Revista EIA, ISSN 1794-1237 / Year XI / Volume 11 / Issue N. 21 / January-June 2014 / pp. 155-166
Technical-scientific biannual publication / Escuela de Ingeniería de Antioquia —EIA—, Envigado (Colombia)

RISK ASSESSMENT IN WATER DISTRIBUTION SYSTEMS FRAMED IN A WATER SAFETY PLAN

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ABSTRACT

Risk assessment is a key stage in a water safety plan (WSP) and it is achieved by identifying hazards or hazardous events and estimating risks. This study evaluated health risks in the drinking water distribution system (DWDS) of the city of Cali (Colombia), which is supplied by the Cauca River. Hazardous events were identified, and, subsequently, a risk estimation was completed using a previously adapted semi-quantitative risk matrix. The risk estimation was initially made without considering the existing control measures in the DWDS. It was then redone considering the level of effectiveness of these measures. The results showed the events with the highest level of risk associated with the loss of physical and hydraulic integrity of the DWDS (damage to water pipelines, pressure fluctuations, lack of systematized information about the DWDS, human error, lack of training, supervision, and awareness about the concept of water safety , and internal and external corrosion in the elements of the DWDS). Risk assessment is a management tool for water providers which allows for prioritizing human and financial resources toward improving control measures as a strategy for reducing health risks and ensuring the quality of drinking water in the DWDS.

KEYWORDS: Risk assessment; Hazard identification; Semi-quantitative risk matrix; Water safety plan (WSP); Drinking water distribution systems (DWDS).

EVALUACIÓN DEL RIESGO EN SISTEMAS DE DISTRIBUCIÓN DE AGUA POTABLE EN EL MARCO DE UN PLAN DE SEGURIDAD DEL AGUA

RESUMEN

La evaluación del riesgo es una etapa clave de un Plan de Seguridad del Agua (PSA) y se logra mediante la identificación de peligros o eventos peligrosos y la valoración del riesgo. Este estudio evaluó los riesgos en el Sistema de Distribución de Agua potable (SDA) de la ciudad de Cali (Colombia) abastecido por el río Cauca, identificando los

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Paper history:
Paper received on: 10-IX-2013 / Approved: 05-I-2014
Available online: May 12th 2014
Open discussion until May 2015

DOI: http://dx.doi.org/10.14508/reia.2014.11.21.159-169

eventos peligrosos y posteriormente realizando la estimación del riesgo usando una matriz semicuantitativa adaptada. La estimación del riesgo se efectuó inicialmente sin considerar las medidas de control existentes del SDA y luego se reestimó considerando el nivel de eficacia de las mismas. Los resultados mostraron los eventos con mayor nivel de riesgo asociados al deterioro de la integridad física e hidráulica del SDA (daños en tuberías, fluctuaciones de presión, ausencia de información sistematizada sobre el SDA, fallas humanas, falta de capacitación, supervisión, conciencia del concepto aseguramiento del agua, corrosión interna y externa de elementos del SDA). La evaluación del riesgo es un instrumento de gestión para empresas prestadoras del servicio que permite priorizar recursos humanos y financieros hacia el mejoramiento de las medidas de control como estrategia para reducir los riesgos y asegurar la calidad del agua potable en el SDA.

PALABRAS CLAVE: evaluación del riesgo; identificación de peligros; matriz semicuantitativa de riesgo; plan de seguridad del agua (PSA); sistema de distribución de agua potable (SDA).

AVALIAÇÃO DO RISCO EM SISTEMA DE DISTRIBUIÇÃO DE ÁGUA POTÁVEL NO MARCO DUM PLANO DE SEGURIDADE DO ÁGUA.

RESUMO

A avaliação do risco é uma etapa chave dum Plano de Seguridade do Água (PSA) e consegue-se mediante a identificação de perigos ou eventos perigosos e a valoração do risco. Este estudo avaliou os riscos no Sistema de Distribuição de Água potável (SDA) da cidade de Cali (Colômbia) abastecido por o rio Cauca, identificando os eventos perigosos e posteriormente realizando uma estimação do risco usando uma matriz semiquantitativa adaptada. A estimação do risco efetuou-se sem considerar as medidas de controle existentes do SDA e logo reestimou-se o nível de eficácia dessas. Os resultados mostraram os eventos com maior nível de risco associados à deterioração da integridade física e hidráulica do SDA (danos em tubulação, flutuações de pressão, ausência de informação sistematizada sobre o DAS, falhas humanas, carência de capacitação, supervisão, consciência do conceito asseguramento do água, corozão interna e externa de elementos do SDA). A avaliação do risco é um instrumento de gestão para empresas prestador de serviços que permite priorizar recursos humanos e financeiros para o melhoramento da medidas de controle como estratégia para reduzir os riscos e garantir a qualidade do água potável no SDA.

