CHALMERS
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# Risk assessment in drinking water supplies of Sweden and Latvia

An overview within the Water Safety Plan framework

*Master of Science Thesis in the Master's Programme Infrastructure and Environmental Engineering*

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## ABSTRACT

Risk-based approaches to assess and manage the risks in the drinking water system are required to guarantee a reliable supply of safe drinking water. The World Health Organization (WHO) proposes water safety plans (WSP) as the most effective way to ensure a safe drinking water supply. WSPs are an integrated risk management framework covering all steps in the water supply from catchment to consumer. Development of WSPs is not well documented in Sweden, therefore it is important to explore the level of implementation that has been achieved; and if not, what other risk assessment methodologies are used to ensure a safe supply of drinking water. The work is a collaboration with Riga Technical University; hence, Latvia has also been included in the thesis project.

A literature review of the global state-of-the-art of WSPs has been carried out. Interviews were conducted with the national authority, Livsmedelsverket; local authorities in Gothenburg and Alingsås; three water suppliers in Sweden (Gothenburg, Alingsås and Östersund); and the Latvian Water and Waste Water Works Association (LWWWWA). A comparison between the views and methods in Sweden and Latvia is drawn. Similarities and differences between large and small waters suppliers (Gothenburg and Alingsås, respectively) are noted. The effects of a waterborne outbreak in Östersund and the rest of Sweden are studied.

There is a positive attitude towards risk assessment in Sweden. All the interviewed suppliers have mostly carried out Hazard Analysis and Critical Control Points (HACCP) and qualitative analyses. Gothenburg has done more quantitative work in their system than Alingsås, which could be due to the difference in size. The outbreak in Östersund was a revelation for all of Sweden, increasing the perception of the risks in the suppliers' systems. Sweden has almost all the parts of a WSP already in place, though it is not a proper WSP. Latvia, on the other hand, seems to have done less work integrating risk assessments into their systems. The perception that it is unnecessary and costly might hinder the level of progress achieved.

Further quantitative analyses are necessary to improve the level of information about the risks in the systems. Cost-benefit analyses of implementing risk assessment in the water supply are needed. This can be used to support upgrades in the system, and in the case of Latvia, to motivate suppliers to implement a risk-based approach. Based on the literature review of WSPs, some possibilities of improvement in the Swedish drinking water system are proposed: a web search engine to improve the accessibility to information about the drinking water system; online availability of the documentation needed to carry out a WSP for the supplier; and simplified HACCP to enable suppliers with resource constraints to implement a risk-based approach in their system.

Keywords: risk assessment, drinking water, water safety plan, HACCP, waterborne outbreak.

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## SAMMANFATTNING

Riskbaserade metoder för att bedöma och hantera riskerna i dricksvattensystemet krävs för att garantera ett rent och säkert dricksvatten. Världshälsoorganisationen (WHO) föreslår "Water Safety Plans" (WSP) som det effektivaste sättet att garantera en säker dricksvattenförsörjning. WSP är ett ramverk för integrerad riskhantering som omfattar alla steg i vattenförsörjningen från avrinningsområde till konsument. Utveckling av WSP är inte väldokumenterat i Sverige, därför är det viktigt att undersöka hur mycket som uppnåtts inom WSP-arbetet; och om inte WSP används finns det andra riskbedömningsmetoder som används för att garantera en säker tillgång till dricksvatten. Arbetet är ett samarbete med Rigas tekniska universitet, varför också Lettland har inkluderats i examensarbetet.

En litteraturgenomgång av det globala arbetet inom WSP har genomförts. Intervjuer genomfördes med den nationella myndigheten, Livsmedelsverket; de lokala tillsynsmyndigheterna i Göteborg och Alingsås; tre dricksvattenleverantörer i Sverige (Göteborg, Alingsås och Östersund); och den Lettiska Vattenverks- och Avloppsvatten Föreningen (LWWWWA). En jämförelse mellan de synpunkter framförs och metoder som används i Sverige och Lettland görs. Likheter och skillnader mellan stora och små vattenleverantörer (Göteborg och Alingsås) noteras. Effekterna av hur det vattenburna utbrottet i Östersund har påverkat övriga Sverige har studerats.

Det finns en positiv inställning till riskbedömning i Sverige. Alla de intervjuade leverantörerna har till största delen genomfört Hazard Analysis and Critical Control Points (HACCP) och andra kvalitativa analyser. Göteborg har gjort mer kvantitativa riskanalyser i deras system än i Alingsås, vilket kan bero på skillnaden i storlek. Utbrottet i Östersund var en uppenbarelse för hela Sverige, vilket ökat uppfattningen om riskerna i leverantörers system. I Sverige är nästan alla delar av en WSP redan på plats, men det är inte riktig fullt ut en WSP. Lettland verkar å andra sidan ha genomfört mindre integrerade riskbedömningar i sina system. Uppfattningen att detta är onödiga och kostsamma åtgärder kan hindra framsteg som gjorts.

Ytterligare kvantitativa analyser är nödvändiga för att förbättra nivån på information om riskerna i systemen. Kostnads-nyttoanalyser för att genomföra riskbedömning i vattenförsörjningen behövs. Detta kan användas för att stödja uppgraderingar i systemet, och när det gäller Lettland, för att motivera leverantörer att genomföra en riskbaserad metod. Baserat på litteraturgenomgång av WSP, föreslås några möjliga förbättringar för de svenska dricksvattensystem: en webbaserad sökmotor för att förbättra tillgängligheten till information om dricksvattensystemet; online-tillgång till de handlingar som behövs för att utföra en WSP för leverantören; och en förenklad HACCP för att vattenproducenter med begränsade resurser ska kunna genomföra en riskbaserad analys av sitt system.

Nyckelord: riskbedömning, dricksvatten, vattensäkerhet planen, HACCP, vattenburna utbrott.

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Gothenburg, June 2015

Anielka Salinas & Victor Viñas

# Table of Contents

# 1. Introduction

Access to safe drinking water is considered a basic human right and an essential component to health (WHO, 2011). Drinking water is regarded as safe if it does not pose a significant health risk to consumers over the course of their lives. However, because drinking water systems are composed of several parts, there are multiple areas where the system could be compromised and contaminated water be delivered to the public (Lindhe, 2010). Therefore, risk-based approaches to assess and manage the risks in the drinking water system must be utilised to guarantee a reliable supply of safe drinking water.

There are several tools available to perform risk assessments of drinking water systems. They are classified as quantitative or qualitative. Quantitative risk assessments are based on models for generating chain of events and estimating risk levels in numbers (Rosén, et al., 2007). Qualitative assessments are based on checklists and classification of risk levels, providing a relative scale in which to compare the risks. A kind of qualitative assessment encouraged by the World Health Organization (WHO) is the water safety plan (WSP).

Introduced in the Third Edition of the WHO Guidelines for Safe Drinking Water, WSPs are recommended as the most effective way to ensure a safe drinking water supply. The WSP method is an integrated risk management framework covering all steps in the water supply from catchment to consumer. WSPs have been implemented in many parts of the world and are currently being promoted in both developing and developed countries.

At the moment, development of WSPs in Sweden is not well documented in the literature (WHO: Europe, 2007; Baum et al., 2015). Since Sweden aims to provide its population access to drinking water of sufficient quality, it is vital that a risk-based approach to safe drinking water be used. Therefore, it is important to explore how well-established are risk assessment methodologies, WSP or others, in the drinking water supply. Since the project is a collaborative effort with Riga Technical University (RTU), Latvia has also been included in the thesis project.

## 1.1 Aim & Objectives

The main purpose of the thesis project is to present an overview of the current state of integration of risk assessment into the drinking water supply of Sweden and Latvia, within the WSP framework. For this project, integration includes determining the views and attitudes of both authorities and suppliers concerning risk assessment (RA) and WSP in Sweden and Latvia, regulatory requirements in both countries, methodologies used and possible factors that could influence the level of implementation.

One of the objectives was focused on the international perspective of risk assessment: an overview of the integration of WSPs in the world.

