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ISO 22000 STANDARD AS A TOOL FOR ENSURING SAFETY OF WATER PRODUCTION IN A WATER PRODUCING COMPANY

Summary. *This article aims to analyze the procedure for implementing the ISO 22000 standard as a system tool to ensure the safety of drinking water production in a water supply company. The paper covers the fundamentals of ISO 22000, risk management, and HACCP mechanisms; the integration of PRP programs; and the importance of supervision and verification. Using the model water company as an example, it discusses the implementation process and practical aspects: identifying critical control points, monitoring quality parameters, managing incidents, and communicating with external parties.*

Keywords: *ISO 22000, food safety, drinking water, water supply company, HACCP, critical control point.*

Introduction

Ensuring the safety of drinking water is one of the key conditions for protecting public health. Water supply companies are responsible for providing water that meets the legal requirements and expectations of consumers in terms of microbiological and physicochemical parameters [Gunnarsdottir et al., 2023, p. 1747–1760; Guidelines for Drinking-Water Quality, 2017]. In the face of increasing threats, such as contamination of surface and groundwater, technological failures and climate threats, a systemic approach to managing the safety of drinking water is necessary [van den Berget. Et al., 2019, p. 1030-1037].

ISO 22000 is an international standard that sets out the requirements for a food safety management system. It contains elements of management systems, principles for risk analysis and Critical Control Points (CCP), and requirements for communication, monitoring, verification, and continuous improvement [ISO 22000:2018]. The standard is process- and systemic-based, rather than industry-based, and its main components are:

- security policy and objectives for the product/service,

- Hazard Analysis (HA): identification of hazards and determination of Critical Control Points (CCPs) and critical thresholds,
- the Prerequisite Programme (PRP) covers infrastructure, hygiene, supply control, maintenance,
- internal and external communication regarding threats and tracking systems,
- parameter monitoring procedures, calibration of equipment, internal audits,
- procedures for continuous improvement and control of documents and records that confirm compliance with activities.

Although the ISO 22000 standard was originally designed for the food chain, it offers a set of tools and principles that can be effectively applied to the production and distribution of drinking water. The overarching goal of both food and drinking water production is to protect public health by eliminating or reducing biological, chemical and physical risks, and ensuring consumer safety. Therefore, the risk management principles introduced by ISO 22000 in the food sector can be successfully transferred to the water sector [Kosasih et al., 2020, p. 11-18; Ji and Lee, 2022, p. 1–19; Tsoukalas and Tsitsifli, 2018, p. 1-8; Tchórzewska-Cieślak et al., 2021, 1-13].

This approach involves a water treatment/production process (from intake to distribution) with steps and control points similar to those in food production, meaning the HACCP (Hazard Analysis and Critical Control Points) and PRP (Preventive Control Plan) schemes can easily be adapted. The ISO 22000 standard emphasizes the importance of the HACCP system for analyzing microbiological (e.g. *E. coli* and *Legionella* bacteria), chemical (e.g. heavy metals, pesticides and chlorine), physical (e.g. solid pollutants) and technological (e.g. failure of the disinfection or filtration process) hazards in relation to drinking water. This enables the company to identify critical control points, such as the residual chlorine concentration or turbidity after filtration, and implement continuous monitoring, similar to the temperature control or cleanliness of the production line in a food processing plant [Pendić et al., 2017, p. 147-155; Kombo Mpindou et al., 2022, p. 1-20; Pérez–Vidal et al., 2019, p. 1-10; Collivignarelli et al., 2018, p. 2361-2372; Lee et al., 2021, p. 1-24].

On the other hand, in the context of the water supply, Prerequisite Programmes (PRPs) are a set of preventive actions that form the foundation of the system. In a water company, this involves maintaining clean installations and tanks, supervising chemical suppliers (e.g. coagulants and chlorine), maintaining equipment and network infrastructure, controlling staff hygiene, and preventing secondary pollution. These procedures are almost identical to those used in food establishments, only adapted to the nature of the water supply system [Heumer et al., 2024, p. 1-20; Karnaningroem and Sunaya, 2020, p. 1-8; Lane et al., 2022, p. 1-14].

ISO 22000 requires effective internal and external communication with employees, suppliers, customers, and supervisory authorities (e.g. health and safety regulators). Therefore, in the water sector, this is therefore crucial in the event of incidents (e.g. the detection of bacteria in the network). The standard establishes clear guidelines/rules for the responses and the flow of information, thereby minimising chaos and reducing reaction times.