PALAVRAS-CHAVE: Avaliação do risco; Identificação de perigos; Matriz semiquantitativa; Plano de seguridade do agua (PSA); Sistema de distribuição de agua potável (SDA).

1. INTRODUCTION

Drinking water treatment plants (DWTP) can provide water that is safe for human consumption, but its quality can be affected during movement through the water distribution system (WDS) before arriving to the consumer. If the water supply is restricted, the possibility of deterioration in physical, chemical, and, mainly, microbiological quality between domiciles increases (Rojas, 2002; Ainsworth, 2004; Graham & Van Derslice, 2007; OMS, 2007). The WDS's physical and hydraulic integrity and the quality of its water must be protected to guarantee safety in the drinking water supply (National Research Council, 2006).

The World Health Organization (WHO) recommends implementing water safety plans (WSP) as the most effective way of guaranteeing the integrity of the water in each of the components in a drinking water supply system (DWSS) (watershed, treatment processes, distribution system, and final user). Risk assessment is one of the key stages during WSP development. Risk assessment covers the stages of risk identification and risk assessment. Risk identification is the first step in the general focus of risk assessment adopted by different committees of experts, regulatory agencies, and health institutions, among others, to manage efficient control measures (NAP, 2008; Tuhovcak & Rucka, 2009; WHO, 2011).

In addition to identifying possible hazards and hazardous events (events that create hazards or impede their elimination in the DWSS) and ranking or determining the level of risk (probability that a hazardous event will occur), risk assessment identifies the correct measures for controlling the risks that have been identified and helps to confirm whether regulations and goals set by the company are being met (Bartram et al., 2009; WHO, 2011).

One of the tools for estimating risk that has been used in almost all reported WSP experiments to analyze the different components of a DWSS is a semi-quantitative risk matrix, which uses a point scale to measure the levels of probability of occurrence and the impact of a hazard or hazardous event's consequences (Rosén, et al., 2007 & Lindhe, 2008). These matrices are simple, and the result is easy to understand. In addition to risk assessment, these matrices prioritize events according to their level of risk, helping to optimize existing control measures or the implement of new measures that reduce risk levels (Vieira & Morais, 2005; Rosén, et al., 2007; Lindhe, 2008).

This study presents the results of a WDS risk assessment in the city of Cali, Colombia, specifically on the lower network supplied by the Cauca River. The tool used was a semi-quantitative risk matrix previously adapted for application to a WDS.

2. METHODOLOGY

The city of Cali's DWSS supplies approximately 2.5 million inhabitants through four surface water sources: the Cauca, Cali, Melendez, and Pance Rivers. Although the city's WDS is made up of four networks, Lower, Upper, Reform, and Pance (PDA, 2008), this study focused on the lower network, which supplies drinking water to nearly 80% of the population using the Cauca River as its supply source. This water is treated in the Cauca River and Puerto Mallarino DWTPs. The following stages were part of the WDS risk assessment:

- Creation of the WSP team and collection of available secondary information
- Creation of the hazard and hazardous event matrix
- Scoring of risks using the semi-quantitative matrix

2.1 Creation of the WSP Team and Collection of Available Secondary Information

Keeping in mind the WSP methodology recommended as a water quality safety strategy, an interdisciplinary team was created with the support of operational and technical personnel from the water provider, consultants with experience in operation and maintenance of the city's entire DWSS, and academic professionals and researchers.

A search of available secondary information regarding the WDS was made through technical visits to the aqueduct service company and to various organizations such as health, environmental, educational, and municipal planning institutions in order to collect information from city sectors or neighborhoods that make up the lower network and identify potential hazards and hazardous events that could alter the quality of water in the WDS.

