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BIBLIOMETRIC ANALYSIS ON MULTICRITERIA DECISION SUPPORT FOR PRIORITIZING WATER METER REPLACEMENT

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ABSTRACT

A bibliometric analysis was carried out motivated by a research that aims to identify the existence of scientific publications with the theme of multicriteria decision support method for the prioritization of the replacement of water meters in a given territorial region of operation of a state sanitation company, which provides the increase (maximization) of revenue, through the effective reduction (minimization) of apparent losses in water supply systems, caused by the under-measurement of these meters. Thus, the present work uses the Knowledge Development Process-Constructivist – ProKnow-C method, which establishes the procedures, in a structured way, for the selection of the bibliographic portfolio (BP) and its respective analysis, allowing the development of the necessary knowledge to fulfill the motivation of the research. 44 relevant articles were identified and aligned with scientific research and recognition, published between 2005 and 2024. In addition to the selection of articles, the present study carried out a bibliometric analysis, which consists of counting the occurrence of certain variables (characteristics) in the final publications of the BP. With the results, it is possible to quantify existing information and map the structure of knowledge in a scientific field, also serving to build the initial base of research information and identify future scientific opportunities.

Keywords: Water meter, Multicriteria decision support, Bibliometric analysis.

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INTRODUCTION

One of the major concerns today is water scarcity in different territories, which imposes challenges for water utilities in the search for solutions to ensure that the required demand is met with the available water supply. However, if on the one hand efforts and financial resources must be made to expand supply, demand must also be managed, especially in the search for reducing water losses (COSTA NETO et al., 2021).

Water losses in the water supply system can occur in two different types, namely: real losses – caused by leaks in the pipes, overflows and leaks in the reservoirs – and apparent losses – caused by fraud, clandestine connections and errors in measuring the volume of water. The latter causes, in most cases, caused by the inefficiency of the measurement or losses due to under-measurement of the water meters (LAMBERT; HIRNER, 2000).

The first activity suggested by RIZZO et. al. (2007), to reduce apparent water losses, is directly related to the metrological reliability of water meters, which suggests the continuous analysis of the measurement reading data, the execution of periodic maintenance and calibrations, finally, the replacement of water meters, perhaps, do not have financial viability to remain installed, due to the high measurement error.

In this context, depending on the number of water meters installed in the water supply system of a given territorial region, added to the high cost of maintenance and replacement of this equipment, it is essential to use a method that provides decision support to the system manager, in which he can use multiple criteria for the elaboration of a prioritization list for the replacement of water meters, that provides an increase (maximization) of revenue, through the effective reduction (minimization) of apparent losses, which is the theme that motivates this work.

Thus, the following question arises: how to seek and identify necessary information on a given topic, when the researcher has little knowledge, but adopts a certain worldview – theoretical affiliation – so that it is possible to investigate recognized and relevant publications?

In order to answer this question, the general objective of this work is to demonstrate how a researcher can use the investigative process *Knowledge Development Process-Constructivist (ProKnow-C)* proposed by Ensslin et al. (2010), which establishes the procedures, in a structured way, to select relevant articles and identify characteristics of these publications that will contribute scientifically to the fulfillment of the motivation of the

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research. To this end, the following specific objectives were formulated: (a) to select a defined set of publications, which will be entitled Bibliographic Portfolio (PB), with relevance to the theme: support for multicriteria decision for prioritizing the change of water meter; and, (b) to carry out a bibliometric analysis of the BP and the references of each BP publication, based on the quantitative disclosure of certain parameters about the BP publications for the management of information and scientific knowledge. The observable parameters are: the selected articles, their references, authors, number of citations and most relevant journals and their respective impact factors in the area of interest, as well as the most recurrent keywords (ENSSLN et al., 2010).

Thus, this article presents five sections, in addition to this introduction. In the following section you will find the methodology, with the presentation of the methodological framework and method adopted. In the third section, there are the results of the selection of the Bibliographic Portfolio and bibliometric analysis. The fourth section presents the final considerations and recommendations for future work. Finally, the work ends with the section of bibliographic references used throughout the text.

METHODOLOGY

The methodological framework and the method used for the development of this research are presented.

METHODOLOGICAL FRAMEWORK

It aims to present and clarify the methodological procedures used during the research, in the dimensions: nature of the research (research regarding the results), approach to the problem, research based on the general objective (nature of the objective) and technical procedures.

The nature of the research is of the theoretical-illustrative type, because it presents a process to carry out the bibliographic search with emphasis on the researcher's theme, through a guiding guide, with steps to be followed for the bibliographic searches on the problem of multicriteria decision support for prioritizing the change of water meter, adding a practical case of application of the bibliometric analysis process (ALAVI; CARLSON, 1992).

The approach to the problem is qualitative and quantitative, as there is a qualitative analysis in the process developed to identify the articles in the bibliographic portfolio and

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their references, and a quantitative analysis occurs in the count of the variables investigated.

The research is based on the general objective, characterized as exploratory and descriptive (RICHARDSON, 2017). It is exploratory research, because initially, it promotes reflection and generates knowledge for the researchers, that is, for the main agents of the research, who establish the delimitations – theoretical affiliation adopted – for the selection of the material analyzed: the bibliographic portfolio. In the second moment, it delimits the scientific community by illustrating step by step the operationalization of the Proknow-C investigative process. It is descriptive research, as it aims to describe and identify the characteristics of the research problem, through the survey of the bibliographic portfolio and its references.

The technical procedure adopted is scientific research based on the search for scientific publications indexed in the databases made available by the Coordination for the Improvement of Higher Education Personnel (CAPES).

METHOD ADOPTED

Gil (2008) defines "[...] method as a way to reach a certain end. And scientific method as the set of intellectual and technical procedures adopted to achieve knowledge". From these definitions, it is intended to present the method to solve the research problem described in the general objective.

Or *ProKnow-C* It is used for the selection and analysis of the literature review. It consists of four tasks: (i) selection of bibliographic portfolio; (ii) bibliometric analysis of the portfolio; (iii) systemic analysis; and (iv) definition of the question and research objective (ENSSLIN; ENSSLIN; PACHECO, 2012). The **Erro! Fonte de referência não encontrada.** presents the four tasks of the *ProKnow-C*. For the purposes of this article, the first two tasks of the *ProKnow-C*. Thus, part of the necessary knowledge about the researched theme was built.

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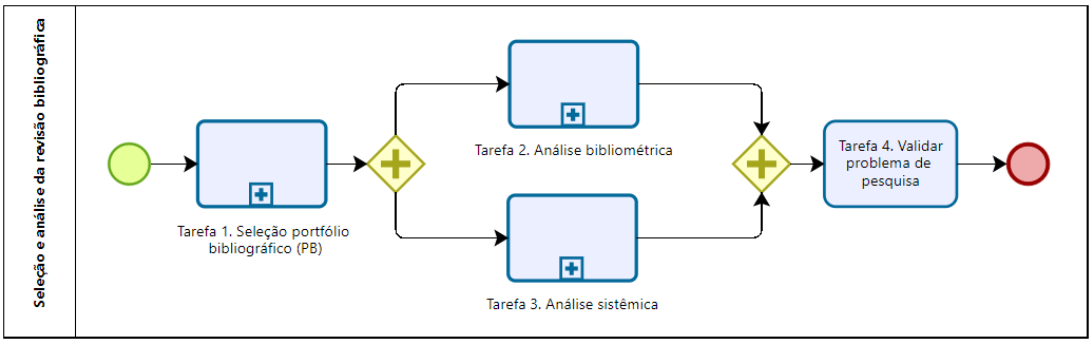
FIGURE 1. PROKNOW-C TASKS.