In addition, ISO 22000 requires constant monitoring of parameters such as chlorine, pH and turbidity, the verification of the effectiveness of actions through microbiological tests, trend analysis, management reviews and the continuous improvement of procedures and documentation. Consequently, the system is not static, but constantly evolving in response to technological, environmental and legal changes [Tchórzewska-Cieślak et al., 2023, p. 1-22].

Furthermore, ISO 22000 has the same High-Level Structure as other standards, e.g. ISO 9001 and ISO 14001. This enables quality, environmental, and safety systems to be fully integrated within a single water company, as demonstrated by the model company used in this study.

The aim of the article is: (1) present the structure and key requirements of ISO 22000;(2) analyze how these requirements can be adapted to the specifics of a water supply company; (3) present a practical implementation scenario based on an analyzed company.

Characteristics of the company

The analyzed company is a municipal water supply company responsible for collecting, treating and distributing drinking water to the city and surrounding municipalities. It owns a water intake facility, a treatment plant, a distribution network and a water quality control laboratory.

The company's main motivations for introducing the standard are to increase water safety and social trust, standardize procedures, improve risk management, and facilitate communication with supervisory authorities. An additional advantage is the possibility of integration with other previously owned systems (e.g. ISO 9001, ISO 14001).

In order to implement the standard, a preliminary analysis was necessary, consisting of a review of the laboratory's existing procedures, documentation, and test results. Next, staff were trained in the principles of ISO 22000, HACCP, and PRP.

The next step was to map the processes and identify hazards by detecting critical control points (e.g. intake, filtration, disinfection, and storage) and carrying out a risk assessment.

Application of ISO 22000 to water production

The production of drinking water by a water supply company typically involves several stages: extraction of the raw material (surface or groundwater); treatment (coagulation, sedimentation, filtration and disinfection); storage; distribution; and support for consumption points. Each of these stages carries specific risks:

- microbiological hazards include bacteria (e.g. *E. coli*), viruses and protozoa (e.g. *Giardia* and *Cryptosporidium*),
- chemical hazards include pesticides, heavy metals (e.g. lead and cadmium), organic compounds and residues of plant protection products and disinfection by-products (e.g. trihalomethanes),
- physical hazards include solid pollution and sedimentation in tanks,
- technological and operational hazards include pump failures, power outages, human error and improper operation of equipment,
- supply chain risks include the quality of treatment chemicals and consumables.

In the context of ISO 22000, identifying these hazards/risks and assigning appropriate control measures is crucial.

Implementation of ISO 22000 in a water and sewage company

The analyzed company's implementation of the food safety management system, the Hazard Analysis and Critical Control Points (HACCP) system, was the first of its kind in Poland's water and sewage industry. Subsequently, the HACCP system was expanded to encompass the requirements of the ISO 22000 standard. Implementation of the food safety management system within the company was based on the HACCP implementation methodology, in accordance with the procedure outlined by Kóska-Wolny and Trela [2017, p. 58-64].

The successful implementation of any management system requires the active participation of management at all levels in company. Security policy must be communicated and implemented throughout the organization. Management is also responsible for allocating financial, human and technical resources. Regarding the system described in the analyzed company, the first stage was to create an interdisciplinary team comprising water technology, laboratory, operations, risk management and health and safety experts, which enabled comprehensive process and competency analysis. Therefore, training in HACCP, monitoring and emergency procedures was necessary. Next, the processes were mapped from water abstraction to delivery to the recipient. A hazard analysis (identification, probability and significance assessment) was carried out for each step. A risk analysis was carried out to determine whether they should be given the status of CCPs or Operational Pre-Programmes (OPRPs). During the hazard analysis, all selected hazards were pre-classified according to the criteria presented in Figures 1 and 2.

Fig. 1. Threat analysis by security impact criterion.

