

Risk management for improving water quality: Application of the HACCP method

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Abstract. Risk management is key to improving water quality and ensuring the safety of the drinking water supply. Identifying sources of risk introduces the first phase of risk management is to identify potential sources of water contamination. That can include industrial pollution, accidental spills, agricultural discharges, failing treatment infrastructure, contaminant seepage into water sources, etc. A thorough analysis of the different sources of risk provides a better understanding of the threats to water quality. Once the sources of risk have been identified, it is essential to carry out a risk assessment. That involves analyzing the probability of occurrence of adverse events and the impact they could have on water quality. Tools such as Failure Modes, Effects and Criticality Analysis (FMECA) can be used to assess risk in a systematic way. Based on the risk assessment, preventive measures should be put in place to reduce the likelihood of occurrence of adverse events. That may include implementing good agricultural practices, regulating industrial discharges, regularly inspecting water treatment facilities, continuously monitoring water sources, etc. The objective is to prevent potential sources of contamination and minimize the associated risks. Regular monitoring of water quality is a key component of risk management. That involves collecting water samples at different stages of the water supply process, as well as testing for the presence of contaminants. Having effective monitoring systems in place allows potential problems to be identified quickly and appropriate corrective action to be taken. Despite the preventive measures, it is important to be prepared for possible emergency situations. Emergency response planning should include clear protocols and actions to be taken in the event of water contamination, to minimize public health impacts. That may include alert plans, communication procedures, alternative means of treatment, and coordination with competent authorities. The objective of This article is to conduct a risk analysis related to the drinking water distribution process. Using the HACCP method applied within the Laboratory attached to the water distribution company in northern Morocco, we will focus on the main causes of the risks tainting This process, based on the results the processing of samples in order to guarantee the safety and quality of drinking water in the Larache region and contribute to the efforts to protect water against the deterioration of the quality and quantity due to pollution and waste.

Keywords : Risk management, environmental threats, water quality, HACCP method, public health.

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1 INTRODUCTION:

The management of drinking water is of paramount importance for several reasons, drinking water is essential for the health and well-being of individuals. Proper drinking water management ensures the supply of clean and safe water, thereby reducing the risk of waterborne diseases (1). That helps prevent the spread of diseases such as diarrhea, cholera, typhoid and other bacterial and viral infections linked to contaminated water. Drinking water is a basic need of daily life. It is needed for human consumption, cooking food, personal hygiene, washing clothes and dishes, and other household activities. Efficient management of drinking water guarantees equitable access to This vital resource for all individuals (2). Appropriate drinking water management contributes to sustainable development. It allows the preservation of water resources in the long term, by avoiding the overexploitation of freshwater sources and by promoting rational consumption practices. In addition, sustainable management of drinking water takes into account environmental, social and economic aspects to ensure the long-term sustainability of water resources. Effective drinking water management also includes the protection of water sources and surrounding ecosystems. That involves the preservation of catchment areas, the prevention of water pollution, the appropriate management of waste and wastewater, as well as the conservation of aquatic habitats and associated biodiversity. Responsible management of drinking water contributes to maintaining the ecological balance and preserving fragile aquatic ecosystems (3). Drinking water management requires long-term planning and the implementation of resilience measures in the face of climate change and increasing pressures on water resources. That involves anticipating future water demands, developing appropriate infrastructure for water treatment and distribution, and adopting water conservation practices. Proactive management of drinking water helps to face future challenges and ensure the continued availability of this precious resource. However, the management of drinking water is of crucial importance for public health (4), sustainable development, environmental protection and resilience in the face of future challenges. Efficient management of drinking water guarantees access to an essential resource, while preserving the environment and meeting the present and future needs of communities.