Objectives focusing on both Sweden and Latvia include:

- Identify risk assessment methods used in Sweden & Latvia
- Identify and compare views, rules and guidelines provided by water authorities Sweden & Latvia
- Identify and compare views and methodologies of water suppliers Sweden & Latvia

Objectives focused on Sweden:

- Compare views and methodologies of water suppliers large city and small city
- Identify the effect of outbreaks in views and methodologies of water suppliers
- Compare WSP implementation in the world with Sweden
- Assess possibilities of improvements in the Swedish system

## 1.2 Limitations

The thesis project was carried out between the months of January and June. All interviews and data collection was done during this time period. The main focus of the thesis project was in centralized drinking water supply systems. This means that private wells and suppliers not covered by the Swedish drinking water regulations (i.e., supply systems that serve less than 50 people or that produce less than 10 $m^3$/day) are not included when referring to water suppliers. In addition, since the studied water supply systems all use the same source (i.e., surface water), the findings might not represent the state of suppliers that use groundwater as their main source.

## 1.3 Outline

The thesis project has been divided in 7 chapters.

Chapter 2 presents a brief background of WSPs and risk assessment tools used in drinking water. This are the most important concepts used in the thesis project.

Chapter 3 details how the literature review was performed and what sources were used. It also describes the methodology used to create the questions for the interview and how it was conducted. In addition, the main points of the comparative analysis are defined.

The main findings from the literature review are presented in Chapter 4, while the results from the interview are mainly presented in Chapter 5.

Conclusions on the results and further discussion are provided in Chapter 6; in addition, some recommendations for further studies. In the last chapter, Chapter 7, a summary of the main findings and some reflections are presented to conclude the report.

# 2. Background

In this chapter, a brief description of the World Health Organization and its framework for safe drinking water is presented. Sustainability aspects of drinking water are also mentioned. Risk assessment from a drinking water supply context is shortly introduced and some tools are described.

## 2.1 World Health Organisation Guidelines

The World Health Organization (WHO) is an organization under the United Nations and works for the right for every human being to have as good health as possible. They work both by preventing outbreaks and by distributing medicine, but also by improving the social, economic and environmental situations for humans. There are 194 member states in the World Health Organization, all countries that are members in the United Nations can be members of WHO as long as they accept the constitution of WHO (WHO, 2015c). Countries that want to join WHO can do so by applying for membership and have to be approved by the majority of the nations that are members (WHO, 2015a).

There are six main priorities that give WHOs work direction (WHO, 2015b):

- **Universal Health Coverage** gives guidance on how to combine access to services and financial protection, to achieve good health and prevent poverty as a result of bad health.
- **The International Health Regulations** where WHO helps countries establish a defence against illness coming from the microbial world. The defence is established to prevent outbreaks.
- **Increase access to medical protection** entails affordable high medical technologies to improve access to medicine all over the world, therefore it is essential with low cost for medicine to improve the global health of the population and prevent major outbreaks.
- **Social, economic and environmental determinants** entails working with other sectors to prevent conditions that causes diseases and bad health. In the environmental determinants improving drinking water is an important task, since surface water can carry microbes and parasites.
- **Noncommunicable diseases**, also known as chronicle diseases, includes cardiovascular diseases, cancers, chronic respiratory diseases and diabetes. The World Health Organization works to prevent these diseases so that they do not overwhelm the health system in place. Noncommunicable diseases are prevented by addressing factors such as tobacco, alcohol, unhealthy diet and physical inactivity.
- **Health-related Millennium Development Goals (MDGs)** are developed to improve health for the population in the countries that are members of WHO before 2015. The MDGs are eight goals that combat poverty, hunger, diseases, illiteracy, environmental degradation and discrimination against women and all of the factors influence the health of the population.

Drinking water quality is a concern for the WHO since there are several waterborne diseases that can infect the population and is an environmental factor that can lead to bad health. The target of concern is mainly infants, young children and elderly. Therefore, the World Health Organization has developed guidelines for the drinking water quality to prevent the waterborne diseases from reaching the population and to improve the common health of the population (WHO, 2015b).

WHO's primary purpose for the guidelines for safe drinking water is to recommend a holistic method of assessing the risk within the drinking water supply to prevent and not compromise the safety of the drinking water (WHO, 2015a; WHO, 2015b).

## 2.2 Framework for Safe Drinking Water

The framework for drinking water includes the basic requirements to ensure safe drinking water from water source to distribution system. A systematic risk assessment is made for the drinking water supply. The WHO believes in a holistic approach to increase the safety of the drinking water supply, where all aspects are taken into account in the risk assessment and risk management.

The World Health Organization divides the framework for safe drinking water into three main parts that will ensure safe drinking water for the population. These guidelines are general and have to be adapted to the local area (see Figure 1). The three main parts of the framework developed by WHO are (WHO, 2011):

- An evaluation of the risks that can occur in the drinking water gives the foundation to determine several **health-based targets** that are used in the process.
- **Water safety plans (WSPs)**
    - To meet the health based targets a **system assessment** must be made to assess whether the whole drinking water supply will deliver drinking water of a good quality that meets the demands.
    - In the drinking water system a measure to secure the safety of the drinking water is to have control measures and to have a constant operational **monitoring**.
    - Documentation on the system, plans describing the actions to be taken in normal operation, plans describing actions to take during incidents, plans on improvement, plans on upgrade and plans for communication are all to be included in the **management** plans.
- **Surveillance** is an important system to have in place, independent of the process in the drinking water system, to verify that the whole system and the WSPs are operating properly.

There are also supporting documents in the guidelines that address the microbial-, chemical-, radiological- and acceptability aspects. World Health Organization has also adapted the guidelines for safe drinking water to special or specific circumstances like climate change, rainwater harvesting, desalination and several other specific circumstances (WHO, 2011).

The guidelines for safe drinking water are to be used by a competent authority to establish regulations and policies that are adapted to the local circumstances and have to take into account the social, economic and environmental issues of the area.

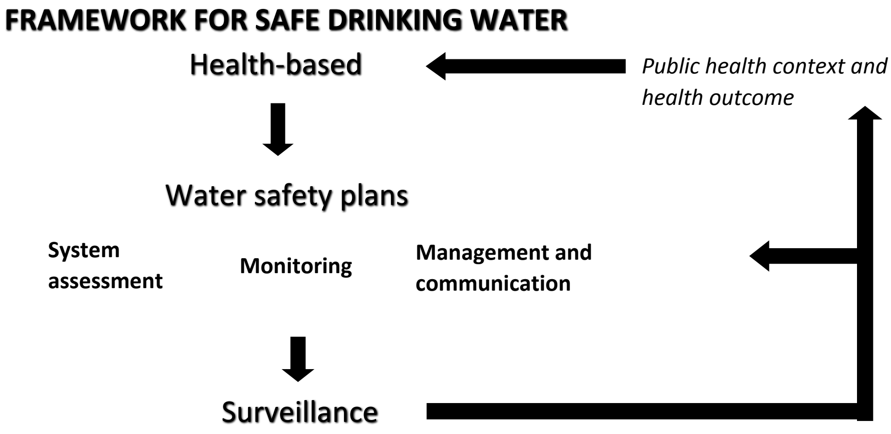



*Figure 1 - Framework for safe drinking water according to the WHO.*

### 2.2.1 Health-based targets

High-level authorities that are responsible for health are the ones responsible to establish the health-based targets. The overall public health is their main focus and takes into account the impact of waterborne microbes and chemicals on the quality of the water. Health authorities can consult other stakeholders, such as drinking water suppliers and affected communities, when health-based targets are set. There are four types of health-based targets (WHO, 2011):

- **Health outcome targets:** are recommended to guide the suppliers to achieve their goals in the drinking water processes.
- **Water quality targets:** are recommended concentrations of substances and chemical that can be of concern for the water quality. Long-term exposure to chemicals and substances with low changes in flow can give long term health risks.
- **Performance targets:** are set for substances and chemicals that can risk the public health either by short-term exposure or with large flow changes that expose the population to high concentrations of the constituents. Drinking water suppliers take the performance targets into account in the process with different technological processes.
- **Specified technology targets:** Smaller municipalities, communities and household drinking-suppliers can have recommendations that differ from the drinking water suppliers that supply large cities. The recommendations are often based on the technology used or the specific circumstances of the area.

In general the health-based targets are derived to secure and protect public health, and have to be adapted to local operation conditions. Several types of targets are used to identify different types of contaminants, and from there derive an appropriate scenario to assess the risks in the drinking water sources (WHO, 2011).

### 2.2.2 Water safety plans

When an outbreak is detected in the population it is important to have a contingency plan to respond and find where the system failure has occurred. A WSP gives an organised and structured overlook of the whole system when it comes to oversight or lapse of management and unforeseen events can be identified at an early stage. Therefore a system assessment must be made with further monitoring and management or contingency plans that are set into motion if an outbreak would occur (WHO, 2011).