2.2 Creation of the Hazard and Hazardous Event Matrix

Based on the information collected in the previous stage and the information reported in the literature regarding WDS behavior, a matrix of hazards and hazardous events was created according to WSP methodology (Bartram et al., 2009; WHO, 2011). WDS components are differentiated, and the matrix was constructed with classification in four components: networks, storage tanks, pumping stations, and other (associated with organizational, financing, and company aspects, as well as external factors or emergency situations that could compromise quality, quantity, and continuity of service).

Table 1 shows an outline of the hazard and hazardous event matrix, which indicates that hazardous events were identified for each component, and each event was assigned a code and the cause or reason for its origin (D: design, O: operation, M: maintenance, EM: emergencies, or E: external factors). The hazards were classified as B: biological, C: chemical, P: physical, R: radiological, I: associated with physical infrastructure (damages to facilities), and Q: associated with the quantity of water (lack of water).

Table 1. Outline of hazard and hazardous events matrix

Hazardous Event								Hazard						
Code	Event	Cause/Reason	Classification					Comment	Classification					
			D	O	M	EM	E		B	Q	F	R	I	C

2.3 Scoring of Risks Using the Semi-quantitative Matrix

Risk scoring included risk estimation, identification of existing control measures, and risk re-estimation. The risk estimation was initially completed without considering existing control measures in the WDS and was later re-estimated bearing in mind these measures' level of effectiveness. The semi-quantitative matrix proposed by the WHO (2011) was adapted by adjusting the meaning of the probability level for occurrence of hazardous events and their severity or impact. Aspects related to the quality and quantity of water and continuous service were also considered, thereby creating a matrix specifically for use with WDS for broad and precise risk assessment. It is important to note that in most of the WSP experiments reported internationally, the generic semi-quantitative matrix proposed by the WHO (2011) has been used with minimum adaptation. **Table 2** shows the matrix proposed for this study.

The final risk classification was based on four levels according to the score obtained: Low (< 6), Medium (6-9), High (10-15), and Very High (>15).

For each hazardous event, the risk estimation was made by multiplying the probability of occurrence (on a scale of 1-5) and the impact or seriousness of its consequences (on a scale of 1-5). This calculation and the adaptation of the matrix were discussed and received feedback from the members of the WSP team using Delphi methodology (Landeta et al., 2011) in which a consensus of opinions was achieved through technical meetings with the WSP team and analysis of the qualitative and quantitative information from the lower network of the DWSS, the criteria based on evidence found in the technical literature, knowledge of the WDS, and the experience of the participants.

The risk score also identified of the need for formulating improvement or support programs for the WSP that include new control measures or improvements on those that already exist as part of the risk management strategies within the WSP focus on risk reduction.

3. RESULTS AND DISCUSSION

3.1 Creation of the WSP Team and Collection of Available Secondary Information

The WSP team included technical, operational, and management personnel from the water provider company, an expert DWSS consultant from the city of Cali with more than 20 years of experience, and academics with careers in teaching and research on the topic of water and DWSS in the city of Cali. **Table 3** shows the institutions in which the information used in the study was collected.

Authors like Sturm et al. (2008), Törnqvist et al. (2008), Bartram et al. (2009), and the WHO (2011) state that one of the issues present in risk assessment is the collection of data on DWSS function since in many cases it is not readily available or does not exist. In this study, although some of the information was not precise (in some cases there was no information or it was improperly compiled and processed by the different institutions consulted), the information collected on the lower network of the WDS was sufficient for construction of the hazard and hazardous event matrix and the semi-quantitative risk assessment matrix. However, the process required systematization, grouping, unification of formats, and processing of existing information, which required time and human and financial resources in order to find the information distributed among different departments within the same company.

Table 2. Semi-quantitative matrix adapted for risk assessment in the lower network of the Cali city WDS