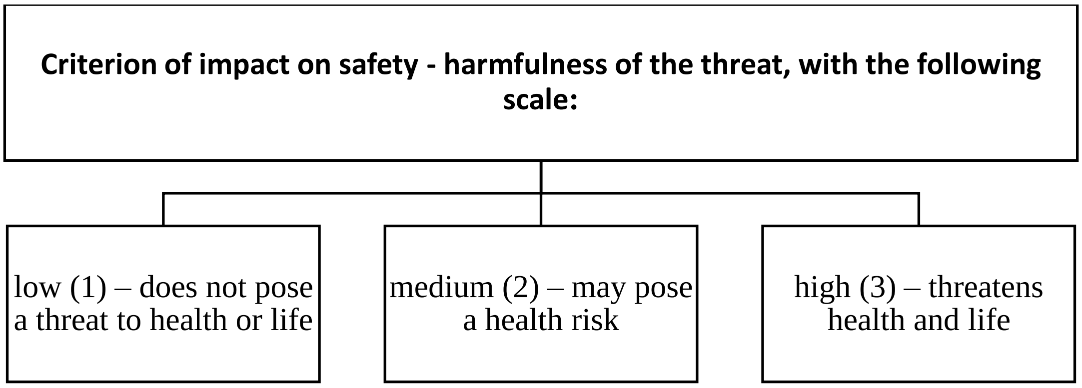
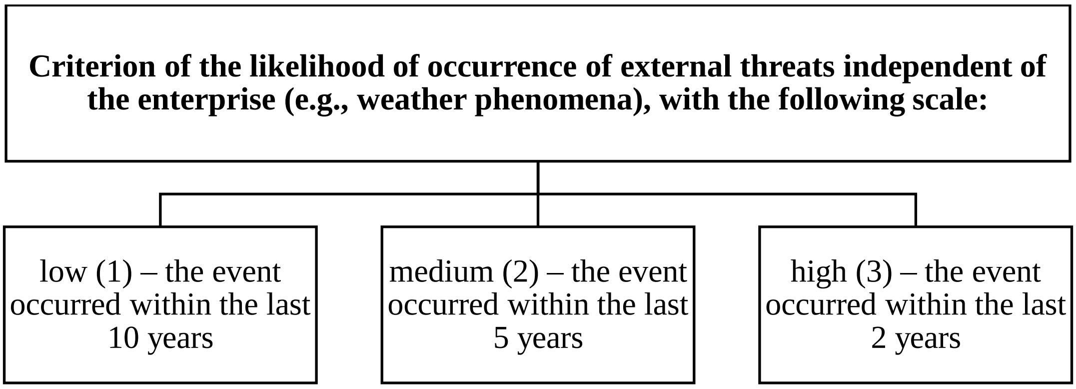


Fig. 2. Threat analysis according to the criterion of the probability of occurrence of external threats independent of the company.



The risk analysis carried out as part of the implementation activities enabled past, present and future threats to water security to be identified, along with their sources, potential causes and effects. The analysis formed the basis of a plan for further actions to increase water safety. An example of an enterprise threat analysis is presented in Tables 1 and 2.

Table 1. An excerpt from the hazard analysis in the water and sewage company in relation to water production.

No.	Stage name	Source of threat / potential source of damage	Description of the hazard	Impact on safety - harmfulness of the threat			Likelihood			Multiplication / Risk
				Low (1)	Medium (2)	High (3)	Low (1)	Medium (2)	High (3)	
1.	Water intake	Violent meteorological phenomena (excessive precipitation deteriorating water quality, melting snow).	Inappropriate parameters of raw water in the field of microbiology and physicochemistry. Damage to raw water mechanical purification equipment. Silting of irrigation pools. Increase in the level of colmatation of natural filter beds. Risk of exceeding the filtration capacity in natural deposits and the possibility of purification with the use of physico-chemical purification equipment (coagulation + filtration)	-	-	3	-	-	3	9
2.	Coagulation	Power failure.	No indications of measuring instruments. Shutdown of equipment (the use of a common power source for all devices of the water treatment plant results in the shutdown of the entire water treatment plant.	-	2	-	1	-	-	2
3.	Filtration and disinfection	Failure to comply with technological regimes.	Improper parameters of clean water. Risk of presence of pathogenic microorganisms in clean water and exceeding permissible limits.	-	-	3	-	2	-	6
4.	Filtration and disinfection	Failure of control and measurement equipment. No indications or incorrect indications of measuring instruments.	Lack of control over the process.	-	2	-	-	2	-	4
5.	Distribution	Failure to comply with technological regimes.	Presence of pathogenic microorganisms and their metabolites.	-	-	3	1	-	-	3
6.	Distribution	Improper operation and maintenance of the network.	Damage to equipment and fittings of the water supply network leading to restrictions in the supply of water to customers and risks related to the risk of carrying out repair works on the water supply network.	-	2	-	1	-	-	2
7.	Distribution	Failure to use anti-contamination valves and their improper use.	Presence of pathogenic microorganisms and their metabolites.	-	2	-	1	-	-	2

For each analysed threat, the proposed scope of control and corrective and preventive actions are prepared, which is presented in Table 2.

