RISK ASSESSMENT IN PURIFIED WATER PROJECTS USING ANALYTIC HIERARCHY PROCESS (AHP) AND GOAL TREE SUCCESS TREE (GTST) – A TOOL FOR DECISION MAKING

José Cristiano Pereira
Professor - Post Doctor Fellow at the National Laboratory for Science Computing – LNCC
josecristiano.pereira@ucp.br

Flavio Luis Souza de Almeida
Mechanical Engineer - Oswaldo Cruz Foundation – Fiocruz
Teacher -Foundation to Support the Technical School of the State of Rio de Janeiro.
flavio.almeida@fiocruz.br

ABSTRACT

The study presents a risk analysis to assist in choosing the design of purified water by osmosis reverse installations in health and biological research establishments. The process of producing and distributing purified water is sensitive in terms of contamination by microorganisms and electrical conductivity when considering the flow regime and the risk of standing water in the pipeline. Several risks are present in the design of installations for the production and distribution of purified water. Those responsible for the correct choice of the purified water production and distribution system should be taken in response to risks. As a methodological approach, research in standards and regulations was conducted, risk analysis was performed in the treated water purification process and distribution projects, AHP was used to prioritize the risks, and GTST was used to define the actions as responses to risks. Identifying the technologies available from different suppliers are factors considered important in the process. The results show the enormous source of uncertainty in the normal processes of production and distribution of purified water, with different regulations, which can compromise the integrity of the project, the sustainability, and the assertiveness of the delivery of the work. A risk analysis conducted as a global enterprise strategy to complement the risk analyzes of isolated disciplines can mitigate tangible risks and identify intangible risks. It increases the enterprise's certainty, legitimacy, and adequate application of public resources. The research points out that the production and distribution of purified water for laboratories is susceptible to contamination. It can make the enterprise unfeasible. The study contributes in two ways. First, it provides elements for identifying a safe production and distribution technology. Second, it contributes to developing a risk analysis based on decision trees that can be used in future projects for other purposes.

Keywords: Risk Analysis, Goal Tree, Purified Water.

1. INTRODUCTION

According to ANA[37], water use management is of fundamental importance for formulating public policies that, ultimately, bring water security to the sector, with economic and environmental sustainability. Within sustainability, the increase in efficiency in the use of natural resources, especially water, should be a goal constant on the agenda of the producer and the government. Water is a fundamental source of life; maintaining its quality is a huge challenge for large urban centers. Water is a product with a high probability of scarcity, and its use and application must be judicious and responsible. There is industrial demineralized and pharmaceutical-grade water in industrial processes, highlighting its application for washing glassware, research, food production, cosmetics production, and injecTable manufacturing. As mentioned by Oliveira and Pellegrini [1], the production of purified water is critical. Like Brazilian Pharmacology Guide, purified water is used in pharmaceutical processes and laboratory procedures.

The purification range also qualifies it. At the same time, there are different systems to produce purified water for pharmaceutical applications. To specify the correct system, it is necessary to know and understand

1 DSc Prof Doctor – LNCC and UCP
2 PhD, Engenheiro Elétrico - UCP

some aspects of standards, water purity, water demand, water flow, distribution system, water tank, and system sanitization procedures. It is also necessary that all involved in the decision process understand how difficult it is to produce purified water and maintain quality water and system control. According to purity grade, maintaining the purity of the water supplied becomes an arduous and critical task in purified water applications. In its natural state, water contains several chemical elements. There is a strong tendency to return to its natural state as it is purified, and the purer, the stronger the tendency. According to Oliveira and Pellegrini [1], water production is considered an extremely delicate operation, as it is the main component in the preparation of several liquid dosage forms. The water purification system can be considered the heart of the pharmaceutical industry. Based on the purpose of water application, the proper treatment must be defined and the respective processes of accumulation, distribution, application by the user through maintenance and quality control. Thus, choosing the type of system to be offered to the user is vital. Whether dedicated only to a laboratory or an enterprise, it needs to be defined in application, purity, and volume criteria. It is not an easy task. Takahiro and Nakamura [17] developed guidelines and requirements for water efficiency management systems for water-using organizations planning or implementing measures to save water. Marins et al. [5], decision-making must seek an option that presents the best performance, the best evaluation, or the best agreement between the decision maker's expectations, considering the relationship between the elements.

None of the researched previous studies presented detailed information related to risk assessment in purified water projects. Some of these researched papers are listed herein in section 2. This study responds to the following important research questions:

Research Question 1: How can project leaders overcome the difficulties in designing the production and distribution of purified water?

Research Question 2: What are the risks factors in implementing the purified water production and distribution system?

Research Question 3: What actions should those project leaders take to correct the purified water production and distribution response to risks?