The HACCP (Hazard Analysis Critical Control Points) method is a widely used risk management approach in the food industry, but it can also be applied to improve water quality. The process of this method involves identifying the points Critical Controls (CCPs) in the water treatment process, where control measures can be put in place to prevent or eliminate risks to water quality (5). For example, that may include steps such as water abstraction, filtration, disinfection, storage and distribution. Once the CCPs have been identified, a risk analysis is carried out to assess the potential hazards associated with each point. . That involves identifying possible contaminants, potential sources of contamination, routes of transmission, public health effects, etc. The objective is to understand the specific risks for each CCP. Based on the risk analysis, critical limits are defined for each CCP. These limits define the acceptable values or the specific control measures to be put in place to guarantee the quality of the water (6). For example, that may include maximum contaminant levels, disinfection parameters, cleaning and maintenance procedures, etc. Regular monitoring of CCPs is performed to ensure critical limits are being met. That may involve laboratory tests, online monitoring measurements, visual inspections, etc. Monitoring allows deviations or potential problems to be detected quickly, in order to take immediate corrective measures (7). Corrective action procedures are put in place for situations where critical limits are not respected or in the event of deviation from the process. These procedures describe the measures to be taken to identify the cause of the deviation, correct the problem, eliminate the contaminants and prevent any recurrence. Throughout the implementation of the HACCP method, it is essential to document all the steps, the decisions taken, monitoring results, corrective actions, etc. That ensures process traceability and transparency, facilitates audits and demonstrates compliance with water quality standards. By applying the HACCP method to risk management for water quality improvement. water, organizations responsible for water distribution can put in place effective control measures, minimize the risk of contamination and ensure the safety of the drinking water supply, is the purpose of That article.

2 NEED FOR SAFE AND HEALTHY DRINKING WATER:

Safe and healthy drinking water is of paramount importance for several reasons. Contaminated drinking water can cause serious health problems, such as gastrointestinal illnesses, bacterial infections, waterborne illnesses and even death (8). Safe drinking water is therefore essential to prevent the spread of these diseases and protect public health. Contaminated drinking water can cause waterborne diseases, such as diarrhea, cholera, typhoid and other bacterial and viral infections. The implementation of safety and sanitation measures for drinking water considerably reduces the risk of contracting these diseases and preserves the health of populations. Health authorities and regulatory bodies set standards and guidelines for drinking water quality. Ensuring that drinking water meets these standards is essential to ensuring its safety. Implementing safety measures ensures that drinking water quality parameters meet regulatory requirements (9). The safety and wholesomeness of drinking water are key elements in maintaining consumer confidence. When people are confident that the water they consume is safe and of high quality, they have more confidence in the water delivery system and are more likely to consume it in adequate amounts, which helps to their

health and well-being. The safety and wholesomeness of drinking water also includes the preservation of the environment and the protection of water resources. Responsible and sustainable management practices, such as the preservation of catchment areas, the prevention of water pollution, the appropriate management of waste and wastewater, are essential to preserve the quality of drinking water and the integrity of aquatic ecosystems. The safety and wholesomeness of drinking water are essential to protect public health, prevent water-borne diseases, respect quality standards, maintain consumer confidence and preserve the environment. Effective measures must be put in place at all levels, from the protection of water sources to distribution, to guarantee the safety and wholesomeness of drinking water and to ensure the health and well-being of populations.

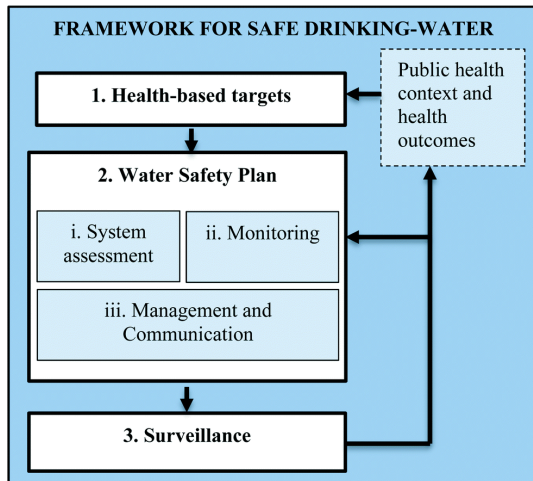


Fig. 1. The water safety plan to water reuse

The management and management of drinking water is essential to guarantee a safe, sustainable and high quality water supply for populations. Rigorous planning and effective management of water resources are necessary to meet present and future drinking water needs (10). That includes assessing available water resources, managing water demand, forecasting future needs, identifying new water sources and implementing water conservation measures. Drinking water management includes the design, construction, operation and maintenance of infrastructure and distribution systems. That involves the establishment of efficient distribution networks, the monitoring of water pressure and quality, the detection of leaks, the repair and maintenance of pipelines, as well as the optimization of water treatment processes. the water. Drinking water management also includes water treatment to guarantee its quality and potability. That can include steps such as filtration, disinfection, contaminant removal, remineralization, and water quality control at every stage of the treatment process. Drinking water management requires continuous monitoring of water quality through regular sampling and laboratory testing. That makes it possible to quickly detect any degradation in water quality, identify sources of contamination and take appropriate corrective measures. Drinking water management also includes the identification, assessment and management of water quality risks. That involves identifying potential hazards, implementing appropriate control measures, dealing with emergency situations and planning for business continuity in the event of disruptions to the water supply system. Effective drinking water management includes raising public awareness of the importance of conserving water resources, responsible consumption and adopting sustainable practices. Transparent communication about water quality, the measures taken to ensure its safety and the results of quality tests is also crucial to maintaining public confidence. The management and management of drinking water involves planning, resource management, infrastructure maintenance, water treatment, quality monitoring, risk management and public awareness. Effective and responsible management of drinking water is essential to ensure the availability of a vital resource, preserve public health and promote sustainable development(11).