Semi-quantitative Risk Matrix			Impact				
			INSIGNIFICANT No repercussions. Not detectable. Safe water distribution in **entire** WDS.	**LOW** Supply that does not fulfill organoleptic characteristics in **part** or **all** of the WDS.	**MODERATE** Consequences for public health in the long term (chronic risk) and/or organoleptic characteristics. < **12 hours** of lack of water in **part** of the WDS.	**HIGH** Incompliance with regulations that has repercussions on public health in the short (acute risk) **or** long term (chronic risk). Lack of water > **12 hours** in **part** of the WDS.	**CATASTROPHIC*** Incompliance with regulations that has repercussions on public health in the short (acute risk) **and** long term (chronic risk. Lack of water in the **entire** WDS.
			Value: 1	**Value: 2**	**Value: 3**	**Value: 4**	**Value: 5**
Probabilidad de ocurrencia	**ALMOST CERTAIN*.** It has occurred several times, and it is almost certain that it could happen again. Frequency: daily of several times a month.	**5**	5	10	15	20	25
	PROBABLE. It has occurred several times. Frequency: once or several times a year.	**4**	4	8	12	16	20
	MODERATE. It has occurred. Frequency: at least once in 5 years.	**3**	3	6	9	12	15
	IMPROBABLE. It is possible and cannot be overlooked completely. Frequency: it has occurred at least once in 5-10 years.	**2**	2	4	6	8	10
	RARE. It has not occurred, but it is possible. Frequency: once in more than 10 years.	**1**	1	2	3	4	5

Risk Score	< 6	6-9	10-15	≥ 16
Risk Level	Low	Medium	High	Very High

Source: Adapted from Bartram et al., 2009; WHO, 2011a

*If there is not enough information to determine whether the risk is high or low, it must be considered significant until subsequent research can dispel uncertainty (Bartram et al., 2009)

Table 3. Information collected and entities that supplied information

INFORMATION COLLECTED	OFFICE	INSTITUTION
Reports on water quality information and IRCA* values for the stations monitored by EMCALI in the network	Central Laboratory for Water Quality Control	EMCALI EICE ESP
Information on damages and repairs in home connections	Operational Attention Department	EMCALI EICE ESP
Information on damages and repairs in sewer system	Wastewater Collection Department	EMCALI EICE ESP
Information on incorrect connections in sewer system		
Flood zones in the city of Cali		
Zones with aqueducts and no sewer system		
Information on pressure in the network	Distribution Department	EMCALI EICE ESP
Type of material in the network by neighborhood		
Dead zones, low speed zones, and remote points in the distribution system		
Information on tank and network maintenance		
Age of pipes		
Registry of drinking water distribution system		
Existence of crosses in the distribution network with the sewer system	Wastewater Distribution and Collection Department	EMCALI EICE ESP
Reports of complaints regarding drinking water quality	Commercial Management	EMCALI EICE ESP
Information on replacement of networks in sewer system and aqueducts	Engineering Department	EMCALI EICE ESP
Inventory of type of material used in in-home connections, age of internal facilities	Aqueduct Management Engineering Department. Fire Department Operational Attention	EMCALI EICE ESP Fire Department
Information on educational campaigns completed with the population regarding management of in-home connections	Commercial Management Department of Environmental Management	EMCALI EICE ESP Health Secretariat
Census on buildings, institutions (hospitals, schools, malls) with in-home storage	EMCALI Aqueduct and Sewer System Management Engineering Department	EMCALI EICE ESP
Report on quality of water for human consumption in the Santiago Municipality of Cali	Environmental Management Department	Health Secretariat
Information on studies regarding prevention of diseases associated with the environment		Health Secretariat
Basic mapping of the Santiago Municipality of Cali	POT and public services	Municipal Planning
Seismic microzoning in the Santiago Municipality of Cali	Risk Management Department	DAGMA
Research projects on DWSS	Library, research centers	Universidad del Valle, Javeriana

It is fundamental to understand and raise awareness about the value of adequate WDS information collection by the different actors involved in assuring water quality since many difficulties were encountered during the information collection process. For example, although information on water complaints by end users are compiled by the company, the information is fragmented among different departments and is not used as a possible indicator of water quality, but rather is considered to be a commercial factor. This information is key for evaluating WDS behavior and serves as a control measure to detect potential failures in the WDS since reports on changes in the water's appearance, smell, or taste, a loss of water pressure, etc. could indicate the occurrence of hazardous events that compromise the quality of drinking water (Ainsworth, 2004; Cunliffe et al. 2011).

3.2 Creation of the Hazard and Hazardous Event Matrix

The information collected on the WDS, from its description to its function, is fundamental to determining the points in the system that are vulnerable to hazardous events and identifying the types of relevant hazards (Vieira & Morais, 2005; Bartram et al., 2009). Based on the information collected, knowledge of the SDA, and studies done on the SDA such as that of Pérez et al. (2012), a matrix of hazards and hazardous events was constructed for the lower WDS network, where a total of 38 hazardous events was identified (21 in networks, 3 in storage tanks, 3 in pumping stations, and 11 in other sectors).