Preparing a risk analysis based on a decision tree can guide the best choice of water production and distribution system. The innovation justifies this study in applying risk analysis using the Hierarchical Process Analysis Tools and Goal Tree Success Tree to optimize the development of water purification system projects. It identifies critical points and align the assumptions of prefiltration systems, reverse osmosis size, distribution system, and quality control parameters. The study guides users and decision-makers to understand the parameters and risks related to the production, distribution, application project, and possible sources of water contamination, maximizes the possibilities of validating the systems together with the health surveillance agencies. There is also a lack of recent studies related to risk analysis to identify the main risk factors on purified water system selection. The innovatively of this paper is related to a sustainable solution for installation and application of purified water system, by mapping the responsibilities and risks of the process regarding water contamination by the formation of bacterial biofilms or by capturing the elements from the water available in the environment. This study offers a tool to prevent common problems in purified water installations in laboratory facilities at a Research Foundation.

The paper is structured as follows: Section 2 describes the methodology and previous studies on Quality and Operational Risk Assessment, AHP and GTST, Organizational Sustainability Risk Assessment. Section 3 presents the discussion, and section 4 the conclusion. In the end, the list of references used in this paper is provided.

2. DESCRIPTION

2.1 Methodology

The study was conducted following these steps: In the first step, research in the state-of-the-art literature was done on Google Scholar, Capes, Scopus, and Web Science. It was conducted using the keywords Risk Analysis, Goal Tree, Purified Water, and national and international standards references and guides. In the second step, the authors mapped out the elements of the water treatment process, such as water source, prefilters, water purifier, defined here as Reverse Osmosis, storage tank, distribution looping, and quality controls. In the third step, they identified risks using a survey completed by specialists. The authors reviewed the data to define the risk categories in the fourth step and created an AHP matrix. In the fifth step, the high score risk scores were identified. In the sixth step, responses to the high risks were established. A Goal Tree was prepared to identify detailed response actions to the high risks identified in the seventh step. The main goal or objective and subgoals were defined, and the resources, standards, and activities were organized in hierarchal levels. The model with the factors and relevant criteria to help project leaders select purified water production and distribution systems was finalized in the eight-step. Figure 1 shows the flowchart with these steps.

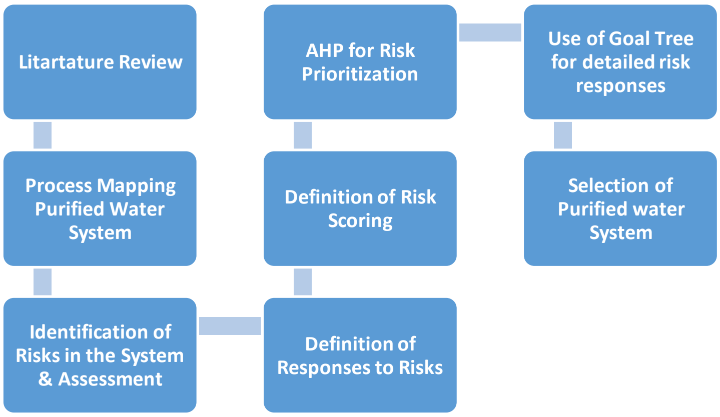

Fig. 1. Methodology steps.

2.2 Quality and Operational Risk Assessment

Organizations strive to satisfy, or preferably exceed, the wants and expectations of the customers subject to meeting the demands of the other stakeholders to fulfill the organization's aim. Quality of product can only be achieved by organizations that control their processes and functions and continually improve themselves. However, company and local image can affect these quality dimensions and work as a filter. If a provider is good in the eyes of the customer, minor mistakes will be forgiven. If the image is negative, the impact of any mistake will often be considerably more significant than it otherwise would have been. For Dyllick and Hockerts [2], quality is broad, multi-interpreTable, relative, and dynamic. Quality standards state that the most crucial focal point in the quality management approach is the customer. Above all, quality is delivering an output meeting or exceeding customers' expectations. Hence quality is measured by, for instance, customer satisfaction rates or complaints. Economic reasoning explains the strength of this perspective, as shown in Pereira and Fayer [13], water as a precious resource, sustaining human life, production, processes, and ecosystems. Thus, particular attention should be paid to water resources management. The goals of manufacturing and services excellence efforts include maintaining market share, improving profitability, and the firm's ability to compete in a global marketplace [9]. This author describes the concept, approaches, and identification of critical success factors, performance measures for lean manufacturing and services practices. Quality and innovation are two key competitive strategies that many organizations pursue to win customers in their business. International quality standards such as ISO 9001-2015 [31] and ISO 31000/2018[32] require implementing an operational risk management process to improve safety. According to Islama et al. [3], work overload and stress increase the likelihood of human error and potential accidents. They developed an application in human factor risk assessment that can improve safety and reliability in operations.

2.3 Organizational Sustainability

Corporate sustainability means meeting the needs of a firm's direct and indirect stakeholders (such as shareholders, employees, clients, pressure groups, communities, etc.) without compromising its ability to meet future stakeholders' needs. Sustainability has also been developed towards a more relative concept. The level of sustainability is related to the needs of stakeholders and the extent it is fulfilled [2]. Furthermore, the relative importance of the different stakeholders can change and the needs of the stakeholders. It implies that the meaning of sustainability also has become dynamic. The need to specify the responsibility is also relevant when an organization applies sustainability to its supporting activities. In literature, the nature of the responsibility is established through the stakeholder concept [2]. However, since there is more than one stakeholder, the ambiguity concerning the sustainability approach has not been decreased. An organization must specify the boundaries of the chosen responsibility system. According to Hörischa et al. [38], the Stakeholder Theory postulates that corporations have duties to multiple stakeholders. Stakeholders can be internal, such as employees, including management, or external, customers, suppliers, banks, environmentalists, governments, and other groups. Some stakeholders may be considered both internal and external, such as stockholders. Stakeholders can also be divided into primary and secondary groups. The primary one has a more direct influence or is influenced by the company to a greater degree than the secondary ones [44].

