about public administration should be made available according to the Federal Law nº 12527/2011, Access to Information Law.

RESULTS AND DISCUSSIONS

International IWS studies

When we analyse results of the systematic review process, we identify a definition of IWS in 25 articles, which 15 define intermittency as a piped water supply for a period of time less than 24 hours per day. One of them also distinguished IWS by its causes, for example, inadequate access to water, energy and distribution deficiencies, pipe breakages and poor governance (BIVINS et al., 2017). Three definitions indicate the lack of supply and the rotation supply to different zones as main characteristics of IWS (SASHIKUMAR; MOHANKUMAR; SRIDHARAN, 2003). Two papers relate IWS with an inability of the system to continuously maintain positive pressure in water supply network (ERICKSON et al., 2017; WALTER; MASTALLER; KLINGEL, 2017). Kumpel and Nelson (2014) define intermittency as a supply cycle process that consists of 4 stages: pipes at atmospheric pressure when they are empty, transition process when they are filling, water network pressurized when there is supply and depressurize when pipes are emptying. Others 5 define IWS as a method of controlling water demand (VAIRAVAMOORTHY et al., 2007), and 4 define as the increasing of demand compared with the supply capacity (BATISH, 2003). The study of Soltanjalili et al. (2013) identified two terms: "hedging" and "intermittency", which hedging means delivering an amount of water between zero and demand and intermittency means supplying the full demand or stopping distribution. Figure 1 shows a classification of presented definitions according to their keywords.

Brazilian regulatory agencies

The lack of a unified definition of IWS is easily identified within the legislation of regulatory agencies of water supply operations in Brazil, and its consequences

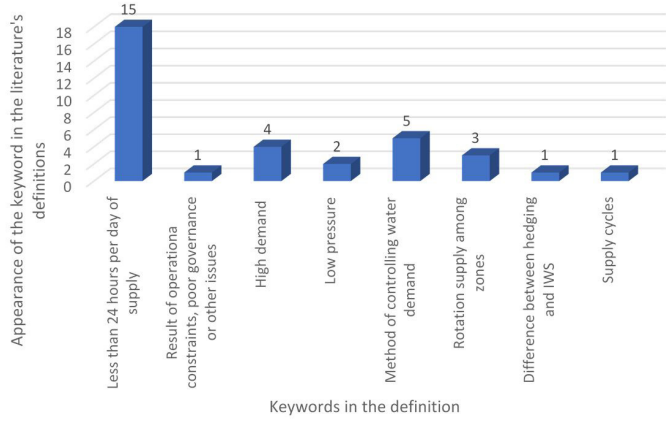

Figure 1 – Classification of the literature's IWS definitions according to their keywords.

are harmful to the benchmarking and to the clarity of regulation's system. In our study, we identified that 11% of the 26 states plus the federal district does not have a state regulatory agency for water supply services, there was not found any information about intermittency in 19% of states, 30% does not have a definition of IWS and 41% has a definition. Table 1 describes the main information of each state regulatory agency while Figure 2 shows the result obtained for the IWS search.

As can be seen, only 11 states have a definition developed by their state regulatory agency. Among them, there were 11 different terms for intermittency in water supply: continuity, regularity, interruption, long-term interruption, water supply stoppage, discontinuity, scheduled interruption, scheduled event of water supply stoppage, unscheduled interruption, individual case of water supply stoppage and the definitions of discontinuity based on excluded cases. They are detailed below.

"Continuity" is used by 3 regulatory agencies (ADASA, AGENERSA, ARSAE and ARCE) and for all of them, it means an uninterrupted water supply service.

The term "regularity" is used as a satisfactory quantity and quality of water supply by 2 agencies (ARCE and AGENERSA), and also as a preservation of water supply asset and environment for ADASA.

"Interruption" is related to the individual cases of water supply stoppage for AGERSA and AGRESE, and, according to AGEPAN, it is related to the supply interruption caused by network improvements and maintenance such as by fortuitous event or force majeure.

"Long-term interruption" is described by AGERGS as a shortage of 12 consecutive hours or more, except for scheduled, emergency or public calamity cases of supply interruption.

"Water supply stoppage" is the term used by the regulatory agency ARSAE, it is similar to the "long-term interruption" of AGERGS, but it is a shortage of more than 12 consecutive hours.