3 RISK MANAGEMENT TO ENSURE THE SUSTAINABILITY OF DRINKING WATER:

Risk management is essential to ensure the sustainability of drinking water. It is important to identify potential risks that can impact the quality and availability of drinking water. That can include risks related to water contamination, overexploitation of water resources, climate change, natural disasters, aging infrastructure, etc. Once the risks have been identified, it is necessary to assess their probability of occurrence and their severity. That allows risks to be prioritized and appropriate management measures to be determined. Risk assessment can be based on technical studies, statistical analyses, predictive models and environmental assessments. Risk management involves the implementation of prevention and control measures to reduce the probability of occurrence of risks and minimize their impact. That may include measures such as protection of water sources, implementation of water quality monitoring procedures, adoption of sustainable agricultural practices to reduce water pollution, proper waste management and sewage, etc. Risk management also includes contingency planning to deal with critical situations such as sudden water contaminations or water shortages (12). It is important to put in place emergency response plans, early warning systems, communication

and coordination procedures with stakeholders to ensure an effective response in the event of a crisis. Risk management requires continuous monitoring of water quality, water sources and infrastructure. That allows early detection of signs of potential problems, identification of risk areas and appropriate preventive or corrective action. Public awareness and education are key elements of risk management. Informing communities about the risks associated with drinking water, good water use practices, responsible behaviors and prevention measures helps to build resilience and stakeholder participation. Risk management is essential to ensure the sustainability of drinking water. It involves the identification, assessment and management of potential risks, the implementation of prevention and control measures, emergency planning, continuous monitoring and public awareness. A proactive approach to risk management helps preserve the quality of drinking water, protect public health and ensure the sustainability of water resources.



Fig. 2. A conceptual Water Reuse Risk Management

There are several instruments used in risk management for water quality improvement. Risk analysis is a key tool for assessing and prioritizing potential water quality risks. It makes it possible to identify the sources of contamination, to estimate the probability of occurrence of the risks and to assess the consequences on public health and the environment. Quality management systems, such as ISO 9001 standards and Quality Assurance principles, are used to establish procedures, protocols and guidelines to ensure the quality of drinking water. They enable the establishment of quality control processes, staff training programs and monitoring and auditing mechanisms to ensure compliance with quality standards. Contingency planning is an important tool for dealing with water quality incidents or crises. It includes the establishment of emergency response plans, the definition of roles and responsibilities of stakeholders, the coordination of actions and communication with the public (13). Water quality monitoring is carried out using instruments such as monitoring stations, real-time sensors, regular sampling and laboratory analysis. These instruments make it possible to continuously monitor water quality parameters, detect variations and contamination, and intervene quickly if quality thresholds are exceeded. Modeling tools, such as hydrological models and water quality models, are used to predict potential impacts on water quality under different scenarios. These tools help to make informed decisions about water resources management and to assess the consequences of human activities on water quality. Public awareness and education are essential instruments for involving communities and stakeholders in the management of water quality risks. Awareness campaigns, educational programs and public participation initiatives help raise awareness of potential risks, promote good water use practices and strengthen collective responsibility (14). These instruments are complementary and must be used in an integrated manner in risk management to improve water quality. They help identify, assess, prevent and control risks, while enhancing transparency, accountability and public confidence in the drinking water supply system.

4 THE HACCP METHOD FOR THE PRESERVATION OF WATER

The implementation of the Lean six sigma approach in a Moroccan environmental SME, dismisses the idea that it is a process reserved for large companies and would set an example to others that it is feasible with the means they have. To This end, SMEs will invest in the project to implement the Lean six sigma process, which would allow them to adopt operational excellence, which has become a customer requirement.