Of the hazardous events identified, 58% of the total are mainly related to maintenance problems, 55% are related to operation, and 45% are related to design. Finally, external factors and those associated with emergencies or chance events are also related, as is indicated by the National Research Council (2006), which states that maintenance is one of the main activities necessary for assuring WDS integrity.

By way of example, **Table 4** shows a fragment of the WDS hazard and hazardous event matrix for each of the WDS's components, along with its associated risk.

One example of the hazardous events cited in **Table 4** is the one denominated EV_7_N. Although the service provider has increased the number of monitoring points as defined in resolution 0811 of 2008 (MPS, 2008) and the recommendations made by Montoya et al. (2009), adjustments are still being made in some points due to problems with their physical adaptation. This is an important action since a lack of coverage in water quality control can affect decision-making regarding the system's operation. Having a true and precise diagnostic of water quality allows for identification of risk zones and their causes and timely action in case of drinking water contamination (Montoya et al, 2009; WHO, 2011).

3.3 Scoring of Risks Using the Semi-quantitative Matrix

Once the hazards and hazardous events have been systematized, the existing control measures for each of the 38 hazardous events defined on the WDS hazard and hazardous events matrix were identified. The risk assessment for each event was initially made without considering the existing control measures and was then re-estimated considering the effectiveness of the control measures. **Table 5** shows a fragment of the risk assessment matrix, showing one hazardous event for each of the WDS components and its respective risk estimation with and without control measures.

Figure 1 shows the risk classification with and without control measure percentages. The table also shows that when control measures are not considered, of the 38 hazardous events identified, 31 are classified as having a very high risk level, and the other 7 have a high risk level, with no hazardous events at a medium or low risk level. When the control measures identified are applied along with their level of effectiveness, the risk level for the events was reduced (9 events at a very high risk level, 20 at a high level, and 9 at a medium level, with none at a low level).

Although the existing control measures reduced the levels of risk, no hazardous event was reduced to a low level, and 9 events were still classified at a very high level of risk, indicating the need for reinforcing existing control measures to improve their effectiveness and/or evaluating new measures in order to reduce risk levels.

Tabla 4. Fragmento matriz de peligros y eventos peligrosos del SDA red Baja Cali

Component	Código*	Hazardous Event	Associated Risk
NETWORK:	EV_7_R	Low water quality monitoring coverage in the WDS	Biological, chemical, and physical
	EV_21_R	Inadequate practices in construction of new networks by developers and/or service provider	Biological, chemical, physical, lack of water, and infrastructure
Storage Tanks	EV_1_T	Inadequate hydraulic function of storage tanks	Biological, chemical, and physical
	EV_2_T	Growth of biofilm on tank walls and accumulation of sediments	Biological, chemical, and physical
Pumping Stations	EV_1_E	Failure or blackout in pumping stations	Biological, chemical, physical, lack of water, and infrastructure
	EV_3_E	Inadequate operation and maintenance of pumping stations	Biological, chemical, physical, lack of water, and infrastructure
Other	EV_2_O	Lack of security, acts of vandalism, and terrorism in the Supply System	Biological, chemical, physical, lack of water, radiological, and infrastructure
	EV_7_O	Lack of financial resources and inadequate management	Biological, chemical, physical, lack of water, and infrastructure

*EV: EV: Event_ event number _component: N network, T storage tanks, P pumping stations, and O other

The hazardous events with a very high risk level were mainly associated with damages in drinking water pipes related to the type of material, pressure fluctuations due to the system's hydraulic function, elevated water age, improper repair and replacement practices regarding WDS components, a high percentage of losses in the system which increased the non-revenue water index, the lack of systematized information on WDS behavior, human error (lack of training, supervision, awareness of the concept of water quality assurance, or commitment of operative and administrative personnel) and internal and external corrosion of WDS elements (pipes, structures, equipment, valves). A large number of these hazardous events have been indentified in other studies as critical, since they are the most common and important in WDS (Lee & Schwab, 2005; National Research Council, 2006; Moreno, 2009; WHO, 2011).