A WSP includes several steps of documentation, and assessments are made to provide safe drinking water. A multiple-barrier principle is used to build the WSP and critical control points are located through the system whilst based on a hazard analysis. The WSP is done for the whole system: from abstraction, treatment to delivery of the drinking water (WHO, 2011).

#### *System assessment and design*

The drinking water should accomplish the health-based targets by following routines, since the drinking water will vary through the system the risk assessment assesses the capacity of the system to deliver water with a high quality. The assessment can be used in several systems from piped distribution systems to individual domestic supplies (WHO, 2011).

#### *Operational monitoring*

Monitoring the drinking water system is essential to a water safety plan since there are different parameters that are constantly monitored and when the levels of different indicators vary, measurements are taken to maintain the drinking water quality. Often the operational monitoring are simple observations that are carried out rapidly to assess the system (WHO, 2011).

To eliminate, reduce or prevent contamination in the drinking water supply, control measures are implemented. Turbidity, chlorine residual and structural integrity are some of the parameters monitored. To validate and verify the water quality, microbial and chemical tests are used and take more time to analyse. To get the right concentration of different pathogens in the drinking water, indicator organisms can be used in the operational monitoring (WHO, 2011).

#### *Management plans, documentation and communication*

A loss of control may occur, and in the WSPs documentation is of the utmost importance. The describing actions should be documented for the drinking water plants operating normally and under incident. The WSP should also assess and document what is required to run the drinking water plant optimally. The documents should include detailed information on (WHO, 2011):

- Assessment of the drinking water system
- Control measures, operational monitoring, verification plans and performance consistency
- Routine operation and management procedures
- Incident and emergency response plans
- Supporting measures, including:
    - Training programmes
    - Research and development
    - Procedures for evaluating results and reporting
    - Performance evaluations, audits and reviews
    - Communication protocols
- Community consultation

An active communication with the population regarding the drinking water quality issues can give the population an understanding about the services given by the water suppliers. A general knowledge among the population can also make them contribute to decisions (WHO, 2011).

### 2.2.3 Surveillance

The quality of public health safety is monitored by surveillance agencies and should be carried out periodically to locate any existing contamination-caused outbreak. If an outbreak has been found by the surveillance agency, they have to be able to assemble a taskforce to respond and rectify incidents of contamination (WHO, 2011).

The surveillance from the national surveillance agency should monitor the quality of drinking water from the water source to the tap. Data has to be collected throughout the system and surveys are often handed to the population to have their input about the water quality. Several inspections are made to the different parts of the drinking water system to supervise it (WHO, 2011).

Testing and analytical results can in some cases be inappropriate since analysing the results can take days, and the frequency of testing can be low, which gives a delay in the actions that have to be taken when an outbreak is found in the system. A grading scheme is an appropriate way of analysing the hazards and preventing outbreaks (WHO, 2011).

## 2.3 Sustainable development in drinking water

Sustainable development aims to take care of the ecosystems so that the future generations will be able to survive. There are three dimensions to sustainable development: social, economic and ecological. They are dependent of each other and have to be in balance to build a sustainable future (NGO Committee on Education, n.d.).

Water has no known substitute and is important for all living organisms on Earth. Making it an important building block for a sustainable future. Special characteristics that only water has are essential for several industrial processes, human survival, and the population economic, social and cultural life depend on fresh water. A trend that has been observed is that developed countries have a greater quantity of renewable fresh water resources while most of the developing countries lack those resources (Abu-Zeid, 1998).

Water management is a complex process and dependent of the changes in the environment e.g., floods and droughts. The amount of water available is in some parts of the world becoming scarcer, in the 1990s there are 26 countries (300 million people) with water shortage. Food production will be affected by the lack of water and this will have a wide series of consequences for the population. With the lack of founding and change in the climate the deaths attributed to water borne diseases are expected to increase. According to Abu-Zeid (1998), the sustainability of the planet is threatened by the lack of fresh water and will have serious ramifications for the future.

Management of international bodies can in the future be a social and cultural problem when water scarcity becomes a fact, since 47 percent of the land area are shared rivers and lake basins. In Africa and South America nearly 60 percent are shared basins and rivers (Saeijs & Van Berkel, 1995).

Water plays an important role in the development of a country, 62 percent of the fresh water is aimed for food production and the industrial requirements are expected to increase to 24 percent for a country under development. Furthermore the water quantity used in a household increases when the living standards improves. If poverty alleviation succeeds, the amount of fresh water needed will increase remarkably (Asit & Biswas, 1991).

Waste products are also a consequence of an increase in the population and can contaminate available raw water sources if not treated properly. In developing countries due to a lack of funding and proper monitoring wastewater programmes, it is impossible to estimate to which extent the water is polluted decreasing the raw water quality (Asit & Biswas, 1991).

## 2.4 Risk Assessment in Drinking Water Supply

Risk can be defined as the likelihood of an undesired event occurring under a specific event or period (Pollard, 2008). Another way of expressing risk is as a combination of a probability of an event and its consequence. Risk assessments serve to inform and support decision-making in matters of risk. Figure 2 shows the parts associated with risk assessment within a risk management framework. The basic steps of a risk assessment are identifying the hazards and calculating its risks; determining if the risk is acceptable and if necessary, analysing risk-reducing measures.

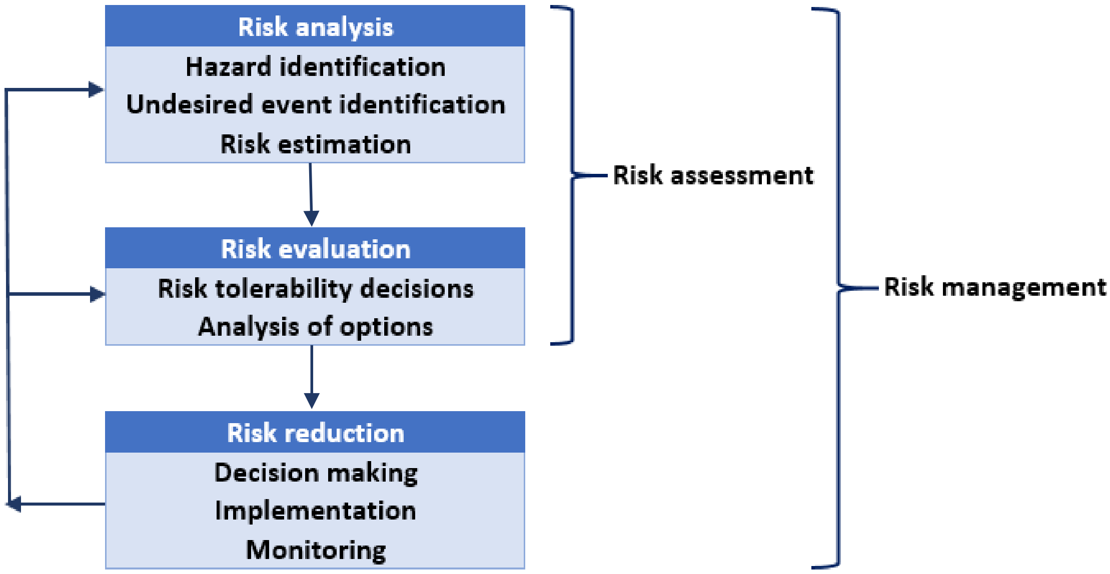



*Figure 2 – Parts of risk assessment and risk management according to IEC. Adapted from (Tuhovcak & Rucka, 2009).*

Traditionally, organizations handling the drinking water supply have not placed much effort on managing their risks; however, this is changing (Pollard, 2008; Tuhovcak & Rucka, 2009). Stricter regulations, need to reduce costs, expectations of high quality service, among other drivers, are making the integration of risk assessments more common in the water supply management. This paradigm shift is recognized by the World Health Organization, which states that "*the most effective means of consistently ensuring the safety of a drinking water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the water supply from catchment to consumer*" (WHO, 2011). A risk-based approach to drinking water supply is also encouraged in several national guidelines, such as Australia and Canada (Lindhe, 2010). Due to the increasing importance of risk-based approaches to drinking water supply, a wide range of tools are available to carry out risk assessments with differing levels of sophistication. They can be classified as quantitative methods or qualitative methods.