2.4 Risk Assessment with Analytic Hierarchy Process (AHP)

Saaty [6] first introduced the Analytic Hierarchy Process (AHP) to provide a relative weight of criteria according to a hierarchical structure. The method depends on a pairwise comparison of alternatives, which is quantified in a matrix. The technique has been used in numerous disciplines to solve complex decision problems and, according to Rabihah [20] it improves the Understanding of a Problem. The hierarchy organizes the problem into risks and sub-risks. The hierarchy links the risks, sub-risks, and decisive goals. It divides a complicated problem into smaller parts that can be ranked hierarchically. The first stage of AHP is to construct a pairwise comparison matrix [8]. Each element aij (i, j = 1, 2, ..., n) represents the relative importance of elements i and j. A higher value denotes a stronger preference of element i over element j [21]. The values can be specified according to a relative importance scale provided [6].

2.5 Goal Tree Success Tree (GTST)

The process of Goal Tree Success Tree analysis has been known by experts for almost thirty years. However, there seem to be few publicly available documents that provide comprehensive coverage from basic principles to advanced techniques. According to Terrance R. Ingoldsby [45] "All models, including attack trees, will break down if they are used beyond their limits." According to Gaol [18], a Goal Tree Model (GTM) will be documented and will become a reference in developing the stages of the business process that focus on the organization's goal. This paper aims to present how to use GTST to be purified water system over to avoid a disastrous erection than wrong design than unappropriated construction. Three conditions must be present to an attacker (also known as a threat agent) to carry out a successful attack against a defender's system.

The defender must have vulnerabilities or weaknesses in their system; of course, different resources are required to exploit different vulnerabilities; to identify team understanding about purified water system. The threat agent must have sufficient resources to exploit the defender's vulnerabilities; this is known as capability. The threat agent must believe they will benefit by performing the attack, the expectation of benefit drives motivation. According to Pereira & Almeida [19], there are common philosophic points about improving quality and company sustainability. It is necessary to map all processes to increase actions and identify actions to achieve results To create a Goal Tree. Each step, resource, standard, and activity must be organized by hierarch level so, the first step in developing a goal tree model involves the definition of goal or objective. This top goal must be explicitly defined in terms that make it a single unambiguous statement. From this definition, the analyst will identify and relate all the different plant goals and subgoals that must be achieved to attain the overall objective.

To construct a GT model after identifying all tasks, steps, sources, events, and their relationship, the analysts write each one in a box and connect all of them with arrows to understand all connections from the primary goal box until the low line box level. Many levels are used to find all relations that could impact the primary goal, and also can use many kinds of charts until finish quality improvement. Tropos et al. [11] introduce primitives for modeling actors of the system (agentive entities) and goals that actors intend to achieve. A task represents an abstract way to do something, and its execution can be a means for satisfying a goal. When goals/tasks are at high abstraction levels, they can be refined through and/or decomposed into finer sub-goals/sub-tasks. A resource represents a physical or informational entity. Finally, a dependency allows actors to depend on one another to fulfill goals, execute tasks, and provide resources.

2.6 Reference Standards

Many purified water systems must have followed some parameters. Tachi and Nakamura[4] show that there are worldwide standards around the water system production and quality regarding the pharmaceutical application, identify best practices, and clarify followed standards. The ISO/TC 224 committee on service activities relating to drinking water supply, wastewater, and stormwater systems has published more than 15 international standards over the 18 years since it was first established. It continues to work actively on new crisis management, water loss management, and corporate governance standards. According to the Brazilian Pharmacopoeia [14], purified water is used to prepare medicines that do not require sterile and pyrogenic water and can be prepared by distillation, ion exchange, reverse osmosis, or another process. It should not contain the addition of any substance. According to Ferrario and Zio [40], chemical incompatibilities can cause secondary compounds in pharmaceutical products, precipitation, toxic products. It can lead to total inactivation or partial loss of pharmacological activity, stability problems, drug decomposition, inactivation by multivalent ions (calcium, magnesium, iron, and aluminum), explosions, among other problems. Regularly control analyzes of drinking and purified water to control the growth of colonies of total bacteria, which interfere with quality, under the specifications contained in Ordinance No. 518/2004 (14). The results obtained in the microbiological analyses of purified water demonstrated compliance with the American and Brazilian Pharmacopoeia [14], the differential critical points being the degree of system control and the final stages of purification necessary to remove bacteria bacterial endotoxins and reduce conductivity.