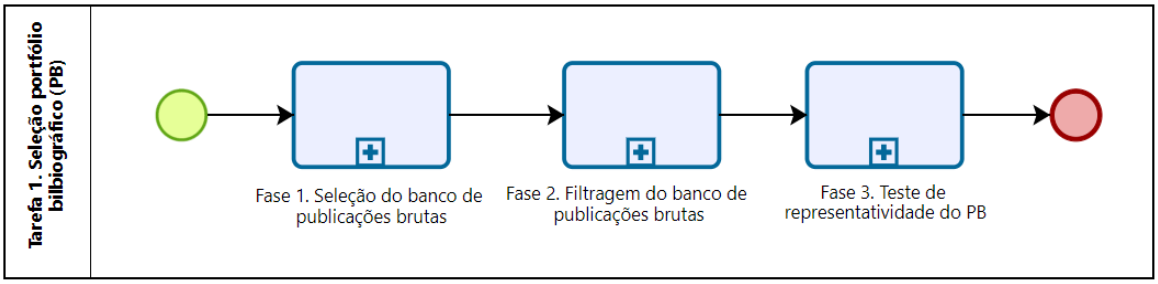
CAST IRON: ADAPTED FROMENSSLIN ET AL. (2010).

RESULTS

TASK 1. BIBLIOGRAPHIC PORTFOLIO SELECTION (PB)

It consists of obtaining a portfolio of publications aligned with the research theme and with scientific recognition. The **Erro! Fonte de referência não encontrada.** describes this task, which is carried out in three phases (KUSTERKO, 2015): (i) the selection of articles in the databases that make up the Gross Article Bank; (ii) the filtering of the selected articles based on the alignment of the search; and, (iii) the PB representativeness test.

FIGURE 2. PHASES OF THE BIBLIOGRAPHIC PORTFOLIO (PB) SELECTION.



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For this research, the following delimitations were used:

- Search field: article *title*, abstract and/or keywords;
- Temporal: publications from January 2005 to November 2024;
- Sources: databases aligned with the research theme described in the general objective;
- Types of publications: journal and conference articles, dissertations and theses;
- Availability: only publications available in full; and

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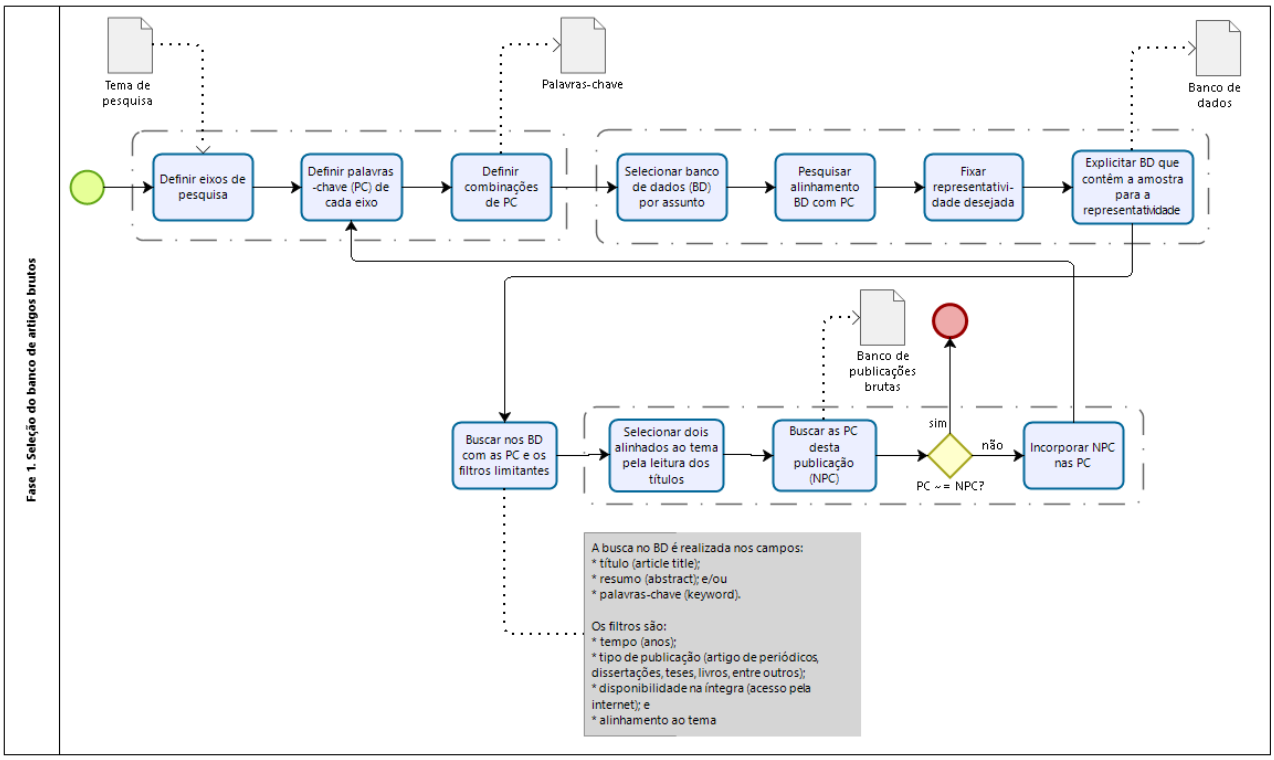
- Alignment with the theme according to the researcher's perceptions during the study: definition of keywords, reading of titles, reading of abstracts and full reading of the article.

Phase 1: Selection of the raw articles bank

The **Erro! Fonte de referência não encontrada.** presents the process flow for that phase. At this stage, the keywords of the axes of the research theme should be defined. Then, establish the database that will be consulted and search for publications in this database by using keywords. Finish with the keyword adherence test. It is suggested that the information of each publication be exported to the bibliographic manager *Endnote*® 20, in RIS format.

FIGURE 3. PHASE 1 PROCESS FLOW: SELECTION OF THE RAW ARTICLES BANK.



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The adhesion test serves to verify the need or not to include new keyword(s) to the axes. This need is verified through the selection of two publications, a priori, considered adherent to the theme, among which the alignment of the keywords with the research theme should be evaluated. If adherence is not satisfactory, new keywords should be incorporated into the initial ones and the search should be restarted.