The HACCP method (Hazard Analysis Critical Control Point) has several advantages and uses in the field of food safety and the preservation of water quality. The HACCP method makes it possible to identify potential hazards that can compromise the safety and quality of water. That includes microbiological, chemical and physical contaminants, as well as risks related to water treatment, storage and distribution processes. The preventive approach of the HACCP method aims to prevent risks rather than detecting them a posteriori. By identifying critical control points (CCPs) and establishing critical limits, control measures can be put in place to prevent or reduce hazards to acceptable levels. By applying the HACCP method, businesses and organizations responsible for water conservation can implement effective control measures to ensure food safety and water quality. That helps to reduce the risk of waterborne diseases and protect public health. The HACCP method is widely recognized and accepted internationally as a systematic approach to ensuring food safety and the preservation of water quality. Its use makes it possible to comply with the regulations and standards in force in the field of drinking water. By identifying critical control points and implementing adequate control measures, the HACCP method helps to improve the efficiency of water preservation processes. That can result in reduced losses, optimized resources and better risk management. The application of the HACCP method demonstrates the commitment of a company or organization to food safety and the preservation of water quality. That builds confidence among consumers, regulators and stakeholders, and promotes better communication and transparency. By anticipating risks and implementing emergency response plans, the HACCP method helps to manage crisis situations related to water quality. That allows for a quick and effective response to minimize impacts on public health and the environment. The HACCP method is a valuable tool for guaranteeing food safety and the preservation of water quality. It helps identify, prevent and control potential hazards, comply with regulations, improve process efficiency and build consumer confidence.

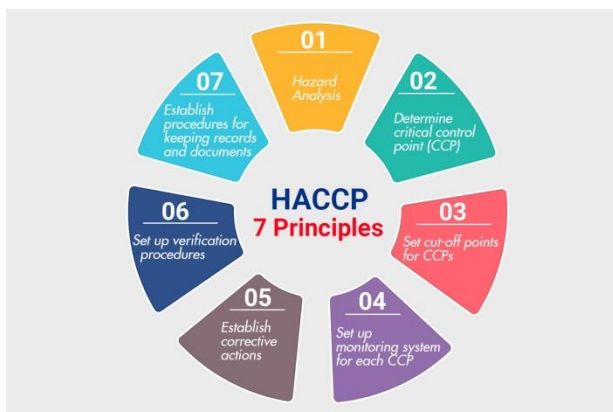


Fig. 3. HACCP Principles

The HACCP method is a systematic and preventive approach used in various sectors, including water conservation, to identify, assess and control potential hazards that can compromise the quality and safety of water. The first step in the HACCP method is to perform a thorough analysis of the potential hazards associated with water conservation. That may include identifying sources of contamination, such as chemical pollutants, pathogenic microorganisms, toxic substances, accidental spills, etc. Once the hazards have been identified, the Critical Control Points (CCPs) are determined. These are the specific steps in the water preservation process where control measures can be applied to prevent, eliminate or reduce identified risks. For example, water treatment, storage, distribution, etc. Critical limits are defined for each CCP to ensure that the control measures are effective. These limits are based on specific criteria, such as water quality standards, health regulations, safety thresholds, etc. CCPs are regularly monitored to ensure critical limits are met. This may involve monitoring water quality, checking treatment procedures, visual inspection, laboratory testing, etc. If critical limits are not met, appropriate corrective actions are implemented to rectify the situation. That may include process adjustments, cleaning and disinfection procedures, investigation of causes of non-compliance, etc. The HACCP method requires regular verification of the effectiveness of the water preservation system. That can be achieved through internal checks, external audits, independent lab tests, document reviews, etc. Records should also be kept to document all steps and actions taken. The HACCP method requires complete documentation of all procedures, plans and records. In addition, it is important to train the personnel involved in water preservation on the principles of the HACCP method, good hygiene practices, safe handling of chemicals, etc. By applying the HACCP method to water conservation, it is possible to prevent potential risks and ensure water quality and safety. That helps protect public health, comply with environmental regulations.