In general, risk assessment and the analysis of control measures provided evidence of the measures' effectiveness and indentified the need for improving existing measures and formulating new measures to generate risk reduction as part of any WSP's focus. **Table 6** summarizes the proposed programs which could be developed to optimize existing control measures and/or new proposals that could be an instrument for prioritizing and investment planning for the service provider, as well as measures for reducing risk levels.

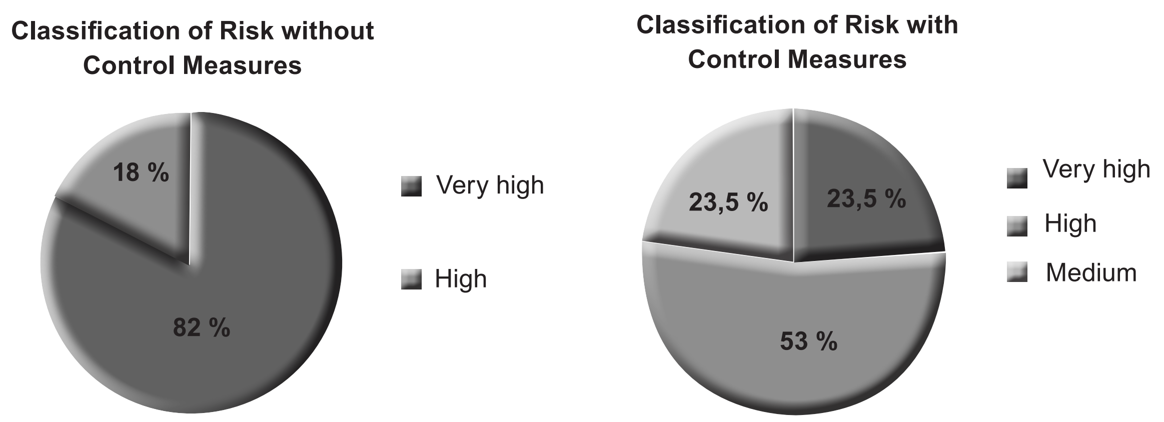
Assigning time and resources to the execution of improvement programs depends on planning and the decisions of directors or upper management, which underscores the importance of their participation and commitment in development, implementation, and sustainability of the WSP in order to guarantee its success (Davison & Deere, 2007; Bartram et al., 2009). Some of the programs proposed are applicable to different hazardous events. Therefore, in addition to considering the risk level, this could also be a decision-making criterion in prioritizing which programs to execute. During program execution, monitoring must be guaranteed to be sure that new risks are not introduced and to ensure continual updates to the WSP (Bartram et al., 2009).

Table 5. Fragment of the WDS risk assessment matrix

Hazardous Event	Risk Estimation without CM			Control Measures (CM)	Risk Estimation with CM		
	P	I	R		P	I	R
Network: Low water quality monitoring coverage in the WDS	4	4	Very High	Continue with implementation and/or adjustment of monitoring points. Preventive maintenance and calibration of monitoring equipment.	3	4	High
Network: Inadequate practices in construction of new networks by developers and/or service provider	3	4	High	Checking and approval by service provider of aqueduct and sewer system designs created by developers and private contractors. Constant supervision of works to check compliance with approved designs and construction procedures. Supervision of quality of materials used in construction activities.	2	4	Medium
Storage tanks: Growth of biofilm on tank walls and accumulation of sediments	5	4	Very High	Adequate operation of treatment barriers (control cloudiness, corrosion, Fe and Mn concentration, organic material, etc.). Washing and sanitation of storage tanks (min. 4 times/year). Monitoring water quality at inflow and outflow points of storage tanks. Operating the WDS avoiding minimum or high levels of water in storage tanks, which increase the water's age due to current hydraulic problems in the WDS.	2	4	Medium
Pumping stations: Inadequate operation and maintenance of pumping stations	4	4	Very High	Executing inspection and maintenance programs in pumping stations (component replacement, correction of leaks, control of external corrosion) Updating operation procedures, maintenance, and continuity of the quality management process.	3	4	High

CM: Control measures, P: Probability, I: Impact, R: Risk, PM: Puerto Mallarino

Figure 1. Classification of WDS risk assessment matrix with and without control measures



According to Rojas (2006), in order to adequately respond to a risk, it is necessary to have multidisciplinary and inter-institutional participation from all interested parties to guarantee a comprehensive vision and solution for the event. Therefore, it is essential to define responsibilities in order to raise awareness among the different actors involved regarding the repercussions of their actions as a strategy for controlling oversight and water quality, as maintained by the WHO (2011). In this way, proper function of control measures for reducing risk and consolidating water quality assurance depend to a large degree on commitment and cooperation between the water service provider and the relevant institutions in charge of oversight and quality control for drinking water, as well as the attitude of users (Davison & Deere, 2007; Bartram et al., 2009).