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The execution of phase 1 is described below:

- Define research axes: Initially, the axes were chosen, based on the general objective, namely: apparent water losses, sub-measurement of water meters and multicriteria decision support method.
- Define keywords (CP) for each axis and combinations: From the definition of the search axes, the keywords were selected. For the "apparent water losses" axis, the keywords are: loss, water *water and loss*. The "sub-measurement of water meters" axis has the following keywords: hydrometer, "water meter", sub-measurement, "measurement error", *hydrometer, "water meter", under-registration, sub-measurement and sub-metering*. Finally, the keywords were chosen for the "multicriteria decision support method" axis, namely: "multicriteria decision support method", "multicriteria decision support method", "multicriteria decision-making method", *"multiple criteria", multicriteria, multi-criteria, "several criteria" and multicriterial.*
- Select the database: We chose to use the CAPES Journal Portal. This Portal is a virtual library that brings together and makes available a collection of more than 45 thousand titles with full text, 130 reference databases, 12 databases dedicated exclusively to patents, in addition to books, encyclopedias and reference works, technical standards, statistics and audiovisual content (BRASIL, 2021). Also, the Google Scholar database was selected. This database collects information from repositories of educational institutions, libraries of government agencies and dozens of national and international periods.
- Search for publications to form the database of raw articles: The search took place in December 2024. The search was carried out as described in this phase. Only publications from 2005 to 2024 were analyzed in the selected databases, using keywords in different combinations in the fields of title, abstract, and keywords of the publications, and, as for the type of publication, only journal articles, dissertations, and theses were used. Or **Erro! Fonte de referência não encontrada.** Displays the combinations of keywords used and the number of publications found in the selected database.
- Verify adherence to the research: After the search, two articles were chosen (SZILVESZTER; BELTRAN; FUENTES, 2017 and FONTANAZZA et al, 2015) that had the titles adhering to the research theme, then, the alignment of their respective

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keywords was verified, thus, positively concluding the adherence test, ending this phase without the need to incorporate new keywords to the initial ones, making it unnecessary to search for publications.

Table 1. Keyword combinations and the number of posts found.

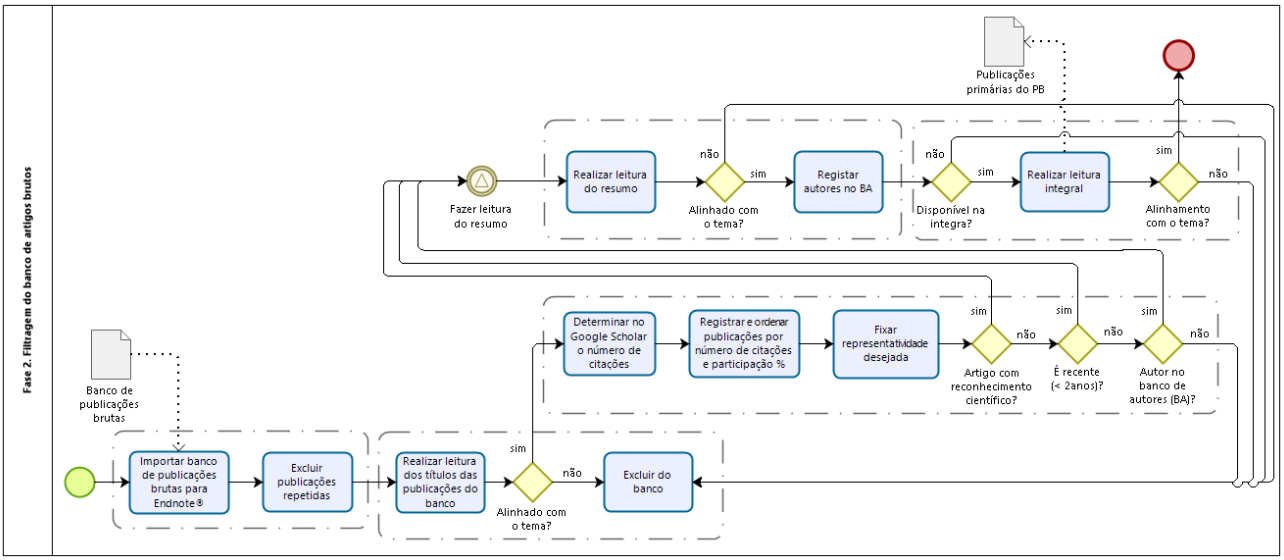
Search with keywords	Google Scholar
multi-criteria water loss (hydrometer *OR* "water meter") (replacement OR exchange) (sub-metering *OR* sub-metering *OR* "measurement error")	9
water loss "water meter" (substitution OR replacement) ("multiple criteria" OR multicriteria OR multi-criteria OR "several criteria" OR multicriterial)	273

SOURCE: OWN AUTHOR.

Phase 2: Filtering the raw goods bank

The Figure 4 presents the process flow for that phase. It is proposed to filter the raw article bank according to the following aspects (ENSSLIN; ENSSLIN; PINTO, 2013): (i) redundancy (exclusion of repeated publications); (ii) alignment of the titles of the publications with the theme (exclusion of non-aligned titles); (iii) scientific recognition of publications; (iv) alignment of the abstracts of the publications with the research theme; and, (v) availability of the publications in full in the databases.

FIGURE 4. PHASE 2 PROCESS FLOW: FILTERING OF THE RAW GOODS BANK.



CAST IRON: ADAPTED FROMENSSLIN ET AL. (2010).

To filter redundancy, title alignment, and abstract alignment, it is suggested to use the *Endnote*® 20 bibliographic manager. To verify scientific recognition, a Google *Scholar query* was performed to survey the number of citations of each publication.

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It is suggested the creation of a spreadsheet, in which the publications, selected in terms of compliance with the alignment of the title, should be ordered in descending order according to the number of citations. Next, the selection of publications that have the value of the sum of their citations within a percentage of 80% of the total accumulated participation of citations must be carried out. That is, prepare a Pareto graph with a y-axis representing the sum of citations of each publication and select only the publications that occupy the most significant 80%. For these publications, the authors were extracted from the Authors Bank (BA).

For publications with scientific recognition to be confirmed, it is necessary to carry out a reanalysis, accepting the inclusion of recent publications (less than two years) whose title and abstract were aligned with the theme and/or with authors present in the BA.

Finally, the alignment of the publications in full with the theme of the research should be verified, and it is suggested that all these publications be read in full. After this reading, those that are not aligned with the theme should be excluded.

The execution of phase 2 is described below:

- Filter raw articles: In this phase, which occurs after the adherence test, it began with the analysis of 282 (two hundred and eighty-two) publications, excluding repeated ones. Then, the titles were read and 100 (one hundred) publications aligned with the theme were found, then the scientific recognition of the publications was verified, through the number of citations of each publication in *Google Scholar*, with 29 (twenty-nine) publications being selected that are among the 80% most significant. Then, 19 (nineteen) publications were identified with alignment of the abstracts with the theme, only a single publication was not available in full in the database, thus, the remaining 18 (eighteen) publications were read in full and it was identified that all are aligned with the theme described as a general objective.

Phase 3: Bibliographic Portfolio (BP) representativeness test

The Figure 5 presents the process flow for that phase. This phase consists of analyzing all references from BP publications in search of a publication relevant to the research that could be incorporated into it. Time restriction and type of publication must be carried out. It is suggested to use the bibliographic manager *Endnote*® 20 to list the references.