ARSAL, AGERSA and AGEPAR do not consider "discontinuity" when the stoppage is caused by network improvements and maintenance operations, when consumers improperly manipulate hydraulic equipment of water supply network, when consumers are supplied by an alternative source, or when consumers violate any clause of the contract with the water facility.

"Discontinuity" means the interruption of water supply or when the supply system is working but the pressure at the node is not enough to supply, according to ARSESP.

ARSESP also uses the term "scheduled interruption" to the supply interruption caused by network improvements and maintenance such as replacement of pipes, valves and pumps, repairs and network expansion. ARSI elaborated 3 terms to classify intermittency in the water supply: "scheduled event of water supply stoppage", which is caused by

Table 1 – Information of Brazilian State Regulatory Agency

State	Regulatory agency	Status
Acre	AGEAC	No information was found
Alagoas	ARSAL	There is definition
Amapá	ARSAP	No information was found
Amazonas	There is no state regulatory agency for water services	--
Bahia	AGERSA	There is definition
Ceará	ARCE	There is definition
Espírito Santo	ARSI	There is definition
Federal District	ADASA	There is definition
Goiás	AGR	There is no definition
Maranhão	MOB	There is no definition
Mato Grosso	AGER	There is no definition
Mato Grosso do Sul	AGEPAN	There is definition
Minas Gerais	ARSAE	There is definition
Pará	There is no state regulatory agency for water services	--
Paraíba	ARPB	No information was found
Paraná	AGEPAR	There is definition
Pernambuco	ARPE	There is no definition
Piauí	AGRESPI	No information was found
Rio de Janeiro	AGENERSA	There is definition
Rio Grande do Norte	ARSEP	There is no definition
Rio Grande do Sul	AGERGS	There is definition
Rondônia	AGERO	No information was found
Roraima	There is no state regulatory agency for water services	--
Santa Catarina	ARESC	There is no definition
São Paulo	ARSESP	There is definition
Sergipe	AGRESE	There is definition
Tocantins	ATR	There is no definition

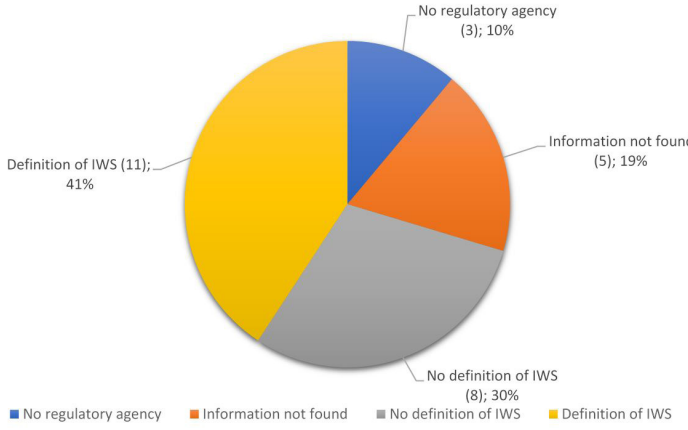

Figure 2 – Results obtained for the IWS search in the Brazilian regulatory agencies.

network improvements and maintenance operations, "unscheduled interruption", caused by incidents, externalities, emergency or public calamity cases and "individual case of water supply stoppage" related to the stoppage of a specific consumer.

Figure 3 presents the main keywords of the definitions elaborated by Brazilian Regulatory Agencies.

When we analyse the definitions found in the literature review and in the regulatory agencies files, it is possible to identify a lack of convergence between them. In some cases, the descriptions are contradictory, for example, when we compare the definition of "interruption" by AGEPAN, which is caused by network improvements, and the definition of "discontinuity" of AGERSA and ARSAL, which includes all the cases of stoppage, except the ones caused by network improvements. Another divergence is related to the scope of terms, some approaches describe IWS in a restricted perspective, an example is the definition of intermittency as a stoppage caused only by system improvements, conversely, others cover a very broad range of situations, as when intermittency is related to any case of interruption of WSS. ARSESP and ARSI also use terms related to IWS in a distinguished circumstance, where the stoppage is associated to the improvement operations of the WSS and not to a degradation process, showing the diversity and complexity of IWS cases.