3 RESULTS

During the case study conducted in the facilities of the company, the following information was raised: The authors identified additional expenses risks of adjustments or corrections of systems that were assembled inappropriately, often subject to contamination generated by ignorance of production and distribution processes, by applications with different degrees of purity for the same enterprise, specification of distribution systems inadequate. For each type of water, there is more than one treatment system option. This system is made up of a set of elements that can vary according to the quality of the available water source. The source can be from rivers, lakes, or water companies. Regarding the type of water to be produced, the dimensions and technologies depend on the solution of each manufacturer. Thus, developing a tool to guide the selection of water production systems offers greater design efficiency and sustainability. After defining the specification of the desired water, it is necessary to define both the production system and the distribution system. It must consider factors such as water volume per consumption point, simultaneity, flow regime, type of pipe material, avoid dead spots, and others. The more purified the water, the more care is needed in production, distribution, and quality controls. The classification of water as type III (demineralized water), Type II water, and type I water (WFI - water for infectious), is given in Tab. 1.

Tab. 1 – Purified water quality schedule.

Greatness	Type III	Type II	Type I	WFI
Condutivity: µS/cm a 25,0°C	1,0 a 5,0	0,1 a 1,3	0,1 a 1,3	0,055 a 0,1
Resistivity: MW-cm	> 0,2	> 0,1	> 0,1	> 18,0
Total Organic Count – TOT - mg/L	≤ 0,20	≤ 0,50	≤ 0,50	0,05 -0,003
Total Bacteria Count: UFC/ml	-	≤ 100	≤ 100	0,0
Microbiological count: UFC/100ml			<10	1,0
Endotoxin			<0,25	<0,10

Lack of knowledge about the purified water system has been present at a studied company, as observed in implementing the last three recent water purification systems. Those problems affected sustainability, causing expensive extra costs to correct water treatment system, looping system, reliability loos, and delays in work deliveries. The risk factors gathered by the authors from the most current literature on PW production systems and the maintenance problem report on the studied company were classified into six categories: Client, Designer, and CEO. The authors raised ten factors related to Client (Clt1-Clt10), ten related to Designer (Des1-Des10), and related to CEO (CEO1-CEO5). The experts were asked to estimate the level of importance for each risk factor contributing to PW system failure when producing purified water. The importance index was assigned to each risk factor based on the percentage of experts who understood the risk factor as having an impact on PW system failure. Tab.2 was used to attribute the index of importance to each risk factor presented in Tab. 3.

Tab. 2 – Probability Score.

Level of Lack Understanding	Index	Percentage of experts who did not understand the Purified Water System
Low	1	0 - 20
Medium	2	0,21 – 0,40
High	3	0,41 – 0,60
Very High	4	0,61 – 1,00

The index related to the level of understanding of the risk factors that would affect the success of the project was obtained from experts is presented in Tab 3. The level of understanding was obtained using a form that was shared with designers, clients, and contributors.

Tab. 3 – Index of Importance.

Categories	Risk Factor Code	Risk Factors	Index
Client knowledge	Clt1	Lack of knowledge about standard	4
	Clt2	Client lack of application conditions	4
	Clt3	Client lack of knowledge about System Process	3
	Clt4	Client lack of knowledge about controls	2
	Clt5	Client lack of knowledge on applying	3
	Clt6	Client lack of knowledge on operations	3
	Clt7	Client lack of knowledge on maintenance	2
	Clt8	Client lack of knowledge on sanitization	2
	Clt9	Client lack of knowledge on logistics	1
	Clt10	Client lack of knowledge on water consumption	1
Designer knowledge	Des1	Lack of knowledge about standard	4
	Des2	Designer lack of application conditions	4
	Des3	Designer lack of knowledge about System Process	3
	Des4	Designer lack of knowledge about controls	2
	Des5	Designer lack of knowledge on applying	3
	Des6	Designer lack of knowledge on operations	3
	Des7	Designer lack of knowledge on maintenance	2
	Des8	Designer lack of knowledge on sanitization	2
	Des9	Designer lack of knowledge on logistics	1
	Des10	Designer lack of knowledge on water consumption	1
CEO knowledge	CEO1	Designer lack of knowledge about standard	4
	CEO2	CEO lack of knowledge about System Process	3
	CEO3	CEO lack of knowledge about wrong Implementations Risks	2
	CEO4	CEO lack of knowledge about Rework Impacts	1
	CEO5	CEO lack of knowledge on water consumption	1

The risk factors listed in Tab. 3 were classified into the following categories: client knowledge, designer knowledge, and CEO knowledge, as shown in the first column of this Table. The risk factors were classified into pertinent risk sublevels so that the causes and consequences of each risk could be defined. Tab. 4 shows the risk levels, sublevels, and the associated risk factors (color-coded according to the level of lack of understanding). As an example, this Table shows that design poorly prepared (SL1) may be caused by poor knowledge of PW equipment (SL1), Poor knowledge on PW looping (SL2), and lack of data demand (SL3). Poor knowledge on PW equipment (SL1) may be caused by lack of knowledge about standard(Clt1), Client lack of application conditions(Clt2), Client lack of knowledge about System Process(Clt3), lack of knowledge about standard(Des1), Designer lack of application conditions (Des2), Designer lack of knowledge about System Process(Des3). Poor knowledge on PW looping (SL2) may be caused by lack of knowledge about standard (Clt5); Client lack of knowledge on operations (Clt6), Designer lack of knowledge on applying (Des5), Designer lack of knowledge on operations (Des6) and Client lack of knowledge on maintenance (Des7). The lack of data demand (SL3) may be caused by the Client's lack of knowledge about controls (Clt4), Designer's lack of knowledge about controls (Des4).