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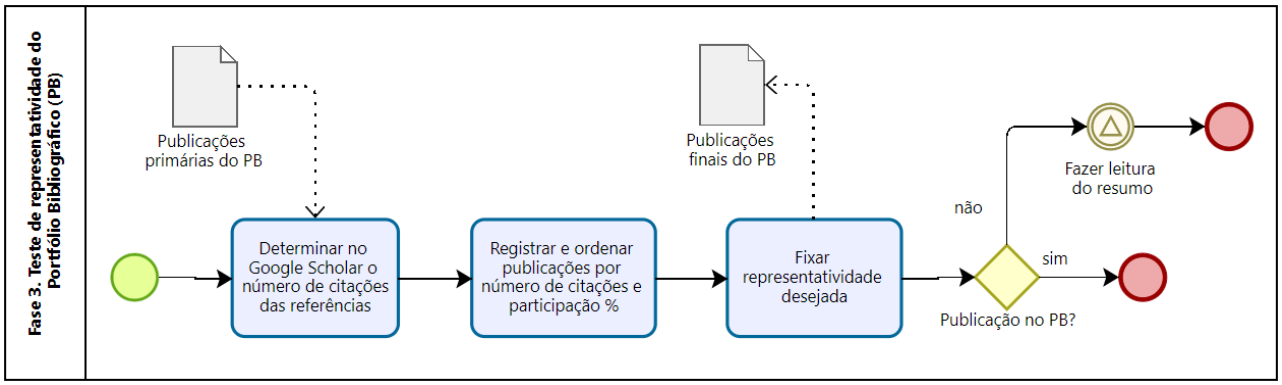
FIGURE 5. PROCESS FLOW OF PHASE 3: TEST OF REPRESENTATIVENESS OF THE BIBLIOGRAPHIC PORTFOLIO.



CAST IRON: ADAPTED FROMENSSLIN ET AL. (2010).

According to Kusterko (2015), the Bibliographic Portfolio is the restricted set of publications with scientific recognition and prominence, with title, abstract and complete content, aligned with a certain theme according to the perception and delimitations of a researcher.

The implementation of phase 3 is described below:

- Test the representativeness of the Bibliographic Portfolio: In this phase, 26 (twenty-six) publications were identified, based on the analysis of the references of the publications identified in the previous phase, aligned with the theme, according to the perception and delimitations of the author of this research, thus, the 18 (eighteen) publications of the previous phase were added, totaling 44 (forty-four) publications of the BP according to Table 2. Thus, the construction of the theoretical framework was completed and the bibliometric analysis was allowed.

Table 2. Publications of the Bibliographic Portfolio (PB).

No.	BP Description
1	ARREGUI, F. J.; CABRERA, E.; COBACHO, R.; GARCÍA-SERRA, J. *Key factors affecting water meter accuracy*. ***In: Proceedings of the IWA Leakage 2005 Conference***, 2005.
2	ARREGUI, F. J.; CABRERA, E.; COBACHO, R.; GARCÍA-SERRA, J. *Reducing Apparent Losses Caused by Meters Inaccuracies.* ***Water Practice & Technology*****,** v. 1, n. 4, 2006. p. 1-8
3	ARREGUI, F. J.; COBACHO, R.; CABRERA, E.; ESPERT, V. *Graphical Method to Calculate the Optimum Replacement Period for Water Meters.* ***Journal of Water Resources Planning and Management***, v. 137, n. 1, 2011. p. 143-146
4	ARREGUI, F. J.; COBACHO, R.; SORIANO, J.; GARCÍA-SERRA, J. *Calculating the optimum level of apparent losses due to water meter inaccuracies.* ***In: Proceedings of the IWA Water Loss 2010 Conference***, 2010. p. 6-9
5	ARREGUI, F. J.; GAVARA, F.; SORIANO, J.; PASTOR-JABALOYES, L. *Performance Analysis of Ageing Single-Jet Water Meters for Measuring Residential Water Consumption.* ***Water***, v. 10, n. 5, 2018.

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6	ARREGUI, F. J.; MARTINEZ, B.; SORIANO, J.; PARRA, J. *Tools for improving decision making in water meter management.* ***In: Proceedings of the IWA Water Loss 2009 Conference***, 2009. p. 225–232
7	ARREGUI, F. J.; PARDO, M.; SORIANO, J.; PARRA, J. *Quantification of meter errors of domestic users: a case study.* ***In: Proceedings of the IWA Water Loss 2007 Conference***, v. 2, 2007. p. 23-26
8	BEZERRA, F. C. F. **Reduction of Losses Through the Management of Hydrometry in the West Unit of Fortaleza by the Loss Control System**. 2019. Course Completion Work (Specialization) – Federal Institute of Ceará, Fortaleza, CE, 2019.
9	BORGES, E. J. B. **Analysis of the micro-measurement of the volume of household drinking water and its influence on the calculation of losses in the distribution system**. 2007. Dissertation (master's degree in Civil Engineering) – Federal University of Uberlândia, Uberlândia, MG, 2007.
10	CORDEIRO, C.; BORGES, A.; RAMOS, M. R. *A strategy to assess water meter performance*. ***Journal of Water Resources Planning and Management***, v. 148, n. 2, 2022. p. 05021027
11	COUVELIS, F.; VAN ZYL, J. *Apparent losses due to domestic water meter under-registration in South Africa.* ***Water SA***, v. 41, n. 5, 2015. p. 698–704
12	CRIMINISI, A.; FONTANAZZA, C. M.; FRENI, G.; LA LOGGIA, G. *Evaluation of the apparent losses caused by water meter under-registration in intermittent water supply.* ***Water Science & Technology***, v. 60, n. 9, 2009. p. 2373-2382
13	DAVIS, S. *Residential Water Meter Replacement Economics.* ***In: Proceedings of the IWA Leakage 2005 Conference***, 2005.
14	DE MARCHIS, M.; FONTANAZZA, C. M.; FRENI, G.; LA LOGGIA, G. et al. *A mathematical model to evaluate apparent losses due to meter under-registration in intermittent water distribution networks.* ***Water Science & Technology: Water Supply***, v. 13, n. 4, 2013. p. 914-923
15	DEPEXE, M. D.; GASPARINI, R. R. **Determination of annual reduction rates of water meter measurement efficiency**. 23rd AESABESP Technical Meeting, 2012.
16	FANTOZZI, M. *Reduction of customer meters under-registration by optimal economic replacement based on meter accuracy testing programme and unmeasured flow reducers.* ***In: Proceedings of the IWA Water Loss 2009 Conference***, 2009a. p. 233–239.
17	FANTOZZI, M.; CRIMINISI, A.; FONTANAZZA, C. M.; FRENI, G. et al. *Investigations into under-registration of customer meters in Palermo (Italy) and the effect of introducing Unmeasured Flow Reducers.* ***In: Proceedings of the IWA Water Loss 2009 Conference***, 2009b, p. 589–595.
18	FERREOL, E. *How to measure and reduce water meter park efficiency?* ***In: Proceedings of the IWA Leakage 2005 Conference***, 2005.
19	FONTANAZZA, C. M.; FRENI, G.; LA LOGGIA, G.; NOTARO, V. et al. *A composite indicator for water meter replacement in an urban distribution network.* ***Urban Water Journal***, v. 9, n. 6, 2012. p. 419-428
20	FONTANAZZA, C. M.; NOTARO, V. P.; PULEO, V.; FRENI, G. Effects of network pressure on water meter under-registration: An experimental analysis. ***Drinking Water Engineering and Science Discussions***, v.6, 2013. p. 119-149
21	FONTANAZZA, C. M.; NOTARO, V.; PULEO, V.; FRENI, G. *The apparent losses due to metering errors: a proactive approach to predict losses and schedule maintenance.* ***Urban Water Journal***, v. 12, n. 3, 2015. p. 229-239
22	HERNÁNDEZ-GARCÍA, A.; BAZÁN, L. A.; VALERA-TALAVERA, O.; ARREGUI, F. J. *Development of an economic model for the management of water meters installed in battery in supply networks.* ***Water Engineering***, v. 24, n. 1, 2020. p. 1
23	HOVANY, L. *Error in Water Meter Measuring Due to Shorter Flow and Consumption Shorter Than the Time the Meter was Calibrated.* ***InTech***, 2012.
24	KANG, D.; LANSEY, K. *Optimal Meter Placement for Water Distribution System State Estimation.* ***Journal of Water Resources Planning and Management***, v. 136, n. 3, 2010. p. 337-347
25	MBABAZI, D.; BANADDA, N.; KIGGUNDU, N.; MUTIKANGA, H. et al. *Determination of domestic water meter accuracy degradation rates in Uganda.* ***Journal of Water Supply: Research and Technology - AQUA***, v. 64, n. 4, 2015. p. 486-492