As described above, there are different approaches to IWS, resulting in distinct definitions. In order to have a better understanding of the perspectives found in the literature and in the Brazilian Regulatory Agencies, Figure 4 shows which characteristic each definition is based on.

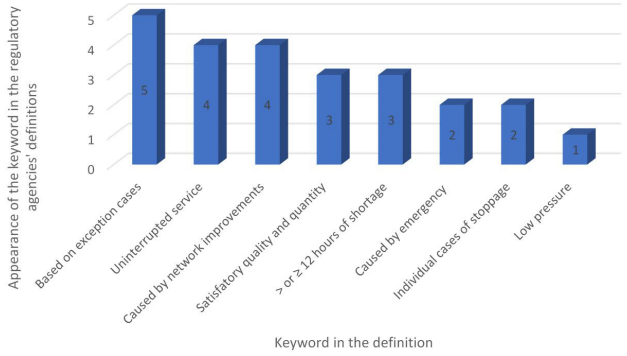

Figure 3 – Classification of the Brazilian regulatory agencies' IWS definition according to their keywords.

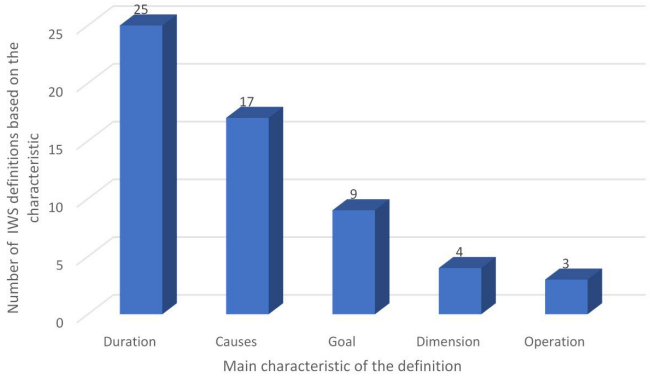

Figure 4 – Classification of the IWS definitions according to the characteristic which they are based on.

The characteristics are duration of stoppage, that in some cases is 12 hours or more; causes of IWS operation, including operational constraints, and poor governance; goal of IWS operation, e.g. to address the shortfall between supply and demand; geographic dimension of stoppage, that could be individual or supply zones, and operational process of IWS, that defines intermittency from a hydraulic perspective.

Because all definitions use one or maximum two characteristics to describe IWS, their point of view is too restrict resulting in an oversimplified or a very specific categorization. Furthermore, none of the definitions explicitly analyses the frequency of stoppage that is an important characteristic of IWS systems due to its direct relation to the consequences for consumers and lifespan of the infrastructure.

5. CONCLUSION

Although there are several different research approaches to IWS in the literature, only a few define intermittency, and most of the definitions are too ample vague, e.g. "less than 24 hours per day water supply".

A well-structured definition is a key aspect of solution and improvement related to the different aspects of IWS (social, technical, economic and ecological), and it is the background of effective policies and legislation against intermittency.

In a Brazilian scenario, the results show that the state regulatory agencies are in an incipient stage of IWS discussion. The problems found are the inexistence of a state regulatory agency, the lack of transparency in the gathered information and the lack of IWS definition. Eleven of twenty-six states plus federal district define some terms related to the intermittent water supply, and among them, there is no commonly accepted standard.

Given that, the main responsibility of regulatory agencies is to ensure the quality of water supply services through inspection and the establishment of norms and standards, it is necessary a unique and a verifiable definition of IWS.

Some of the definitions found are too broad resulting in a difficulty to deal with the variety of cases and making their inspection and analysis infeasible. An important characteristic missing in the definitions is the frequency and the duration of stoppages without which the categorization of cases is inefficient. These aspects also directly affect the lifespan of hydraulic equipment, the management and equity of supply and the consumers' coping costs.

Therefore, despite intermittency operation being a very common condition in developing countries, and its well-known drawbacks, the IWS definition is still underestimated resulting in a wide variety of terms and definitions that are often divergent.

This study, therefore, indicates the need for a more in-depth discussion of IWS. Because it is a very complex water supply operation, the elaboration of IWS categories based on its cause, duration, goal, dimension and operation as well as current cases-study of IWS could be the background fora better standardized definition.

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