Table 2. Part of the proposed scope of control and corrective and preventive actions for the analyzed risks in relation to water production.

No.	Stage name	Proposed scope of audits			Corrective actions within the company's internal procedure for corrective and preventive actions Proposals	
		Place of inspection / testing	**Frequency of inspections**	**Limit**	**Corrective actions**	**Surveillance measures**
1.	Water intake	Shore shot. Raw water tank.	According to the test schedule and at the request of the management.	Input: Turbidity depending on the capabilities of individual objects (50 or 200 NTU). Output: 5 NTU	Periodic interruption or restriction of water intake. Adaptation of technology to changed raw water abstraction conditions.	Constant monitoring of raw water parameters.
2.	Coagulation	Visually at the place where the devices are installed. With the use of an ICT network.	Up to date Online	Correct indications of control and measurement equipment.	Repair or replacement of damaged equipment components. Taking control of the indications over the process by the Water Testing Laboratory.	Appropriate selection of equipment. Proper operation and maintenance. Maintaining measurement consistency and checking control and measurement equipment.
3.	Filtration and disinfection	In a place designated for water sampling/laboratory. At the site of installation of control measuring devices.	According to the laboratory test schedule Online On Demand	Parameters; Turbidity: recommended up to 1 NTU, should not exceed 5 NTU, Fecal type Coli bacteria 0, chlorine 1 mg/l	Compliance with technological regimes, correction of disinfectant doses	Appropriate selection and training of employees. Supervision by the supervisor over the proper performance of duties by employees Appropriate selection of equipment
5.	Filtration and disinfection	Visually at the place where the devices are installed. With the use of an ICT network.	Up to date Online	Correct indications of control and measurement equipment.	Repair or replacement of damaged equipment components. Taking control of the indications over the process by the Water Testing Laboratory.	Appropriate selection of equipment. Proper operation and maintenance. Maintaining measurement consistency and checking control and measurement equipment.
5.	Distribution	In a designated place for water sampling/laboratory.	According to the research schedule.	Guidelines according to the Regulation of the competent Minister.	Repair, renovation and replacement of water supply systems. Use of corrosion inhibitors. Rinsing the ends of the network and connections.	Selection of the right materials in the construction of water supply systems. Use, in the construction of water supply systems, modern technological solutions.

No.	Stage name	Proposed scope of audits			Corrective actions within the company's internal procedure for corrective and preventive actions Proposals	
		Place of inspection / testing	**Frequency of inspections**	**Limit**	**Corrective actions**	**Surveillance measures**
6.	Distribution	In a designated place for water sampling/laboratory.	According to the research schedule.	Guidelines according to the Regulation of the competent Minister.	Repair, renovation and replacement of water supply systems. Use of corrosion inhibitors. Rinsing the ends of the network and connections.	Selection of the right materials in the construction of water supply systems. Use, in the construction of water supply systems, modern technological solutions.
7.	Distribution	In a place designated for water sampling/laboratory. At the site of suspected contamination.	According to the test schedule. Depending on needs.	Guidelines according to the Regulation of the competent Minister.	Cutting off and disinfecting the contaminated section of the network. The use of anti-pollution valves.	Use of anti-contamination valves as intended.

Hazards for which the multiplication score exceeded 3 points according to Table 1 were assessed using a decision tree, which is a logical sequence of questions and answers for each step of the technological process, to allow for the designation of CCPs. This decision tree is presented in the publication by Kóska-Wolny and Trela (2017, p. 58-64). This enabled the identification of the areas of greatest importance in terms of water safety, as well as the activities that may pose a threat and over which control is limited or non-existent.