4. CONCLUSIONS

It is fundamental to understand and raise awareness among the different actors involved in water quality assurance on the value of appropriate information collection regarding the function of the WDS to be evaluated. Having an appropriate system for collecting, processing, and analyzing reliable information allows for greater precision and representation of potential risks and solutions, facilitating timely and exact reactions when a hazard or hazardous event that affects drinking water quality occurs.

The hazardous events categorized in the risk assessment matrix for the lower network of the Cali WDS with a very high risk level are mainly associated with damages to pipes, pressure fluctuations, elevated water age, improper repair and replacement practices for WDS components, lack of systematized information on WDS behavior, human error (lack of training, supervision, awareness of the concept of water quality assurance, or commitment of operative and administrative personnel), and internal and external corrosion of WDS elements.

The risk assessment identified hazardous events by estimating the risk and prioritizing existing control measures and the necessity of implementing additional measures, which is highly useful during development of a water safety plan. The results of this study show the usefulness of semi-quantitative matrices as easy-to-apply risk management tools. This particular tool, which could be adapted for other DWSS, was adapted for this study and not only included the criterion of water quality which is commonly applied, but also the concept of water quality and continuity of service as key factors for ensuring water quality.

Table 6. Programs for optimization of WDS control measures

Programs for WSP Improvement or Support	Actors Involved		
	Service Provider	Health and Sanitation Authorities	End User
Completion of studies to identify the need and location of re-chlorination stations in the WDS, studies on hydraulic behavior oriented toward the implementation of mechanisms to reduce water hammering, and studies on optimization of the hydrodynamic behavior of storage tanks using modeling tools.	X		
Complete setup of remaining WDS monitoring points, establishment of a washing and sanitation plan for tanks, designed according to each tank's hydraulic function, and adjustment of procedures in the company's technical area to assure appropriate design, construction, or repair of networks and tanks.	X		
Optimization of pricing policy, planning, and management of economic resources for rapid repair of damages and reduction of fix time in order to guarantee maintenance and proper calibration of WDS components and measuring equipment.	X		
Promotion campaign for national organizations to raise awareness regarding the necessity of optimizing the analytical capacity of the country's laboratories and facilitating legal processes for hiring accredited international laboratories.	X	X	
Training engineering and construction unions on existing regulations regarding correct location of aqueduct and sewer networks, training users regarding the importance of promptly and correctly reporting anomalies in service, about the care of WDS components and the user's legal responsibilities (Decree 1575/07), training service provider personnel to raise awareness on the importance of water quality and the necessity of optimizing reception, management, and redirection of information collected regarding WDS management.	X	X	X

It is important to have comprehensive assessment and management of WDS risks which cover not only the traditional approach of monitoring water quality, but also an integration of different tools that include other operational factors such as damages to the network, drinking water quality complaints, hydraulic characteristics, and others, which can also be alerts regarding the existence of diverse hazards and hazardous events that could compromise drinking water quality. Also, the applicability of the tools used will depend largely on aspects such as the availability of information, the interested parties' knowledge of the system, and human and economic resources, among others.

ACKNOWLEDGEMENTS

The authors appreciate the support received in terms of human resource training (Colciencias: doctorates and young researchers) and of research (Colciencias, EMCALI EICE ESP, Universidad del Valle: Cofinancing Project: "Identification, Assessment, and Management of Risk in the Water Supply of the Lower Network in the City of Cali, within the Framework of a Water Safety Plan (WSP)").

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Amézquita-Marroquín, C. P.; Andrea Pérez-Vidal, A.; Torres-Lozada, P. (2014). Risk Assessment in Water Distribution Systems Framed in a Water Safety Plan. *Revista EIA*, 11(21) January-June pp. 155-166. [Online]. Available on: http://dx.doi.org/10.14508/reia.2014.11.21.159-169