Tab. 4 - Risk Levels, Sub-Levels, and Associated Risk Factor

Risk Level		Risk Sub-Level		Associated Risk Factor
L1	Design poorly prepared	SL1	Poor knowledge of PW equipment	Clt1, Cl2, Clt3, Des1. Des2, Des3
		SL2	Poor knowledge on PW looping	Clt5, Clt6, Des5, Des6, Des7
		SL3	Lack of data demand	Clt4, Des4
L2	Improper Material & System	SL4	Wrong choice of assembling system	Clt1, Cl2, Clt3, Clt5, Clt7, Des1. Des2, Des3
		SL5	Improper looping materia selected	Clt1, Cl2, Clt3, Des2, Des3, Des7,
		SL6	Improper PW material properties	Clt1, Cl2, Clt3, Clt5, Des1. Des2, Des3, CEO1, CEO2
L3	Uncorrected PW Implementation	SL7	Improper connection Looping x System	Clt1, Cl2, Clt3, Clt5, Clt7, Des1. Des2, Des3
		SL8	Ineffective quality control implemented	Clt7, Clt8, Clt9, Des2, Des3, Des7,
		SL9	Wrong sanitization procedure	Clt7, Clt8, Clt9, Clt0, Des6. Des7, Des8, Des9, Des10, CEO3, CEO4
L4	Equipment/ looping Failure	SL10	Processing equipment failure	Clt1, Cl2, Clt3, Clt5, Clt7, Des1. Des2, Des3
		SL11	Processing looping failure	Clt7, Clt8, Clt9, Des2, Des3, Des7,
		SL12	Process control equipment failure	Clt7, Clt8, Clt9, Clt0, Des6. Des7, Des8, Des9, Des10, CEO3, CEO4
L5	Unfavorable Management & Environment	SL13	Material control failure	Clt7, Clt8, Clt9, CLt10, Des8, Des9, Des10, CEO3, CEO4, CEO5
		SL14	Equip./instr. control failure	Clt7, Clt8, Clt9, CLt10, Des7, Des8, Des9, CEO3, CEO4, CEO5
		SL15	Environment control failure	Clt7, Clt8, Clt9, CLt10, Des7, Des8, Des9, CEO3, CEO4, CEO5

L6	Negative Organization Factor	SL16	Monitoring & control ineffective	Clt5 Clt6, Clt7, Clt8, Clt9,
		SL17	Quality &safe management ineffective	Clt1, Clt2, Des1, Des2, CEO3, CEO4, CEO5
		SL18	Lack of adequate resources	Clt1, Clt2, Clt10, Des1, Des2, CEO1, CEO2, CEO3, CEO4, CEO5

The risk factors levels and sublevels were defined using an internal organization form. To analyze the risk level impact, pairwise comparisons were made, as recommended by Saaty [6]. The authors prepared the relative importance matrix evaluation in Fig.2 considering the Risk Sub-Level and the associated Risk Factor affecting the failure of the Purified Water System shown in Tab. 4.

Criteria Comparison Matrix													
Risk Factors	Design poor prepared	Improper Material & System	Uncorrected PW Implementation	Equipment/ looping Failure	Management & Environment	Negative Organization Factor	Normalized Matrix						Weights
Design poor prepared	1	7	9	7	5	5	**0,56**	0,80	0,51	0,31	0,18	0,23	0,43
Improper Material & System	1/7	1	7	7	9	3	0,08	**0,11**	0,40	0,31	0,33	0,14	0,23
Uncorrected PW Implementation	1/9	1/7	1	7	5	3	0,06	0,02	**0,06**	0,31	0,18	0,14	0,13
Equipment/ looping Failure	1/7	1/7	1/7	1	7	5	0,08	0,02	0,01	**0,04**	0,26	0,23	0,11
Unfavorable Management & Environment	1/5	1/9	1/5	1/7	1	5	0,11	0,01	0,01	0,01	**0,04**	0,23	0,07
Negative Organization Factor	1/5	1/3	1/3	1/5	1/5	1	0,11	0,04	0,02	0,01	0,01	**0,05**	0,04
TOTAL	**1,80**	**8,73**	**17,68**	**22,34**	**27,20**	**22,00**							

Fig. 2. AHP Matrix

The GTST shown in Fig.3 was then prepared based on the risk assessment and the prioritization of risk factors obtained by AHP. The purpose of this chart is to define detailed responses to the risks with higher impact. In order to achieve the main goal in the first line, *"To install the PW System correctly,"* it is necessary to address the critical success factors (CSF) on the second line. These are "*Align the Correct PW System to Enterprise and Check the main Standard & Technologies available*". In order to obtain success in the items listed in the second line (CSF – Critical Success Factors), the items listed on the third line (CE – Clarify expectations) need to be addressed. These are *"Align with client PW demand*", "*Select reverse osmose system" and "Design correct distribution looping."* In order to obtain success in the items listed in the third line, the items listed in the fourth line (PD – Proper Design) need to be addressed. These are *"Correct Material Specification," Correct Reverse Osmosis System", "Implement Quality Program", and "Improve Maintenance Program."* In order to obtain success in the fourth line, the items (SC – Standard Checks) in the fifth line need to be addressed. In order to obtain success in the fifth line, it is necessary to specify the equipment solution, as shown in the sixth line.