### 2.4.1 Quantitative risk assessment

Quantitative methods of risk assessment are used to obtain numerical values for risk (Lindhe, 2010). A quantitative assessment is advantageous in that it enables risks to be compared to one another and is useful to analyse complex systems. A variety of methods exist, with differing areas of application.

Quantitative microbial risk assessment (QMRA) is used to estimate the risk of infection of a consumer, by combining the probability of occurrence of a pathogen at the tap with the consumption pattern and dose-response relationships (Petterson, et al., 2006). Quantitative chemical risk assessment (QCRA) is a method developed by the U.S. Environmental Protection Agency to assess health risks posed to humans from exposure to chemicals in the water (Rosén, et al., 2007). Both methods are founded on four key elements: a system description that includes hazards and events, exposure assessment, effect assessment or dose-response curve and characterization of risk (Hokstad, et al., 2009). They can be used, for example, to support decisions regarding barriers at a water treatment plant. However, they require extensive data and expert knowledge to be implemented appropriately (Rosén, et al., 2007).

Logic tree models are used to link events that could either develop from, or lead to, a hazardous event (Burgman, 2005). Some types of logic tree models include event trees, fault trees, Bayesian networks and Markov models. Event trees initiate from a starting event and progress in a systematic way generating a range of possible outcomes. The outcomes are dependent of the success or failure of the sequence of events. Although the outcomes are usually assumed to be binary, they can also include multiple options (Rosén, et al., 2007).

Fault trees, on the other hand, are built differently. A critical event, also known as top event, is identified and the causes of this critical event are expressed at lower levels of the tree. The relationships between the events that cause the top event are described by the use of logic gates (AND, OR gates). Events at the lowest level of the fault tree are known as basic events (Lindhe, 2010).

A comprehensive list of methods and description of each can be found in Rosén et al. (2007) and Hokstad et al. (2009).

### 2.4.2 Qualitative risk assessment

Qualitative methods of risk assessment describe the risk using words or classes. Qualitative methods that add a numerical component to the probability are usually referred to as semi-quantitative. One of the most common qualitative (or semi-quantitative) methods is risk ranking (Burgman, 2005). It mostly relies on expert judgement to create a list of hazards and possible consequences, and estimating the probabilities of occurrence. The results of the ranking are usually presented in a matrix format. A detailed account on the steps to conduct a risk ranking analysis can be found in Burgman (2005).

Risk ranking has the advantage of being a relatively simple method and the results are easy to present. Nonetheless, there are some important limitations with the method. It relies on subjective opinions by experts; usually providing little reference on how to select experts, making estimates or combining judgements (Burgman, 2005). If the team does not have broad technical expertise, it could lead to arbitrary models being created. Hazards are considered as discrete and as having a fixed consequence. This potentially truncates the range of consequences that the hazardous event truly generates.

A semi-quantitative risk ranking is the preferred method by the WHO to carry out WSPs (Lindhe, 2010). Table 1 and Table 2 show an example of a risk ranking analysis as described in fourth edition of the WHO Guidelines for Safe Drinking Water.

*Table 1 – Example of definitions for likelihood and consequence categories. Adapted from WHO (2011).*

| LEVEL | DESCRIPTOR | DESCRIPTION |
|---|---|---|
| **LIKELIHOOD** | | |
| A | Almost certain | Once a day |
| B | Likely | Once per week |
| C | Moderate | Once per month |
| D | Unlikely | Once per year |
| E | Rare | Once every 5 years |
| **CONSEQUENCE/IMPACT** | | |
| 1 | Insignificant | No detectable impact |
| 2 | Minor | Minor aesthetic impact causing dissatisfaction but not likely to lead to use of alternative less safe sources |
| 3 | Moderate | Major aesthetic impact possibly resulting in use of alternative but unsafe water sources |
| 4 | Major | Morbidity expected from consuming water |
| 5 | Catastrophic | Mortality expected from consuming water |

*Table 2 - Example of a qualitative risk analysis matrix - risk level. Adapted from WHO (2011).*

| LIKELIHOOD | CONSEQUENCES | | | | |
|---|---|---|---|---|---|
| | Insignificant 1 | Minor 2 | Moderate 3 | Major 4 | Catastrophic 5 |
| A (ALMOST CERTAIN) | H | H | E | E | E |
| B (LIKELY) | M | H | H | E | E |
| C (MODERATE) | L | M | H | E | E |
| D (UNLIKELY) | L | L | M | H | E |
| E (RARE) | L | L | M | H | H |

E – Extreme risk, immediate action required; H – High risk, management attention needed;

M – Moderate risk, management responsibility must be specified; L – Low risk, manage by routine procedures

## 2.5 Hazard analysis and critical control point (HACCP)

In Sweden, HACCP is the method required in the drinking water plants, this method has been used since the 1980. The method is used widely in the food industry and has been adapted to the drinking water industry. HACCP is a risk based methodology to ensure the quality of the product (Martel, et al., 2006).

The principles of HACCP are (Lindberg, 2015):

1. To identify Hazards that must be prevented, eliminated or reduced to an acceptable level.
2. Identify critical control points, where control is necessary to prevent or eliminate a hazard or to reduce it to an acceptable level.
3. Establish critical limits at critical control points which separate acceptable and unacceptable values in the critical control points.
4. Establish and implement effective monitoring procedures at critical points.
5. Establish corrective actions to be taken when monitoring indicates that the critical point is not under control.
6. Establish procedures, which shall be carried out regularly, to verify that measures are functioning effectively.
7. Establish documents and records, to show that actions are applied effectively.

Torbjörn Lindberg inspector at Livsmedelsverket has made a comparison between WSPs and HACCP, which can be seen in Figure 3. The different steps in the HACCP method can be found incorporated into the definitions of a WSP, an example is the first and second step where hazards and critical control point are identified, and this is also done in the WSP under the system assessment.


*Figure 3 - Comparison between principles of HACCP and their equivalent part in a WSP.*

# 3. Methods

The following chapter details the methodology followed to develop the project and present the results. The thesis project was conceived as a qualitative study and was carried out in three parts:

I. Literature Review: global perspective of WSPs
IIa. Literature Review: drinking water of Sweden & Latvia
IIb. Interview to relevant actors of drinking water supply in select cities of Sweden & Latvia
III. Comparative analysis of the results

## Part I –Literature review of WSP

All WSP documentation available in the WHO website was retrieved and examined. This was done to become acquainted with the WSP methodology. Additionally, a literature review of the implementation of WSPs in the world was carried out. This served as basis for the current state of the art of WSPs across the globe. It also illustrated the different ways countries approached the integration of WSPs into their drinking water legislation and/or drinking water supply. A brief overview of the costs of implementation was also included.

A list of countries with well-documented cases of development and implementation of WSP was compiled from Baum et al. (2015) and the Water Safety Portal webpage (http://www.wsportal.org). The Water Safety Portal and the Chalmers Library Search Services were used to retrieve all publications of the compiled list of countries for the purpose of review.

The results of the literature review are presented in the next chapter (Chapter 4). Countries were grouped by continents. Some continents were grouped together due to having too few countries with available information, i.e., North America and South America; Asia and Oceania. The main findings of the literature review were also used in the comparative analysis part.

## Part IIa – Literature review of Sweden & Latvia

The second part of the project was subdivided in two parts: a thorough examination of the all publications and regulations concerning drinking water supply for Sweden and Latvia, and a set of interviews to actors in select drinking water systems. The literature review of each country was used as theoretical background for the interviews and as data for a comparative analysis.

Swedish national regulation for drinking water was retrieved from Livsmedelsverket's SLVFS 2001:30. Most of the information from Sweden's water supply was extracted from Svenskt Vatten's website and the respective website of the water supplier. Latvian regulation was found in the Regulations of the Cabinet of Ministers Nr. 235. General information on the Latvian drinking water supply was collected during a study visit to Riga Technical University and the Latvia Water and Waste Water Works Association head office. The main findings of this literature review are presented in Chapter 4.

## Part IIb - Interviews

A guide for conducting research interviews by Rowley (2012) was used to create the interview questions, plan the interviews, conduct the questioning and analyse the data. These interviews served to determine the views of the authorities concerning WSP/risk assessment, and the views and methodologies of the water suppliers. Additionally, the interviews were also used as data for the comparative analysis part.