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26	MOAHLOLI, A.; MARNEWICK, A.; PRETORIUS, J. *Domestic water meter optimal replacement period to minimize water revenue loss.* ***Water SA***, 45, n. 2, 2019.
27	MONEDERO, I.; BISCARRI, F.; GUERRERO, J. I.; PEÑA, M. et al. *Detection of Water Meter Under-Registration Using Statistical Algorithms.* ***Journal of Water Resources Planning and Management,*** v. 142, n. 1, 2016.
28	MUKHEIBIR, P.; STEWART, R. A.; GIURCO, D.; O'HALLORAN, K. *Understanding non-registration in domestic water meters: Implications for meter replacement strategies.* ***Water***, 2012.
29	MUTIKANGA, H. E. *Decision Support Tool for Optimal Water Meter Replacement.* ***UNESCO-IHE Institute for Water Education***, 2011.
30	MUTIKANGA, H. E.; SHARMA, S. K.; VAIRAVAMOORTHY, K. *Investigating water meter performance in developing countries: A case study of Kampala, Uganda.* ***Water SA***, v. 37, n. 4, 2011.
31	MUTIKANGA, H. E.; SHARMA, S. K.; VAIRAVAMOORTHY, K. *Methods and Tools for Managing Losses in Water Distribution Systems.* ***Journal of Water Resources Planning and Management***, v. 139, n. 2, 2013. p. 166-174
32	PEREIRA, L. G.; ILHA, M. **Evaluation of water undermetering in residential buildings of social interest located in Campinas**. Ambiente Construdo, v. 8, n. 2, 2006. p. 7-21
33	PEREIRA, R. A.; DA SILVA, M. D. L.; BRITO, V. F.; DA SILVEIRA, V. B. et al. **Application of multicriteria analysis to prioritize the replacement of water meters in the municipality of São Caetano do Sul-SP, with emphasis on loss reduction and revenue recovery**. 28th AESABESP Technical Meeting, 2016.
34	PULEO, V.; FONTANAZZA, C. M.; NOTARO, V.; DE MARCHIS, M. et al. *Definition of Water Meter Substitution Plans based on a Composite Indicator.* ***Procedia Engineering***, v. 70, 2014. p. 1369-1377
35	RIZZO, A.; CILIA, J. *Quantifying meter under-registration caused by the ball valves of roof tanks.* ***In: Proceedings of the IWA Leakage 2005 Conference***, 2005.
36	SCALIZE, P. S.; LEITE, W. C. D. A.; CAMPOS, M. A. S. **Rational replacement of water meters in water supply systems**. REEC - Electronic Journal of Civil Engineering, v. 9, n. 3, 2014.
37	SHIELDS, D. J.; BARFUSS, S. L.; JOHNSON, M. C. *Revenue recovery through meter replacement.* ***Journal AWWA - American Water Works Association***, v. 104, n. 4, 2012. p. E252-E259
38	SILVA, C. M.; PÁDUA, V. L. D.; BORGES, J. M. *Contribution to the Study of Measures for the Reduction of Apparent Water Loss in Urban Areas.* ***Ambiente & Sociedade***, v. 19, n. 3, 2016. p. 249-268
39	STOKER, D. M.; BARFUSS, S. L.; JOHNSON, M. C. *Flow measurement accuracies of in-service residential water meters.* ***Journal AWWA - American Water Works Association***, v. 104, n. 12, 2012. p. E637-E642.
40	SZILVESZTER, S.; BELTRAN, R.; FUENTES, A. *Performance analysis of the domestic water meter park in water supply network of Ibarra, Ecuador.* ***Urban Water Journal***, v. 14, n. 1, 2017. p. 85-96
41	TABESH, M. et al. *Prioritization of non-revenue water reduction scenarios using a risk-based group decision-making approach*. **Stochastic Environmental Research and Risk Assessment**, v. 34, 2020. p. 1713-1724
42	TEODORO, M. F.; ANDRADE, M. A. P.; FERNANDES, S.; CARRIÇO, N. *Water Meters Inaccuracies Registrations: A First Approach of a Portuguese Case Study.* ***Computational Science and Its Applications – ICCSA 2020***, 2020. p. 429–445
43	XIN, K.; TAO, T.; LU, Y.; XIONG, X. et al. *Apparent Losses Analysis in District Metered Areas of Water Distribution Systems.* ***Water Resources Management***, v. 28, n. 3, 2014. p. 683-696
44	YILMAZ, S. et al. *Identification of the priority regions in the customer water meters replacement using the AHP and ELECTRE methods*. **Sigma Journal of Engineering and Natural Sciences**, v. 39, n. 4, 2021. p. 331-342

SOURCE: OWN AUTHOR.

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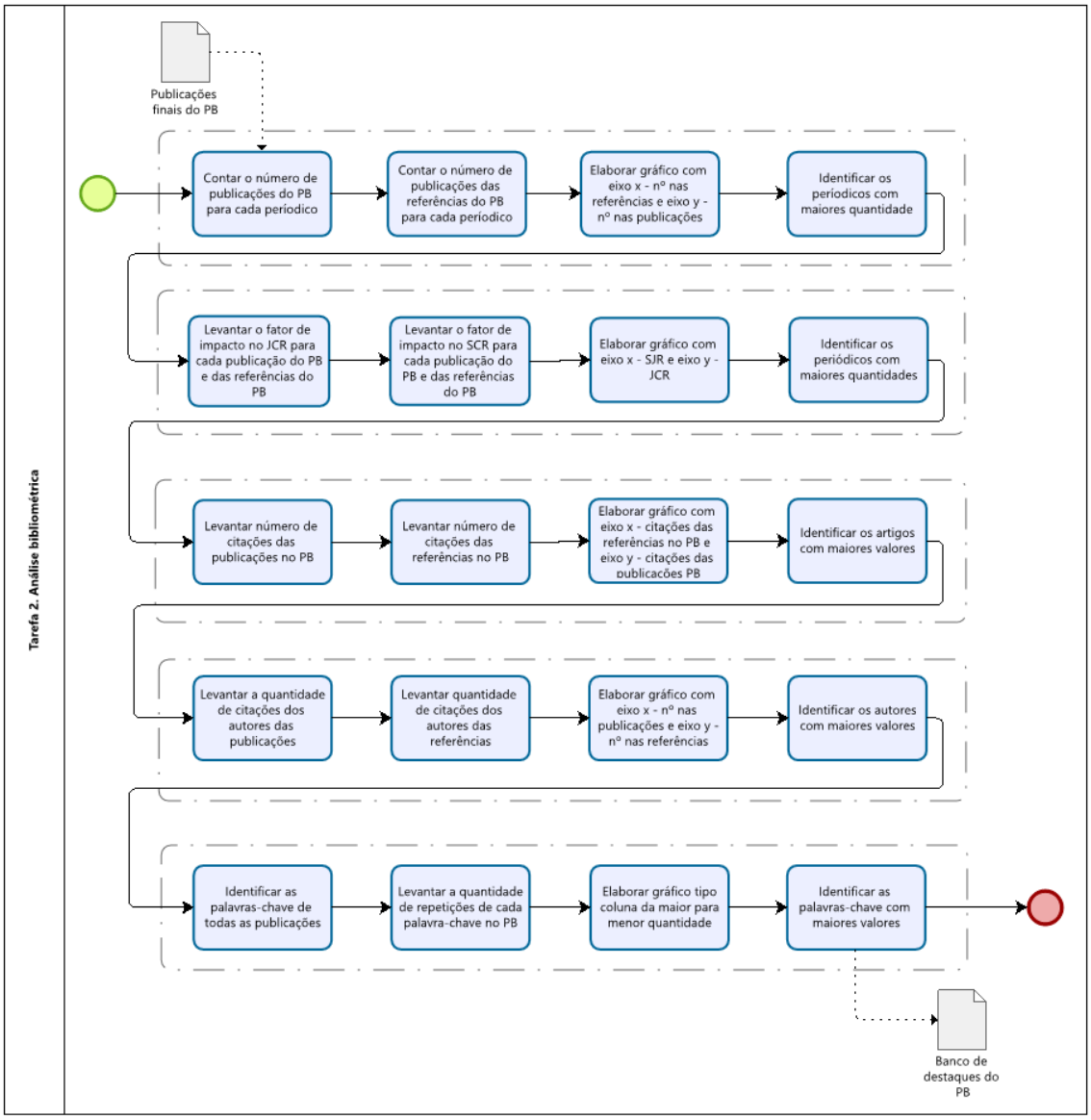
TASK 2. BIBLIOMETRIC ANALYSIS