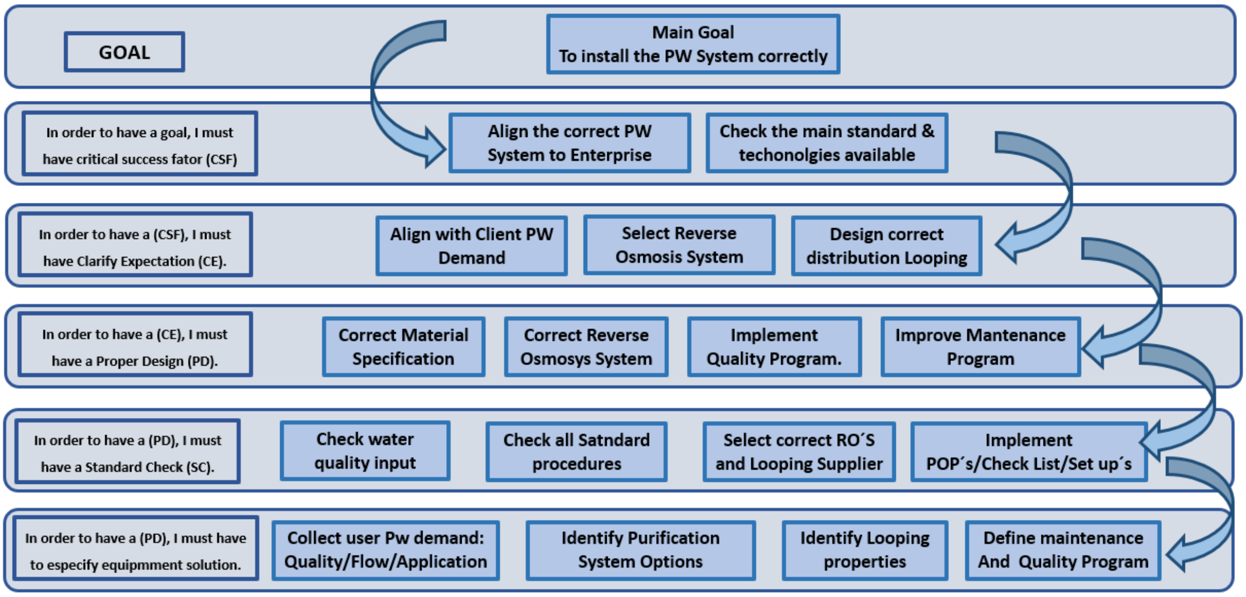

Fig. 3. Goal Tree Success Tree

4 CONCLUSION

The target of the study was to conduct a risk assessment and identify the risk factors in implementing the purified water production and distribution system that could affect operational quality and sustainability. The next step was to propose actions that could be taken to respond to risk factors effectively. The most impactful risk category was design poorly prepared and uncorrected PW implementation.

Based on these risk factors, an AHP matrix was prepared to identify the most impactful risk categories. Response to these risks was defined using GTST, and the actions defined can improve the processes significantly. This contributes to the previous findings of other researchers presented in the section showing a literature review since most of them were based on qualitative approaches only and did not cover a quantitative approach using AHP and with a focus on improving PW systems and organizational sustainability. This paper aimed at completing this gap by proposing and describing a method to apply AHP to prioritize the risks in the PW system and define adequate risk responses by proposing actions that could optimize quality, safety, and sustainability. The study was conducted within the facilities of a research foundation, and the result can be generalized to other organizations using PW systems. The implications are relevant since the proposed actions improve the quality and sustainability of the organizations. The proposed methodology revealed some crucial results, thus contributing to previous studies on the subject and may help overcome some of the challenges operational leaders and other professionals looking for quality and quality in the PW system. The study was conducted based on the experience and knowledge of experts on the subject. As explained in the Introduction Section, several papers have been published addressing PW systems in different domains in the latest years. However, no previous study could be found covering the application of AHP to identify risks in the PW systems. It is noteworthy here that this paper proposes an optimized approach that could be used in any organization. This approach offers direction to understand client demand, guides designers to offer the best system solutions related to quality and expectation, and offers an upgrade on organization quality and sustainability.

In response to the first question, "*How can project leaders overcome the difficulties in designing the production and distribution of purified water?"*. It is concluded that the difficulties can be overcome by clarifying and improving the stakeholders' understanding of purified water (PW) system design. Identifying the level of knowledge of customers, designers, and CEOs was essential to prioritize the risk factors categories, define the responses and show opportunities for the development of other studies.