The interviews were set up as semi-structured. A previously prepared set of questions was used to ensure all the necessary information was collected, while still permitting topics that surfaced during the questioning to be addressed. The questions formulated for the interviews can be found from Appendix A – Interview Questions: National Authority to Appendix C – Interview Questions: Water Supplier. The interviews were performed physically or by telephone, and lasted between forty-five minutes to one-and-a-half hours.

Table 3 lists all the participants for the interviews. Livsmedelsverket was interviewed due to it being the national regulatory authority on drinking water in Sweden. Two additional institutions, Miljöförvaltningen of Gothenburg and Miljöskyddskontoret of Alingsås, were also interviewed as representatives of the local authorities. In total, four water suppliers were chosen to be included in the project: Gothenburg, Alingsås and Östersund in Sweden, and Riga in Latvia.

Gothenburg was chosen as representative of a large Swedish city, since it is the second largest city of Sweden. Alingsås was chosen as representative of a small Swedish city due to having a population smaller than 30,000 inhabitants. An additional criterion for the selection was usage of the same type of raw water source, i.e. the use of surface water as source. Östersund was chosen due to having suffered a waterborne outbreak recently (2010). Riga was selected as representative of a large city in Latvia. A site description of the selected cities can be found in sections 4.2.7 and 4.3.2.

*Table 3 – Information of the Institutions and persons interviewed for this project.*

| INSTITUTION | ROLE | LOCATION | INTERVIEWEE |
|---|---|---|---|
| Livsmedelsverket | National authority | Sweden | Torbjörn Lindberg |
| Miljöförvaltningen | Local authority | Gothenburg | Daniel Eek |
| Miljöskyddskontoret | Local authority | Alingsås | Anna Ebbesson; Katarina Björk-Åkesson |
| Kretslopp och Vatten | Water supplier | Gothenburg | Claes Wångsell |
| VA-avdelningen | Water supplier | Alingsås | Tommy Blom; Jennie Eriksson |
| Vatten Östersund | Water supplier | Östersund | Jenny Haapala |
| Latvia Water and Wastewater Works Association / Riga Technical University (RTU) | Water Association / University | Riga | Baiba Gulbe; Talis Juhna & Kamila Gruskevica |

Due to the extent of the information produced with the interviews, only a summary of the responses with the main discussion points are presented in Chapter 5. Excerpts from the interviews are included in quotations to exemplify certain discussion points. Full transcripts of the interviews can be found from Appendix D – Interview Transcript: Livsmedelsverket to Appendix J – Interview Transcript: Latvia.

## Part III - Comparative analysis

The third part of the project comprised a variety of comparisons being carried out:

- Between the WSP framework and drinking water suppliers of Sweden: To assess the progress of Swedish water suppliers in implementing WSPs, the responses from the interviews were contrasted with the parts of a WSP identified in Svenskt Vatten's "Råd och riktlinjer för ansvariga inom dricksvattenproduktion". Figure 4 shows the parts as detailed in the report. It was assumed that if the supplier had all parts fully implemented, a WSP was currently in place for said system. The result of this comparison is presented in Chapter 5.

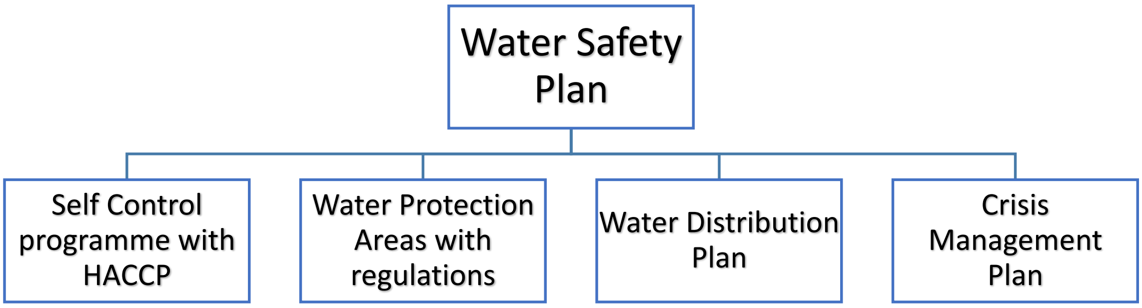



*Figure 4 - Parts of a WSP according to Svenskt Vatten's "Råd och riktlinjer för ansvariga inom dricksvattenproduktion."*

- Between large water supplier and small water supplier: Responses from the interviews to Gothenburg and Alingsås were compared to one another in order to determine similarities and differences in the risk assessment methodology used by each city. The main differences encountered were analysed to determine if they were caused by the difference in system size. The result from this comparison is presented in the discussion (Chapter 6).
- Effect of an outbreak in drinking water suppliers: The majority of the information was taken from the response of the Östersund interviewee, where differences in their drinking water system before and after the outbreak were investigated. Moreover, effects of the outbreak on the authorities, Gothenburg and Alingsås were assessed in the interviews and integrated into this comparison. Responses are presented in Chapter 5. Discussion on the effects of the outbreak is presented in Chapter 6.
- Sweden and Latvia comparison: Similarities and differences between the drinking water requirements covered in the Swedish and Latvian legislations were identified. In addition, resemblances between the tools and methods used by Swedish water suppliers and Latvian water suppliers were assessed. The comparison between countries is presented in Chapter 6.
- Improvements in the Swedish RA methodology: The results from Sweden's implementation of WSPs were also used to analyse the possibility of implementing policies employed in other parts of the world (findings from literature review for Part I). This is presented in the discussion chapter (Chapter 6).

# 4. Literature Review

A brief description of the implementation of WSP in the world will be presented in this chapter. Costs and benefits analyses that have been made in the world regarding WSP will also be mentioned. Additionally, information about Swedish legislation and implementation will be presented as well as information about Latvia.

## 4.1 Water Safety Plan implementation

The most important findings on WSP implementation in the world are presented in this section.

### 4.1.1 Africa

Millennium Development Goals (MDGs) were developed by the United nations in 2000 and one of the main goals is to minimize the percentage of people who does not have access to safe drinking water The MDGs are meant to be met by 2015 (ASC, 2014). Overall almost all countries will meet the MDGs except for Sub-Saharan Africa that has to increase their drinking water coverage by 26 percent (WHO, 2014a).

Africa is a large continent that is facing several challenges to be able to provide the population sanitation and drinking water of good quality. Some of the challenges, are that a large percentage of the population live in poverty, food is not always available or affordable and development is stagnating. The water resources are not handled in a sustainable way in almost all African countries, since the economical capacity is low. The population growth is having a big impact on the water supply since more water is needed and degraded (WHO, 2014b).

Africa is a large continent, and all countries do not have the same conditions, therefore they also are in different levels of progress. Libya, Egypt, Sudan and Algeria belong to North Africa and has progressed rather well they have obtained 92% of the water coverage, which implies that reaching the MDGs will be possible by 2015. Compared to Sub-Saharan Africa North Africa has better possibility to manage the water coverage. Sub-Saharan has to reach a 75 percentage of water coverage, according to the United Nations they have only reached a water coverage of 40 percent (WHO, 2014b).

The varied climate in Africa has also a big impact on the drinking water supply and the natural hazards that can impact the quality of the drinking water. The rainfall in Africa that contributes to the renewable water resources is about 670 mm which is comparable with Europe, the evaporation rate in Africa is much higher than Europe and therefore results in lower precipitation. North Africa and South Africa use ground water and they stand for 40 percentage of the African countries that that use groundwater, while the rest use surface water or other drinking water (ASC, 2014).

WSPs have been implemented in Ghana, Kenya, Morocco, South Africa and Uganda. Since South Africa and Uganda are the African countries that have come the furthest implementing WSPs, they will be described more thoroughly in the following sections.

#### *WSP Implementation in South Africa*

South Africa is one of the driest countries in the world, therefore water is of the outmost importance, not only for sanitation purposes, it also has a critical role in the socio-economic development where 60 percent goes towards irrigation and agriculture and is a critical component to eradicate poverty (South African Government, 2015). The Department of Water Affairs (DWA) is responsible to implement the guidelines set by the United Nations to protect the environment and water resources in South Africa. A Water Services Regulation Strategy is introduced in South Africa by the Department of Water Affairs (DWA). The document aims to protect the consumers by clarifying the requirements and obligations that their water services have to follow (DWA, n.d.).