It consists of counting the occurrence of certain variables (characteristics) in the final publications of the Bibliographic Portfolio, to quantify the existing information and map the structure of knowledge in a scientific field, also serving to build initial knowledge in researchers, in such a way that they know where to look for information on the subject (ENSSLIN; ENSSLIN; PACHECO, 2012). The Figure 6 presents the process flow for that task.

FIGURE 6. PROCESS FLOW OF TASK 2: BIBLIOMETRIC ANALYSIS.



CAST IRON: ADAPTED FROMENSSLIN ET AL. (2010).

Task 2 starts running as follows:

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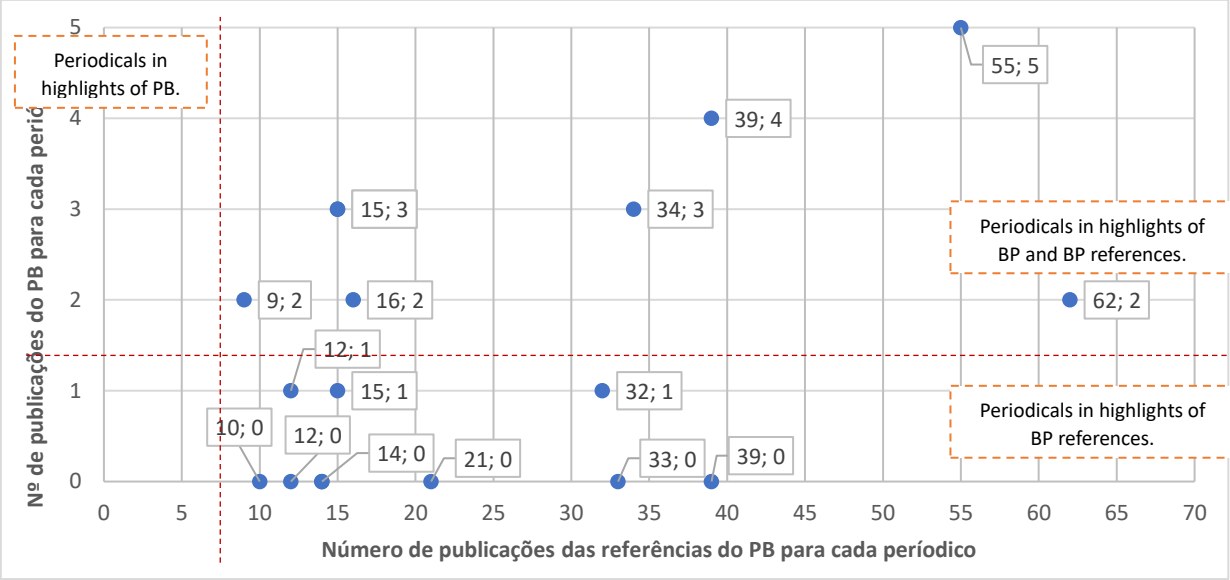
- The number of BP publications and their respective references for each journal were counted;
- The Graph 2 and identified the featured journals, being presented in the Table 3. To highlight the BP criteria in relation to its references, a vertical line and a horizontal line in red were drawn, dividing the Cartesian graph into quadrants, allowing the identification of highlights.

GRAPH 1. JOURNALS AND CONFERENCES FEATURED IN THE PB AND THEIR RESPECTIVE REFERENCES.



SOURCE: OWN AUTHOR.

Table 3. Journals and conferences featured in PB and their respective references.

Periodical / Conference	PB	References
Journal AWWA	2	62
Journal of Water Resources Planning and Management	5	55
IWA 'Leakage 2005' Conference	4	39
Water Supply	0	39
Urban Water Journal	3	34
IWA Publishing	0	33
Water Resources Management	1	32
ISO	0	21
Water Practice and Technology	2	16
5th IWA Water Loss Reduction Specialist Conference	3	15
Water S.A.	3	15
4th IWA Water Loss Reduction Specialist Conference	1	15
Elsevier Science & Technology Books	0	14
Water and Environment Journal	0	14

SOURCE: OWN AUTHOR.

It is possible to observe that most of the prominent journals and conferences presented in the Table 3 are related to the subjects "water" or "water losses", both

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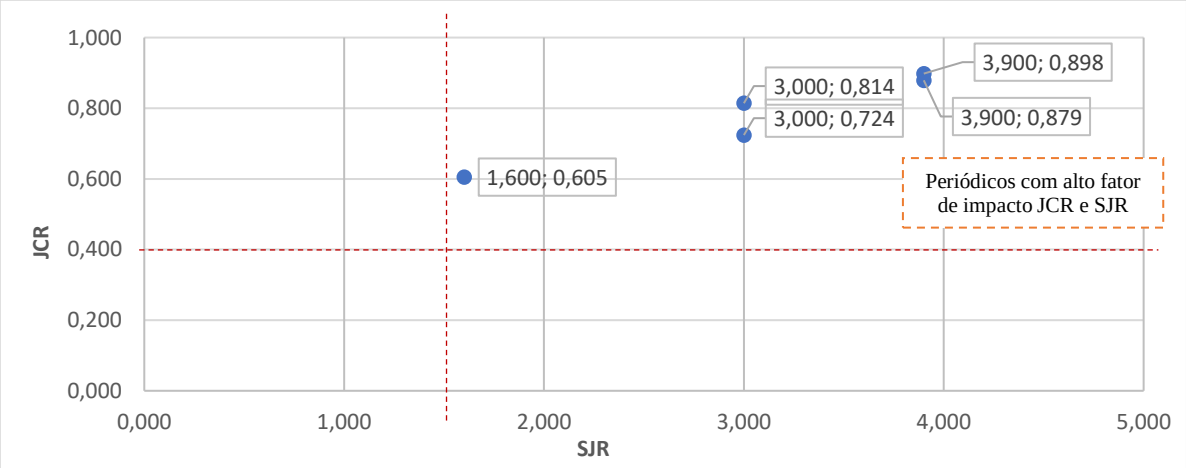
keywords of the research theme. The featured journals are "*Journal AWWA*" e "*Journal of Water Resources Planning and Management*" in relation to BP and their respective references.