In response to the second *"What are the risks factors in implementing the purified water production and distribution system?"* the risk factors were identified by a survey and prioritized using AHP. The application of the methodology has been guiding clients, designers, and CEOs to understand the critical risk factors in the PW System production and distribution.

In response to the third question, *"What actions should those project leaders take to correct the purified water production and distribution in response to risks?"*. The impact of risks associated with Purified Water was predicted quantitatively. GTST was used to define the actions to minimize the downtime of the manufacturing and services process and delay in production and part failure.

The novelty of this paper is the use of AHP and GTST in the risk management of Purified Water System and offers differentiated approaches to address the risks in the development of Purified Water systems for small, medium, or significant customers. In conclusion, this paper presents a method to avoid investment losses, reworks, and additional expenses trying to adjust a poorly designed system.

5 REFERENCES:

[1] OLIVEIRA , F. C., PELEGRINI D. D., Quality control of the reverse osmosis system, SaBios: Rev. Saúde e Biol., v. 6, n.1, p.36-42, http://www.revista.grupointegrado.br/sabios/, jan./abr., 2011

[2] DYLLICK, T., HOCKERTS, K. Beyond the business case for corporate sustainability. Bus. Strat. Environ. 11, 130-141. 2002.

[3] ISLAMA, R., ABBASSIA, R., GARANIYAA, V., KHANA, F., Development of a human reliability assessment technique for the maintenance procedures of marine and offshore operations. Journal of Loss Prevention in the Process Industries. Vol. 41, 2017.

[4] T. TACHI ET AL., "Contribution to and Future Prospects for ISO/TC 224 and ISO/TC 282 International Standardization Activities in the Water Industry," Hitachi Review, 64, pp. 618–623, (Dec. 2015).

[5] CRISTIANO SOUZA MARINS, DANIELA DE OLIVEIRA SOUZA, MAGNO DA SILVA BARROS, The use of the Hierarchical Analysis Method (AHP) in the outlet of management decision – A case of stud, 2009.

[6] SAATY, T. L. The Analytic Hierarchy Process. McGraw-Hill, 1980.

[7] SAATY, T. L., An exposition of the AHP in reply to the paper "Remarks on the analytic hierarchy process." Management Sci. 36(3) 259–268, 1990.

[8] SAATY, T. L. Axiomatic foundation of the analytic hierarchy process. Management Sci. 32(7) 841–855, 1986.

[9] SUKETU Y. JANI, Review of lean manufacturing practices - critical success factors and performance measures for SMEs, 26 October 2016.

[10] MOSS, TR, AND ANDREWS J. D, Reliability and Risk Assessment. 1st Ed. Longman Group UK 1993.

[11] P. BRESCIANI, A. PERINI, P. GIORGINI, F. GIUNCHIGLIA, AND J. MYLOPOULOS, "TROPOS: An agent-oriented software development methodology," Autonomous Agents and Multi-Agent Systems, vol. 8, no. 3, pp. 203–236, 2004.

[12] KNEMEYER, A.M., et al., (2008). ″Proactive Planning for Catastrophic Events in Supply Chains″, Journal of Operations Management.

[13] JOSÉ CRISTIANO PEREIRA AND GEANE CRISTINA FAYER, Strategic decision making to maximize the efficiency of water usage in steel manufacturing process via AHP and BBN: a case study, Int. J. Information and Decision Sciences, Vol. 12, No. 4, 2020.

[14] CHOPRA, S., SODHI, M. S., Managing risk to avoid chain break down. MIT Sloan Management Review 46, 2004.

[15] UNITED STATES PHARMACOPOEIA 30 ed, Rockville: United States **Pharmacopeial Convention**, NF 25, p. 678, 2007.

[16] FARMACOPEIA BRASILEIRA, 6ª edição, Volume I, páginas 787 – 799, 2019.

[17] TAKAHIRO TACHI, HIROKI NAKAMURA, Ph.D. Japan's Involvement in International Standardization for Water Industry Activities of ISO/TC 224 and ISO/TC 282 Technical Committees 2019.

[18] FORD LUMBAN GAOL, JONATHAN DANNY, AND TOKURO MATSUO, Application of organization goal-oriented requirement engineering (OGORE) methods in erp-based company business

processes, https://doi.org/10.1515/eng-2019-0064, published by De Gruyter, Received Jul 11, 2019; accepted Sep 30, 2019

[19] J. C. PEREIRA, F. ALMEIDA, Risk Assessment in Magnetic Particle Inspection (MPI) of critical ferromagnetic parts via Bayesian Belief Networks and Analytic Hierarchy Process and the use of Goal Tree to Improve the on quality and sustainability of organizations, 2021.

[20] RABIHAH MD.SUM, Risk Prioritisation Using The Analytic Hierarchy Process 1Faculty of Science and Technology, Universiti Sains Islam Malaysia (USIM), 71800 Bandar Baru Nilai, Negeri Sembilan. Corresponding author: rabihah@usim.edu.my, 2015.