This assessment identified the CCPs and the risks supervised under the OPRPs. Limit values and monitoring methods were then set for each CCP (Table 3). The next stage was to establish the OPRPs, i.e. the basic measures ensuring safety, such as maintaining cleanliness, proper disinfection, controlling infrastructure, maintaining equipment, training staff and controlling the supply of raw materials (e.g. chemicals for the treatment process). A system was also introduced for monitoring quality parameters (e.g. residual chlorine, turbidity, pH, conductivity and microbiological parameters), and measuring instruments were regularly calibrated. All of these measures, together with systematic monitoring and control, contribute to the maintenance of documentation that enables the registration and tracking of recorded data. Internal and external audits have become a tool for assessing the effectiveness of the system and for continuously improving the processes in place. Verification included microbiological tests, validation tests of disinfection procedures, and other tests to confirm that the system works as intended.

Table 3. A list of sample CCPs with an indication of the source of the threat, the place of control, the monitoring system and the remedial actions in the company analyzed.

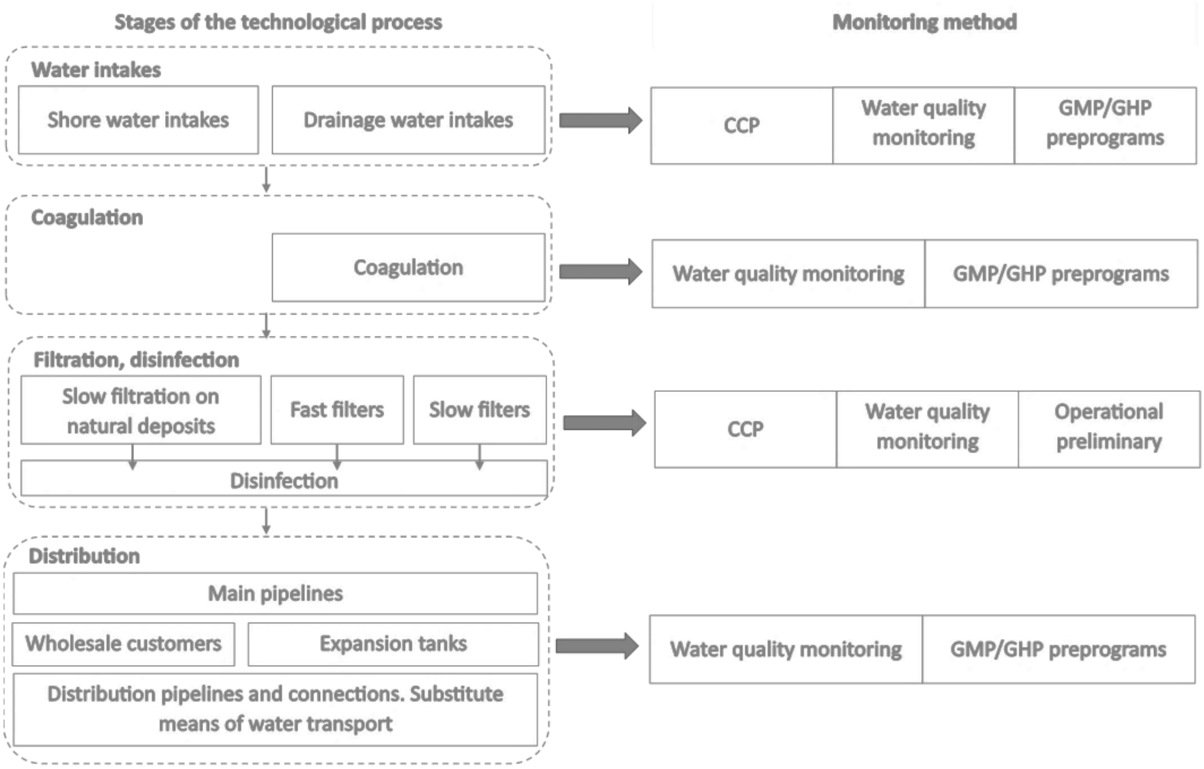
No. CCP	**Process Stage**	**Source of threat / potential source of damage**	**Hazard / threat control point (CCP)**	**Critical / warning limit**	**Monitoring system/surveillance measures**			**Actions to take in case of exceeding the critical / warning limit (Instructions /Procedures)**
					Audit method / audit record	**Frequency of inspections**	**Responsible person**	
1	Water intake	Violent meteorological phenomena (excessive precipitation deteriorating water quality, melting snow).	Shore water intake	Turbidity 40 NTU	On-line turbidity meter	Continuous measurement	Station Operation	Corrective actions: Periodic interruption or restriction of water intake. Adaptation of technology to changed raw water abstraction conditions. Corrective and preventive action procedure.
					Laboratory tests	Specified in the schedule of laboratory tests. On demand	Laboratory Manager	
2	Filtration and disinfection.	Failure to comply with technological regimes.	Water Treatment Station 1	Turbidity 4 NTU *Escherichia coli* 0 Residual chlorine 1.0-1,5 mg/l	On-line turbidity meter Chlorine Analyzer On-Line	Continuous measurement	Station Operation	Corrective actions: Correction of disinfectant doses (object-specific statement). Non-compliant product surveillance procedure For the action limit - corrective and preventive action procedure.
					Laboratory tests	Specified in the laboratory test schedule. On demand	Laboratory Manager	
					Laboratory tests	Specified in the schedule of laboratory tests. On demand	Laboratory Manager	
3	Filtration and disinfection.	Failure to comply with technological regimes.	Water Treatment Station 2	Turbidity 4 NTU *Escherichia coli* 0 Residual chlorine 0.8-1.0 mg/l	Laboratory tests	Specified in the schedule of laboratory tests. On demand	Laboratory Manager	