Then, the execution of task 2 is continued:

- The impact factor survey for each journal and conference of the BP was carried out in the Journal *Citation Reports* (JCR) and *Scimago Journal & Country Rank* (SJR) databases. The JCR Impact Factor uses the *Journal Impact Factor* (JIF), which is a journal-level metric calculated from data indexed in the *Web of Science Core Collection*. The SJR impact factor is a measure of scientific influence of journals that accounts for both the number of citations received by a journal and the importance or prestige of the journals from which such citations come.
- The Graph 2 and the outstanding journals and conferences were identified, which were presented in the Table 4.

GRAPH 2. IMPACT FACTOR OF PB JOURNALS IN THE SJR VERSUS JCR.



SOURCE: OWN AUTHOR.

Table 4. Impact factor of PB journals in SJR and JCR.

Newspaper	ISSN	SJR	JCR
Water Resources Management	0920-4741	0,898	3,900
Stochastic Environmental Research and Risk Assessment	1436-3240	0,879	3,900
Journal of Water Resources Planning and Management	0733-9496	0,814	3,000
Water	2073-4441	0,724	3,000
Urban Water Journal	1573-062X	0,605	1,600
Water Resources Management	0920-4741	0,898	3,900

SOURCE: OWN AUTHOR.

It is possible to observe that the journals with the highest impact factors are "*Water Resources Management*" and "*Stochastic Environmental Research and Risk Assessment*".

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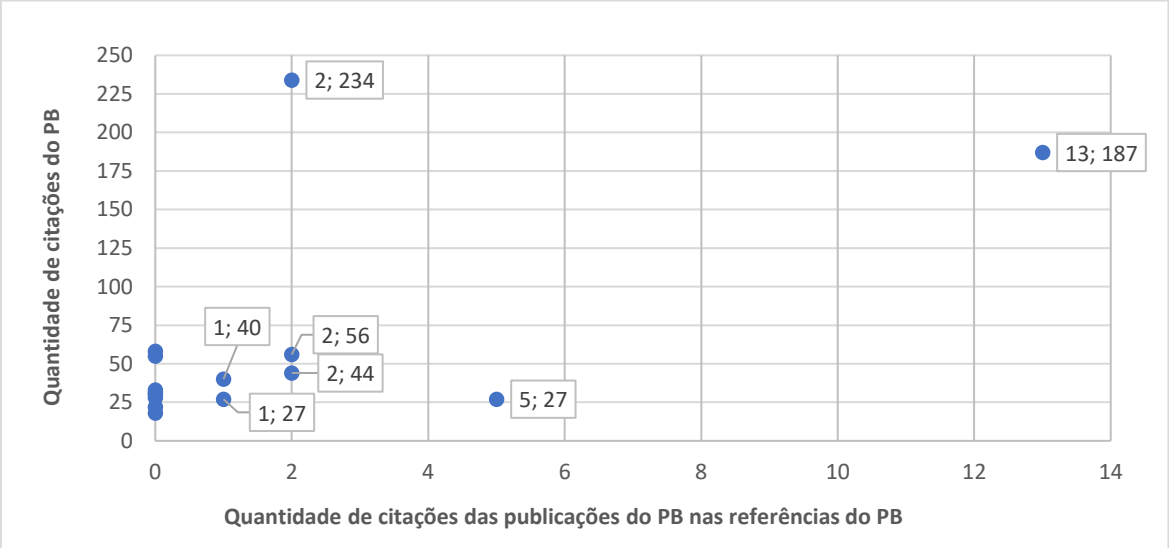
Task 2 is continued:

- A survey of the number of citations of BP publications was carried out in the database of the *Google Scholar*, soon after, the number of times each BP publication was referenced in BP was counted, and the results presented in the Graph 3.
- The Table 5, which presents the publications with the highest number of citations of BP publications (y-axis) and the number of citations of each BP publication in BP references (x-axis).

GRAPH 3. PROMINENT PUBLICATIONS IN PB AND THEIR RESPECTIVE REFERENCES.



SOURCE: OWN AUTHOR.

Table 5. Titles of publications highlighted in the number of BP citations and BP references.

Titles of publications	PB	References
Methods and Tools for Managing Losses in Water Distribution Systems	234	2
Evaluation of the apparent losses caused by water meter under-registration in intermittent water supply	187	13
Quantifying meter under-registration caused by the ball valves of roof tanks	58	0
Apparent Losses Analysis in District Metered Areas of Water Distribution Systems	56	2
Optimal Meter Placement for Water Distribution System State Estimation	55	0
The apparent losses due to metering errors: a proactive approach to predict losses and schedule maintenance	44	2
Apparent losses due to domestic water meter under-registration in South Africa	40	1
Residential Water Meter Replacement Economics	33	0
Domestic water meter optimal replacement period to minimize water revenue loss	31	0
Understanding non-registration in domestic water meters: Implications for meter replacement strategies	30	0
How to measure and reduce water meter park efficiency?	28	0

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A mathematical model to evaluate apparent losses due to meter under-registration in intermittent water distribution networks	27	1

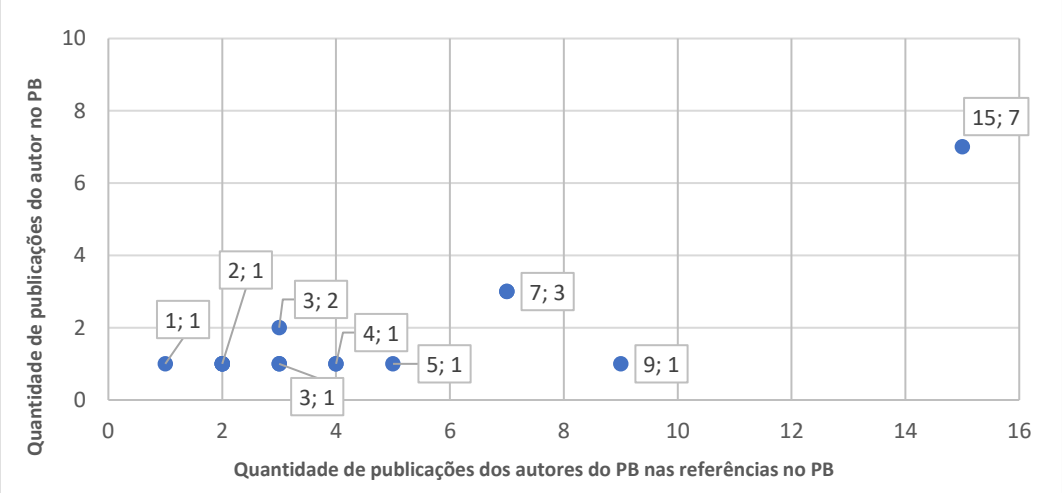
SOURCE: OWN AUTHOR.