South Africa has implemented the WSPs developed by the WHO as an incentive-based approach, and is defined by two programmes: Blue Drop certification which aims to assess the drinking water quality management regulations and Green Drop certification that assesses the wastewater quality management regulations. It is mandatory, as stated in the Water Service Act, to refuse, withhold or provide false information for the certification assessment (DWA, n.d.).

The first effort to monitor the quality of the drinking water was not successful, since only 50 percent of the municipalities were actually monitoring. The Electronic Water Quality Management System (eWQMS), an open source system, was implemented for facilitating access information and monitoring of the water quality. Since the DWA was aiming to improve the monitoring with a proactive approach, the Blue Drop certification was created (DWA, n.d.).

Water treatment is of the outmost importance for a well-functioning country, therefore the personnel in the water plants are not allowed to strike, and if sickness would occur backup staff are always required to be available. In the water supply systems the personnel that operate the plants have to be skilled and experienced, thus a Process Controller Registration certificate is required to operate the drinking water plant. The certification is valid during five years and has to be renewed 90 days before it expires. The Process Controller certification has different levels of expertise. Courses and training are mandatory to ensure that the competency level is maintained. Before becoming a Process Controller, the operator needs to have a Process Controller-in-training certificate for 3 years.

Blue Drop has changed the way South Africa works with drinking water quality in a positive way. Since the programme was introduced, two cycles of Blue Drop assessments have been done and the outcome has been positive. An increase in certified drinking water facilities have been noted from 23 in 2009 to 39 facilities in 2010. The average score in the programme was 53 percent in 2009 and in one year the average score increased to 70.7 percent. Chemical compliance increased from 98.9 percent to 99.5 percent in one year and the microbial compliance increased from 93.3 percent to 97.5 percent. The number of water supply systems with WSP has also increased remarkably during one year, in 2009 there were 9 systems with WSP and by 2010 the amount of water supply systems that incorporated WSP was 154. Funding for drinking water also increased after the National Treasury required Blue Drop to be incorporated into the business plan of the municipality. A search engine called My Water has been made public for the population and allows the municipalities to promote their drinking water (see Figure 5).

Several changes have been made to the way South Africa handles their drinking water, and still there are more challenges ahead, since there still are municipalities with low drinking water quality left.

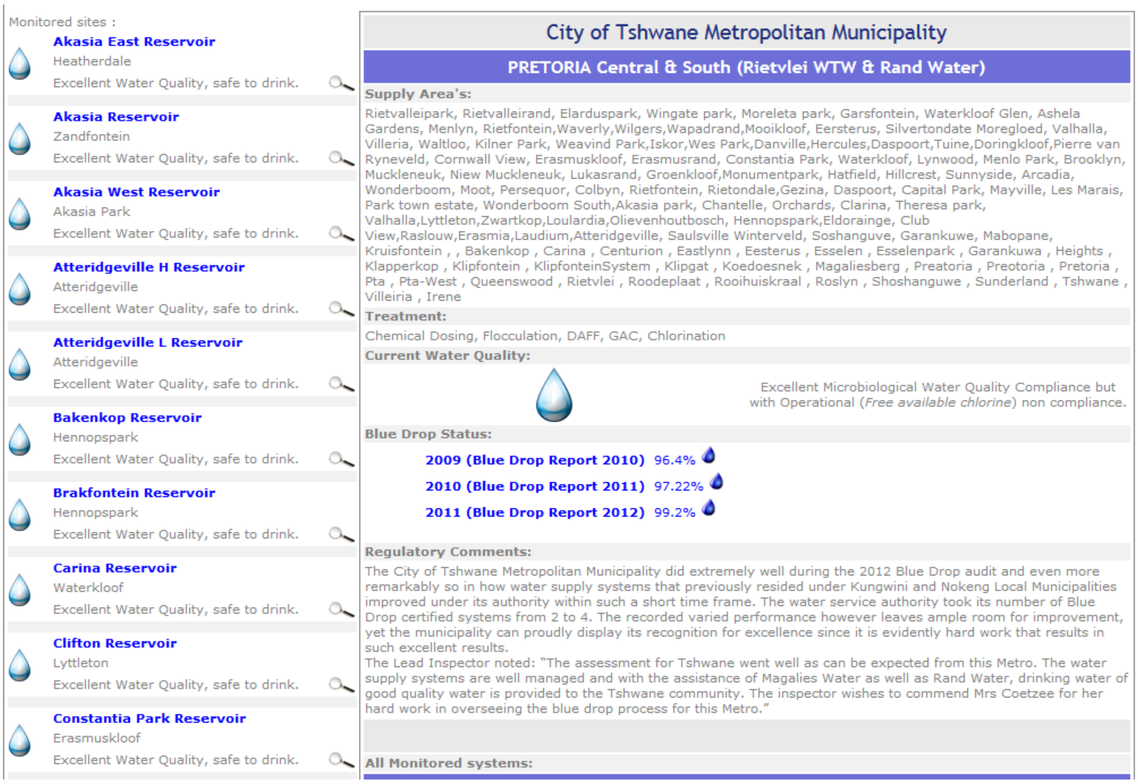



*Figure 5 - Example of the information presented as result of using the MyWater search engine.*

## *WSP implementation in Uganda*

Since the implementation of Framework for Drinking Water, the coverage has increased from 39 percent in 1990 to 65 percent in 2010. Uganda has taken a coherent approach for all the country, which has changed how the sector operates nowadays (O'Meally, 2011).

The legislation in Uganda does not mention the WSP method explicitly, nevertheless, all the steps included in the WSP are mentioned and solicited by the legislation which is based on the WHO guidelines for drinking water. Uganda's legislation was developed between 1994-2000. Packaged water is the main source of drinking water for the people of Uganda. In 2008 the legislation for the drinking water quality was revised and the WSP was made a requirement in three standards (Lillian Amegovu, 2011):

- US 201 Drinking (portable) water
- US 43 Packaged natural mineral waters
- US 42 Packaged water other than natural mineral water

According to the new standards, the operators have to take into account the potential hazards and risks from source to tap, when developing the new WSPs (Lillian Amegovu, 2011).

Uganda National Bureau of Standards (UNBS) regulates the drinking water in Uganda, and this is done by inspecting production processes, product testing and post market monitoring programs. For the drinking water producers, the key issue according to UNSB is to prevent contamination from occurring, therefore the hygiene and sanitation practices is of utmost importance. The UNBS has specified all the requirements that the drinking water must achieve to have a high quality and standard (UNBS, 2013).

The UNSB has a pre-market approval stage, where the operators have to present their plan and there the premises of the manufacturing facility, the integrity and safety of the water source are approved and then a certification is given to the operators (UNBS, 2013).

After the pre-market approval is given operational requirements have to be fulfilled (UNBS, 2013):

- Water source monitoring – The chemical, microbial and physical characteristics of the water are evaluated and monitored periodically.
- Water Safety Plan – A WSP should be developed, implemented and maintained a documented safety plan
- Process control and record keeping – Up to date processing, sampling and quality control has to be available.
- Technical personnel – A qualified and competent staff should be running and supervising the drinking water plant.
- Internal laboratory testing – Key physicochemical and microbiological parameters have to be tested by the drinking water supplier. After 6 months the drinking water facility should have a proper laboratory or else they will not be allowed to operate their facility.
- Packaged material – the materials used have to be safe for packaging water. No cross contamination should come from the packaging material.