[21] J. C. PEREIRA, JOEL TZASCHEL, Risk Assessment of Project Based Learning Failure via Bayesian Belief Networks and Analytical Hierarchy Process – A Literature Review, 2021.

[22] H. SASAYAME ET AL., "Overview of ISO/TC 224/WG7, WG9 andWG6 Meetings in Tel Aviv," Journal of Japan Water Works Association, Vol. 88, No. 5 pp. 43–50, Japan Water Works Association (May 2019) in Japanese.

[23] SHAW, FARWER, BORDINI, Theoretical and Experimental Results on the Goal-Plan Tree Problem (Short Paper), 2011.

[24] KIM & KIM, Decision Analysis Based on AHP and GTST Methodologies with Application to CCF-Defense Strategies, Pages 283-294 | Published online: 10 Apr 2017.

[25] DI MAIO, FRANCESCO, (2019), Simulation-Based Goal Tree Success Tree for the Risk Analysis of Cyber-Physical Systems, Instructions, ESREL 2019.

[26] ZHIGUO ZENG, ET AL., Resilience analysis of multi-state systems with time-dependent behaviors, ESREL, 2021.

[27] ZHIGUO ZENG, ET AL., A Markov reward process-based framework for resilience analysis of multistate energy systems under the threat of extreme events, Reliability Engineering & System Safety - Volume 209, 2021.

[28] QUERAL C., ET AL., Application of Expanded Event Trees combined with uncertainty analysis methodologies. Reliability Engineering & System Safety, Volume 205, 2021.

[29] NATIONAL INSTITUTES OF HEALTH NIH – Design Requirements Manual – Revision 1.0:, (1.15.6 Risk Assessment, System Failure & Disaster Mitigation; Chapter 12 – Special Process – Piping Systems (purified water system). 02/12/2018.

[30] OLIVEIRA, D. R. Pretreatment of the reverse osmosis process using microfiltration and investigation of membrane cleaning and recovery techniques. 2007. 119 f. Dissertation (Master of Science in Chemical Engineering) – Federal University of Rio de Janeiro, Rio de Janeiro, 2007.

[31] ABNT NBR ISO 9001 – Quality Management System, 2015.

[32] ABNT NBR ISO 31000:2018 – Risk Management — Guide

[33] ISO, "ISO 24510:2007 Activities relating to drinking water and wastewater services — Guidelines for the assessment and for the improvement of the service to users,".

[34] ISO, "ISO 22519-2019 Purified water and water for injection pretreatment and production system.

[35] ISO, "ISO 20468-1:2018 Guidelines for performance evaluation of treatment technologies for water reuse systems — Part 1: General,".

[36] ISO 20468-2:2019 Guidelines for performance evaluation of treatment technologies for water reuse systems — Part 2: Methodology to evaluate the performance of treatment systems on the basis of greenhouse gas emissions.

[37] ANA, Situation of water resources in Brazil 2020: annual report / National Water Agency and Sanitation.2020.

[38] JACOB HÖRISCHA, STEFAN SCHALTEGGERA, R. EDWARD FREEMANB, Integrating stakeholder theory and sustainability accounting: A conceptual synthesis, Journal of Cleaner Production, 2020.

[39] WEN ZHANG A, XING FAN A, YATING LIU B, SAIGE WANG B, BIN CHEN, Spillover risk analysis of virtual water trade based on multi-regional input-output model -A case study, Institute of Environment and Ecology, Shandong Normal University, Ji'nan, Shandong, 250038, China, 2020.

[40] E. FERRARIO A, E. ZIO, Goal Tree Success Tree–Dynamic Master Logic Diagram and Monte Carlo simulation for the safety and resilience assessment of a multistate system of systems , Systems Science and the Energetic Challenge, European Foundation for New Energy, 2014.

[41] FU, J; TANG, Y; GUAN, Q., Objective Bayesian Analysis for Recurrent Events in Presence of Competing Risks. Quality Technology and Quantitative Management 11(3) 265-279. 17, (2016).

[42] GRUBER, A; BEN-GAL, I., Efficient Bayesian Network Learning for System Optimization in Reliability Engineering. Quality Technology and Quantitative Management 9(1) 97- 114, 2016.

[43] GUÉRIN, F; BARREAU, M; CHARKI, A; TODOSKOFF, A. Bayesian Estimation of Failure Probability in Mechanical Systems Using Monte Carlo Simulation. Quality Technology and Quantitative Management 51-70 (4)1, (2016).

[44] PAVEL CASTKA, DANIEL PRAJOGO, The effect of pressure from secondary stakeholders on the internalization of ISO 14001, Journal of Cleaner Production, 2013.

[45] TERRANCE R INGOLDSBY, Attack Tree-based Threat Risk Analysis, Amenaza Technologies Limited, Copyright © Amenaza Technologies Limited – All Rights Reserved, Web: www.amenaza.com, 2009, 2010, 2013, 2021.

[46] JONATHAN T. BRECKENRIDGEI DR. STEPHEN B. JOHNSON, Implementation of a Goal-Based Systems Engineering Process Using the Systems Modeling Language (SysML), AIAA Infotech@Aerospace (I@A) Conference, August 19-22, 2013, Boston, MA