O resultado obtido, permite afirmar que as publicações em destaque no PB são: "*Methods and Tools for Managing Losses in Water Distribution Systems"* e *"Evaluation of the apparent losses caused by water meter under-registration in intermittent water supply"*.

This was followed by the execution of task 2:

- The count of authors' publications in BP was performed, then the number of publications by BP authors in BP references was counted, and the results presented in the Graph 4.
- The Table 6, which presents the quantitative for the authors of the publications in BP (y-axis) and for the authors of BP in the references in BP (x-axis).

GRAPH 4. PROMINENT AUTHORS IN PB PUBLICATIONS AND THEIR RESPECTIVE REFERENCES.



SOURCE: OWN AUTHOR.

Table 6. List of prominent authors of BP and in references.

Authors	PB	Reference
ARREGUI, F. J.	7	15
FONTANAZZA, C. M.	3	7
MUTIKANGA, H. E.	3	7
FANTOZZI, M.	2	3
FERREOL, E.	1	9
KANG, D.	1	5
DE MARCHIS, M.	1	4
TABESH, M.	1	4
Mukhebir, P.	1	3
RIZZO, A.	1	3
COUVELIS, F.	1	2
CRIMINISI, A.	1	2

SOURCE: OWN AUTHOR.

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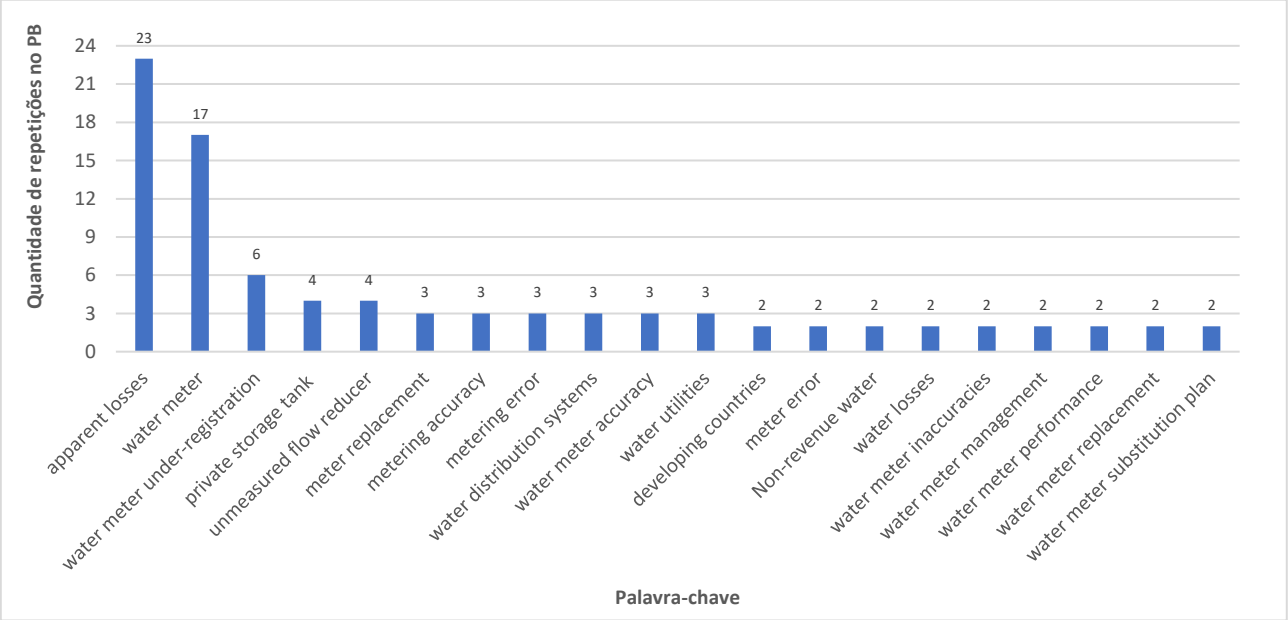
The featured authors are ARREGUI, F. J. and FONTANAZZA, C. M. com 7 and 3 publications in PB, respectively.

Task 2 was completed with:

- The identification, synonym adjustments, and keyword count of each PB publication.
- The Graph 5, which displays the keywords highlighted.

The highlighted keywords are "*apparent losses*" and "*water meter*", being, respectively, the amount of 23 and 17 repetitions between the publications in BP.

GRAPH 5. FEATURED KEYWORDS OF THE PB PUBLICATIONS.



SOURCE: OWN AUTHOR.

FINAL CONSIDERATIONS

It is evident the need to manage the set of water meters (or water meter park) used by the concessionaire, thus providing an improvement in the measurement of the volumes consumed of water. Normally, corrections are carried out by replacing old water meters with new ones, but costs are high and sanitation companies do not have sufficient financial resources to replace all water meters installed in their water supply systems, requiring prioritization.

In this scenario, company managers need to decide which water meters should be prioritized to ensure the metrological reliability of the measurements. For the success of this prioritization, it is essential that those responsible for decision-making know the time of use, the amount and decay of the volume consumed, the profile and category of the property

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where the water meter is installed, the number of unpaid bills, also evaluate other possibilities that allow the reduction of the under-measurement of water meters, reducing water losses with increased revenue.

For the success of the choice of the set of meters, it is acceptable to use solutions such as a multicriteria decision support system in the prioritization of water meter replacement. This time, this work focused on the presentation of a method for selecting bibliographic references to compose a theoretical framework on the studied context, which made it possible to analyze a set of 282 publications, published between the years 2005 and 2024, and ending with the generation of the PB containing 44 documents as presented in the Graph 5.

The selection of the BP allows us to affirm that there is a small number of publications that address the theme of this research. Therefore, the development of a multi-criteria decision support system for changing water meters is something that can offer a scientific contribution and help increase revenues and reduce losses related to the Company, and can contribute to the water and financial sustainability of the sanitation sector in Brazil.

In addition to this selection, the present study performed a bibliometric analysis, which consists of counting the occurrence of certain variables (characteristics) in BP publications and their respective references. With the results, it is possible to quantify the existing information and map the structure of knowledge of a scientific field on the theme of this research, thus, it is possible to know which are the main journals, publications, authors and keywords, being:

- Periods with the highest number of publications (highlighted periods): "*Journal AWWA"* and "*Journal of Water Resources Planning and Management*";
- Periódicos com maior fator de impacto do JCR e SJR: “*Water Resources Management*” e “*Stochastic Environmental Research and Risk Assessment*”;
- Publication with the highest number of citations (featured publications): "*Methods and Tools for Managing Losses in Water Distribution Systems"*;
- Author with the highest number of citations (featured authors): ARREGUI, F.J.; and, FONTANAZZA, C. M.
- Keywords with the highest number of repetitions (highlighted keywords): "*apparent losses*" and "*water meter*".

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The authors of this work reiterate that the bibliographic analysis does not attempt to build a theoretical framework in itself, but contributes to studies on the research theme being based on a structured process for the selection and dissemination of the most relevant publications, authors and journals that will support the theoretical framework of future academic and scientific works.

It is suggested for future research: (a) the continuation of this research with the development of the two missing stages of *Proknow-C*: systemic analysis (BP content analysis) and identification of scientific research opportunities with the suggestion of research questions and objectives; and, (b) the replication of the process to other contexts from a search in various databases available on the CAPES portal.

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