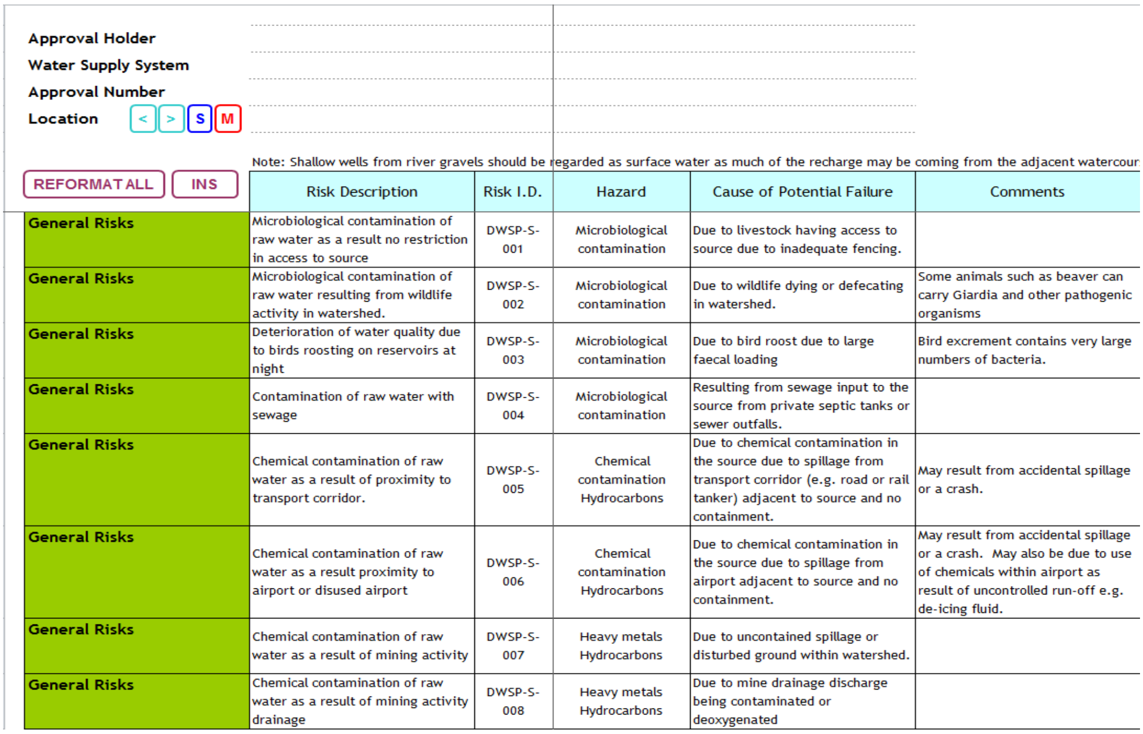
### 4.1.2 Americas

Water safety plans have been introduced in both North America and South America. Though most of the work in Latin America has been done in the form of case studies, the Alberta province in Canada has a legal requirement for the implementation of WSP by all municipal water suppliers.

#### *Water Safety Plan implementation in Canada*

Alberta was the first province in Canada to enact WSPs as mandatory for all drinking water systems regulated by the municipality (Reid, et al., 2014). This was done to counter the limitations in the traditional multi-barrier approach used in the country (e.g., limitations in the sampling programme). The drinking water safety plan (DWSP) developed outlined a proactive approach to risk analysis and estimation; it could be applied to any water system regardless of size or other factors.

As part of Alberta's DWSP, MS-Excel was used to build a template for the four key risk areas: source, treatment, network and consumer (see Figure 6). Generic risks are identified for all key areas and, subsequently, additional system-specific risks are described and added to the template. Scores are assigned to each risk and key risks are identified (i.e., score ≥ 32). Then, action plans are developed in order to reduce the key risks to acceptable levels. All water utilities were expected to have implemented a DWSP by December 2013. However, continuous monitoring of the changes in the system is needed for the DWSP to be effective. The Department of Environment and Sustainable Resource Development (ESRD), who developed the template, was tasked with continuing to update and improve the template after implementation. The template and supporting documentation to guide operators in the making of WSPs can be found in the Alberta Environment and Water website.


Approval Holder
Water Supply System
Approval Number
Location < > S M

Note: Shallow wells from river gravels should be regarded as surface water as much of the recharge may be coming from the adjacent watercour

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| | Risk Description | Risk I.D. | Hazard | Cause of Potential Failure | Comments |
|---|---|---|---|---|---|
| General Risks | Microbiological contamination of raw water as a result no restriction in access to source | DWSP-S-001 | Microbiological contamination | Due to livestock having access to source due to inadequate fencing. | |
| General Risks | Microbiological contamination of raw water resulting from wildlife activity in watershed. | DWSP-S-002 | Microbiological contamination | Due to wildlife dying or defecating in watershed. | Some animals such as beaver can carry Giardia and other pathogenic organisms |
| General Risks | Deterioration of water quality due to birds roosting on reservoirs at night | DWSP-S-003 | Microbiological contamination | Due to bird roost due to large faecal loading | Bird excrement contains very large numbers of bacteria. |
| General Risks | Contamination of raw water with sewage | DWSP-S-004 | Microbiological contamination | Resulting from sewage input to the source from private septic tanks or sewer outfalls. | |
| General Risks | Chemical contamination of raw water as a result of proximity to transport corridor. | DWSP-S-005 | Chemical contamination Hydrocarbons | Due to chemical contamination in the source due to spillage from transport corridor (e.g. road or rail tanker) adjacent to source and no containment. | May result from accidental spillage or a crash. |
| General Risks | Chemical contamination of raw water as a result proximity to airport or disused airport | DWSP-S-006 | Chemical contamination Hydrocarbons | Due to chemical contamination in the source due to spillage from airport adjacent to source and no containment. | May result from accidental spillage or a crash. May also be due to use of chemicals within airport as result of uncontrolled run-off e.g. de-icing fluid. |
| General Risks | Chemical contamination of raw water as a result of mining activity | DWSP-S-007 | Heavy metals Hydrocarbons | Due to uncontained spillage or disturbed ground within watershed. | |
| General Risks | Chemical contamination of raw water as a result of mining activity drainage | DWSP-S-008 | Heavy metals Hydrocarbons | Due to mine drainage discharge being contaminated or deoxygenated | |

*Figure 6 - User interface of the template created for the DWSP in Canada.*

### *Water Safety Plan implementation in Latin America*

The United States Center for Disease Control and Prevention (CDC) has supported several initiatives to pilot WSPs in Latin America, some of them in collaboration with the Latin American and Caribbean Water Safety Plan (LAC WSP) Network. The LAC WSP Network was formed in October 2008 in order to improve the quality of the drinking water supply, by promoting the implementation of WSPs in the region (LAC WSP, n.d.). The LAC WSP group has carried out WSP case studies in different countries of Latin America; however, complete integration into the drinking water systems has not been achieved.

The first case study in the region was performed in Spanish Town, Jamaica and was completed in October 2007 (Environmental & Engineering Managers Ltd., 2008). Though the mechanism for implementation of the WSP could not be determined, the study provided a process flow for WSP development in the region.

Three interesting cases were attempted in Bolivia, implementing WSPs in rural border zones in collaboration with the neighbouring countries (Fundación Sumaj Huasi, 2011). A bi-national WSP was carried out in the border with Peru, in the towns of Desaguaderos; another bi-national WSP was done in the communities of Bermejo, Bolivia and Aguas Blancas, Argentina; and a tri-national WSP was developed for Iñapari (Peru), Bolpebra (Bolivia) and Assis (Brazil). The WSPs were not able to be completed, mainly due to lack of resources. Other important obstacles included the lack of coordination between the water managers of the different communities and differing characteristics of each town's water supply system.

WSPs are being promoted in El Salvador by the Ministry of Health, through a water quality monitoring program that seeks to assist water suppliers in the making and implementation of WSPs (ES Ministry of Health, 2012). Colombia has carried out a small WSP in Valle del Cauca (Pérez Vidal, et al., 2009). The country has shown some interest in introducing WSPs in their legislation. With the aid of the CDC, case studies for WSP implementation have been conducted in Linden, Guyana and San Pedro Sula, Honduras (Gelting, 2009). Other countries in the region that have shown interest in WSPs, but have not done any case study, includes Mexico (PAHO, 2011), St. Lucia and Uruguay (Gelting, 2009).

### 4.1.3 Asia

WSPs have been introduced in many countries of Asia and the Pacific Islands. Nepal, with the enactment of a drinking water directive, has incorporated a WSP approach throughout their water systems, mostly in urban settings (Barrington, et al., 2013). Attempts at bringing WSPs to rural settings have also been made, with methodologies to integrate WSPs to community-based management being developed in case studies. Similar attempts have been made in Bangladesh, where a national Water Safety Framework was adapted from the WHO guidelines in order to assist in the creation of WSPs in piped and non-piped supply systems (Mahmud, et al., 2007).

Lao People's Democratic Republic (PDR) performed its first pilot projects for WSP in the cities of Pakse and Paksan in 2006 and 2008, respectively (Gherardi, 2009). After successful runs, it was decided to be scaled up throughout the entire country. With the aid of government mandates - specifically the Water Law (2009) and a revision to the National Drinking Water Quality Standard - WSPs were required for rural and urban water suppliers (WSP, n.d. (a)). By 2015, it is expected that all of the 17 provincial suppliers in Lao PDR have created and implemented WSPs.