5 RESULTS AND DISCUSSION

In order to improve the safety and wholesomeness of drinking water, the World Health Organization and the International Water Association (have proposed the Water Safety Management Plan Potable "PGSSE". This plan considers that all the installations that make up a water supply system intended for human consumption are real barriers that make it possible to identify critical points, possible failures and the appropriate control measures. This plan has the following objectives: the assessment and prioritization of water-related health risks; programming and management of corrective (operational) measures; reducing the number of cases of contamination and non-compliance; improving water safety and potability and implementing operational plans in the event of contamination. Morocco is threatened by the scarcity and degradation of water quality which has reached a worrying level following overexploitation, climate change, population growth, socio-economic development, industrial development, change in lifestyle and of consumption. In figures, the AESVT indicates that only 59.2% of households occupy a dwelling connected to a public wastewater disposal network: 88.5% in urban areas and only 2.8% in rural areas. Today Morocco is ranked among the twenty most threatened countries in terms of water resources, qualifying it as a risky country in terms of water availability (15) and above all a country that depends on agriculture as a pillar of the economy. Moroccan economy and that rainfed agricultural land represents 85% of the utilized agricultural area. In Morocco, water resources are naturally limited. They are estimated at 22 billion m³, including 18 billion m³ of surface water and 4.3 billion m³ of groundwater. To safeguard these resources, Morocco has followed a policy to deal with scarcity through the construction of 140 dams totaling a capacity of 17.6 billion, drilling and wells capturing groundwater.

The degradation of the quality of water resources generates significant costs. The discharge of wastewater in the absence of connection to the sewerage network leads to water pollution. Following the report, the annual volume of urban domestic wastewater is 528 million m³, and the treatment rate is 38%, That mean that 327 million m³ not treated. The cost of purification is estimated between 1.5 and 3.5 per m³ varying according to the degree of pollution (16). The real challenge of controlling the risks associated with polluted water exists in the distribution network where the risk is serious. These measures taken at the national level remain insufficient and require action at the level of local water distributors, who must contribute to global and national policy to safeguard That natural wealth which continues to deteriorate in terms of quality and quantity.

Morocco also suffers from the problem of waste, the water mobilized in large quantities ends up being wasted, the saving of water and the control of its use is not systematic. "Of the 80% of water consumed by agriculture, 60% is wasted because irrigation is localized (more than 1.5 million hectares) and drip has not been generalized", in In This situation, structures draw abundant groundwater. "The market was opened to them and, in return, there was no work on operating regulations. That rarity can be accentuated by climate change and the threats of water contamination which can constitute a risk for public health. Thus, This situation requires measures to safeguard the quality and quantity of available water. To control the quality of the water distributed, the company opts for the adoption of the HACCP method (Hazard analysis Critical Control Point) and the installation of new technology in the distribution network. Risk management of drinking water quality in Morocco is of paramount importance to ensure the safety and health of citizens. Water quality monitoring programs are set up to collect regular samples in different regions of Morocco. These samples are analyzed for the presence of contaminants, such as bacteria, viruses, chemicals or heavy metals. The competent authorities assess the risks associated with the quality of drinking water in Morocco. That includes the identification of potential sources of contamination, the assessment of the effects on human health, as well as the estimation of the probability of occurrence of these risks. Standards and regulations are in place to establish drinking water quality criteria in Morocco. These standards define acceptable limits of specific contaminants and ensure that drinking water meets international safety standards. Water treatment procedures are in place to remove or reduce contaminants in drinking water. That may include steps such as filtration, disinfection (eg, by chlorination), removal of unwanted chemicals, etc. Particular attention is paid to the drinking water distribution infrastructure to minimize the risk of contamination after treatment. Regular inspections and maintenance measures are carried out to ensure that pipelines, tanks and distribution facilities are in good condition and comply with safety standards. Awareness and education campaigns are carried out to inform the population about the risks associated with the quality of drinking water and the preventive measures to be taken. That may include advice on water conservation, using household filters, practicing proper hygiene, etc. Emergency plans are drawn up to deal with possible crisis situations related to the quality of drinking water. These plans include rapid response measures and procedures to ensure the continuity of the drinking water supply in the event of contamination or distribution disruption. Risk management of drinking water quality in Morocco requires continuous monitoring, enforcement of standards and regulations, implementation of treatment procedures, secure distribution infrastructure, awareness raising and planning for adequate urgency. These measures contribute to guaranteeing the availability of quality drinking water and to protecting the health of citizens.