NOTE - frequency of inspections on request - the management of the TWP department, TWE each time orders laboratory tests to be carried out in the event of the described sources of danger.

Incident management procedures and crisis communication were also developed at this stage, including notifying the relevant authorities (Sanitary-epidemiological station and commune office), as well as communicating with residents. If the critical limit of the CCP is exceeded, the OPRP employee responsible for record-keeping (i.e. the laboratory employee) takes corrective action and follows either the non-compliant device surveillance procedure or the corrective and preventive action procedure.

The CCPs identified in Table 3 were assigned expected, warning, and critical values. Critical values are limit values; exceeding them triggers the entire supervisory mechanism for non-compliant products and ultimately the withdrawal procedure. Due to the often-extensive water supply infrastructure and the need to ensure continuity of supply, this procedure is difficult and expensive. Therefore, implementing an appropriate monitoring method for each CCP formed the basis of a strategic document from the perspective of the ISO 22000 security management system: the HACCP plan (Figure 3).

Fig. 3. An example of a CCP monitoring procedure in the company analyzed.



Based on this, operating procedures, work instructions, emergency procedures and maintenance schedules have been developed. At the same time, a monitoring and data recording system was implemented, including automatic measurements of key water parameters. The final step was to validate and verify the system through performance and microbiological tests, as well as internal audits.

This enabled the implementation of a system that provided the analyzed company with benefits in terms of reducing health risks thanks to better control of critical parameters, improved incident preparedness and faster response times thanks to defined procedures. It also increased transparency and trust among recipients by sharing research results and crisis communication, as well as optimizing operating costs (less waste and more efficient chemical dosing).

Summary and conclusions

It is possible to integrate ISO 22000 with other management systems in water and sewage companies. Although ISO 22000 is a food safety standard, its logic and elements (especially HACCP, hazard analysis and safety management) can complement existing systems in the water supply industry, such as quality management (ISO 9001), environmental protection (ISO 14001), business continuity management (ISO 22301) and information security management systems (ISO 27001), particularly for digital SCADA systems. Integrating these systems with ISO 22000 enables harmonization of documentation, audits and objectives, while reducing implementation and maintenance costs.

Concepts based on ISO 22000 and HACCP are particularly prevalent in areas related to the safety of drinking water. In water and sewage companies, system integration should consist of developing common procedures and documentation, such as one integrated management system policy, common risk management procedures and integrated internal audits. It should also consist of a single integrated management system policy ledger instead of separate documents, and common system elements. ISO 22000 overlaps with other standards in areas such as hazard identification and risk assessment, non-compliance and incident management, continuous improvement, supervision of documentation, employee training and crisis response (which is key in water supply systems). This allows management structures to be merged and simplified. The biggest benefits of such a combination include improved water health and safety management and a more coherent risk management system, replacing the need to keep quality risks (ISO 9001), environmental risks (ISO 14001), health and safety risks (ISO 45001) and health risk management (HACCP) separate. These can all be integrated into one risk matrix, contributing to reduced costs associated with fewer external audits (combined audits), reduced documentation supervision, joint integrated employee training, increased supply security and compliance with legal and sanitary requirements, and improved company image.

Implementing ISO 22000 enabled the analyzed water company to identify and control hazards, prevent water contamination, respond faster to incidents, increase customer trust and comply with legal requirements and quality standards.

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