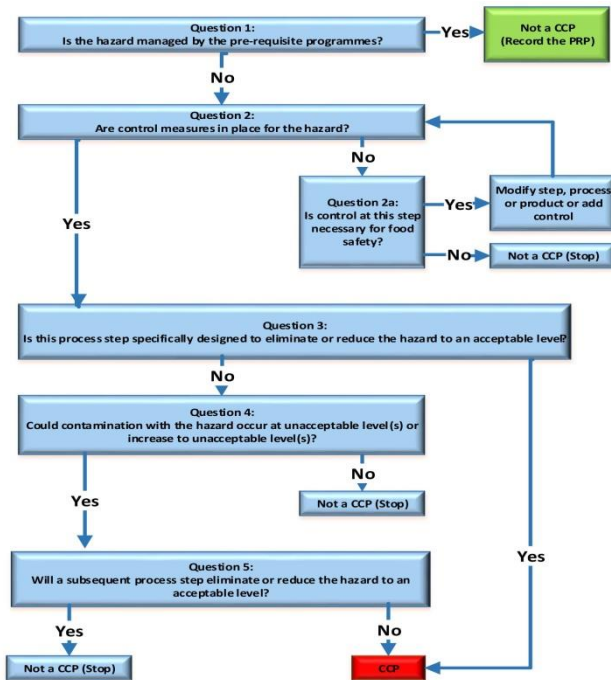


Fig. 4. The decision tree

The development of the decision tree makes it possible to determine the CCPs to be treated, by setting up a monitoring of these critical points. When the control reveals that a CCP is not under control, establish verification procedures in order to confirm that the HACCP system works effectively finally establish a documentary system concerning all the procedures and records appropriate to the seven principles of HACCP and their application. With the aim of increasing the frequency of analyzes and minimizing the time taken to detect the deterioration of water quality, we have installed analysis equipment, the results of which are transmitted instantaneously to the head of water safety water quality. They are installed in the experimentation phase in the entrances of the distribution tanks in order to control it before the distribution and ensure immediate intervention.



Fig. 5. 24/7 analysis device

Concerning the measures to fight against the waste of water following leaks in the network or the non-adaptation of the flow of water to the actual consumption, leak detectors and pressure stabilizers are installed to see their effect on the company's performance. The installation of the stabilizers made it possible to adapt the pressure to the real needs of the citizens to avoid waste, which will positively impact the performance of the company.

From what we have seen on the HACCP plan, it turns out that leaks in the distribution network constitute the most difficult risk to control, hence the need to review the procedures applied by referring to the PGSSE established. A simple comparison between the company's procedures and those of the WSP indicates the existence of steps not applied at the level of the distributor as an example:

- Absence of procedure for assessing hazards and determining how hazards can enter the water

- Lack of development of support procedures for good governance of drinking water
- Absence of control measure monitoring system

Efforts must converge towards alignment with WSP and the adoption of an effective system to detect leaks at the network level which are the main sources of quality degradation and wastage of water at the network level of distribution. The installation of pressure stabilizers and leak detectors gave significant results for performance. The results show a 2.2% increase in overall efficiency, recording a gain of 450,000m³ of water, previously wasted in the distribution network. On the other hand, the increase in the frequency of analyzes and the rapidity of the detection of the degradation of water quality have favored the effective and efficient intervention of the control teams for the restoration of the situation.

6 CONCLUSION:

Effective risk management of drinking water management requires the identification of potential hazards and hazardous events that could occur. This is to identify all potential hazards that could affect the quality of drinking water. That can include microbiological, chemical or physical contaminations, infrastructure malfunctions, extreme climatic events, etc. Once the hazards have been identified, it is important to assess the level of risk associated with each of them. That involves taking into account the probability of occurrence of the hazardous event and the severity of the potential consequences. The evaluation can be carried out using quantitative or qualitative methods. After evaluating the level of risk of each hazard, it is necessary to prioritize them according to their importance. That makes it possible to focus efforts and resources on the most critical risks and to define appropriate management measures. Once priority risks have been identified, risk management strategies must be developed. That may include the establishment of prevention, control and monitoring measures to reduce the likelihood of occurrence of the identified hazards and to mitigate their potential consequences. Risk management measures must be implemented effectively. That involves creating detailed action plans, allocating necessary resources, training staff, setting up monitoring and control systems, etc. It is important to continuously monitor and evaluate the effectiveness of the risk management measures put in place. That makes it possible to make the necessary adjustments and ensure continuous improvement in the management of drinking water. Identifying potential hazards and assessing the associated level of risk are essential steps for effective risk management in drinking water management. That makes it possible to put in place appropriate measures to prevent, control and mitigate risks, thus ensuring the safety and wholesomeness of drinking water for the populations concerned.

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