In Vietnam, WSPs were first introduced in 2007, with case studies being performed in Hai Duong, Hue and Vinh Long, in addition to training 45 of 68 water supply companies in the methodology (WSP, n.d.(b)). As part of the scaling up process, six more pilot projects were carried out in both urban and rural water supply systems. Currently, Vietnam is looking to implement WSPs in 75% of all water suppliers. Vietnam has also done some work to encourage the use of WSPs in the country. It was the first country in the region to test a Water Safety Investment Plan, trying to provide a tool for water suppliers to develop an economic plan for the implementation of WSPs. In addition, the National Institute of Health and Epidemics created a methodology to evaluate the health impacts from WSPs.

Japan's Ministry of Health, Labour and Welfare published in 2008 their recommendations for the management of water quality in the country's water supply system (Kunikane, 2009). A software that contained a WSP format and hazard analysis file was included in the publication. The main output of the software would be a hazard control sheet, detailing control measures, monitoring methods and limits for each hazardous event. An example of the resulting control sheet can be seen in

Table 4. While the target audience for the recommendations were the small and medium water suppliers, WSPs were implemented in some large urban areas, e.g., Tokyo Metropolitan Area, Kobe and Osaka.

*Table 4 - Example of a hazard control sheet recommended by the Japanese guidelines (Kunikane, 2009).*

ITEMS TO BE INCLUDED IN A HAZARD CONTROL SHEET

| ITEM | Example |
|---|---|
| LOCATION OF EVENT OCCURRENCE | Water source |
| HAZARDOUS EVENT | Spill of industrial wastewater |
| RELATED WATER QUALITY PARAMETERS | Cyanides |
| RISK LEVEL | 3 |
| FREQUENCY OF OCCURRENCE | Once a year |
| DEGREE OF IMPACT | Significant |
| EXISTENCE OF CONTROL MEASURES | Yes |
| MONITORING METHODS | On-line monitoring |
| CONTROL POINTS | Pre-chlorination |

Additionally, WSPs are required by the legislation of Australia (Byleveld, et al., 2008), Republic of Korea (K-Water, 2013), New Zealand (NZ Ministry of Health, 2014), and The Philippines (Maynilad, 2012). WSPs have also been implemented, but are not legally required, in Bhutan (Kama, 2010), Mongolia (Sutherland, 2013), China, India, Indonesia, Malaysia, Singapore and Thailand (Baum, et al., 2015).

### 4.1.4 Europe

An overview of the Drinking Water Directive is presented since most of the European Union countries are complying with this regulation. Some of the European countries that have already implemented WSPs are discussed in more detail.

*European Union*

Drinking water in the European Union is regulated by the Drinking Water Directive (Council Directive 98/83/EC of 3 November 1998). It applies to all water intended for human consumption, except for natural mineral waters and water which are medicinal products. The directive aims to protect the health of consumers by ensuring the water is clean and wholesome, setting minimum requirements for microbiological and chemical parameters that the drinking water must meet.

In addition to attaining the minimum values set by the directive, member states of the European Union must ensure that the drinking water does not contain any trace of microorganisms, parasites or other substances that could potentially harm human health. Consequently, the directive states that countries must regularly monitor the quality of the water, either with methods detailed in the document or alternate reliable methods. The relevant authorities in each country are tasked with determining the sampling points and the monitoring programs. When the minimum values are not reached, corrective actions are to be taken as soon as possible to restore water quality.

The Directive also stresses the importance of providing relevant and up-to-date information to the consumers. Every three years a report on the quality of drinking water is published by each state and the European Commission uses this information to generate a synthesis report. The resulting report provides a summary of the quality of drinking water in the European Union and improvements that can be carried out.

There is a planned revision to the Drinking Water Directive, which is looking into supporting a framework for the implementation of WSPs in Europe (WHO: Europe, 2007; Rosén, et al., 2007). However, some European countries already have enforceable legislation requiring WSPs: The Netherlands (Hulsmann & Smeets, 2011), Belgium, Hungary, Iceland, Switzerland and the United Kingdom (WHO: Europe, 2014). Other European countries have also implemented WSPs, but do not require them by law. These include Austria, France, Germany, Ireland, Lithuania, Portugal and Spain (WHO: Europe, 2007; WHO: Europe, 2014; Baum, et al., 2015).

*Water Safety Plans implementation in the United Kingdom*

England introduced a new department called the Drinking Water Inspectorate (DWI) and was formed in 1990. Their main focus is to ensure that the drinking water in England and Wales are safe and uphold a high quality. The inspectorate is divided into three departments (DWI, 2015):

- Operations - handles the technical audit, cover operating practices, assessment of water companies sampling programs, investigation of consumer complaints and incidents potentially affecting drinking water quality.
- Regulatory Strategy – Handle programs for water companies that aims to improve the quality of drinking water. Also oversees the inspectorate’s enforcement processes.

- Science and policy – Lead research programme for drinking water in the United Kingdom, handles communication and knowledge management strategies, product approval, water quality data management and enquiries from the public.

The WSP is incorporated in the legislation for drinking water, in the document The Water Supply (Water Quality) Regulations 2000. There all the regulations and parameters are stated, similar to Livsmedelsverket's regulations in Sweden. In the United Kingdom there are companies that supply the drinking water to the municipalities and these are called public water suppliers, and there are two ways to compete with them, either by being appointed to replace a drinking water service or with a Second Water Supply Licensing (WSL) enacted by the Water Act of 2003. They supply water to non-household consumers (DWI, 2010).

Scotland is a part of the United Kingdom and has public water suppliers. The suppliers are regulated by the Scottish Government, that work closely with the Scottish Environment Protection Agency (SEPA) (Scottish Governments, 2013), who regulate and monitor the raw water source amongst other things (SEPA, n.d.). Scottish Water are the public water suppliers in Scotland and are regulated by The Drinking Water Quality Regulators (DWQR). DQWR promotes that the information about drinking water quality is public (DWQR, n.d.(a)). The drinking water is regulated in Scotland by the Public Water Supplies (Scotland) Regulations 2014 (DWQR, n.d.(c)) and the Cryptosporidium (Scottish Water) Directions 2003 that states that all plants have to test for Cryptosporidium (DWQR, n.d.(b)).

### *Water Safety Plans implementation in Germany*

In Germany, the WSP approach was modified and adapted to fulfil the requirements of the German water suppliers and the resulting procedure was called Technical Risk Management (TRM) (Mälzer, et al., 2010). Supply targets were added, in addition to the health-based targets, to satisfy the national drinking water standards, namely quality, quantity, pressure and continuity of supply targets. A simplified, three-grade risk matrix (instead of a five-grade matrix) was included as the main tool for risk assessment. Additional preparations are being made to integrate the WSP approach as a technical standard for German guidelines.

### *Water Safety Plan implementation in Iceland*

Iceland has been a pioneer in their implementation of WSP in the world, they were one of the first countries to implement and incorporate WSP to the legislation. Drinking water was first categorized as food in 1995 when the new legislations were released, and had therefore to be treated as such. Consequently, HACCP was introduced for the drinking water suppliers as well (Gunnarsdóttir, et al., 2012a).

The Ministry of Fisheries and Agriculture are the ones responsible for the water quality in the country. Icelandic Food and Veterinary Authority manages the drinking water (Gunnarsdóttir, et al., 2012a). Surveillance at a local level is performed by the Local Competent Authorities (LCA) (Gunnarsdottir, et al., 2012b). The association of utilities, Samorka, encourages cooperation amongst the supplies with meetings and training (Gunnarsdóttir, et al., 2012a).

Reykjavik was the first water utility plant that implemented WSP, and they did so in 1997. In the larger utilities plants HACCP is used, while in the smaller plants a five-step method is used. The five step method is a simplified HACCP, which includes risk assessment, procedure for maintenance, control at critical points and deviation response. In the Icelandic guidelines WSP is categorized according to the amount of the population that the plants serve. HACCP is used when the suppliers serve more than 5000. When 500-5000 of the population is served the five step method is used. Suppliers serving 100-500 and suppliers serving food processors should have a sanitary checklist. The guidelines have to be followed to get a working permit in Iceland (Gunnarsdóttir, et al., 2012a)

By 2008, 81 percent of the population was served from suppliers that were using WSP. This corresponded to 31 drinking water plants, 17 of these adapted the WSP and 14 used the five step method (Gunnarsdóttir, et al., 2012a).

### 4.1.5 Estimated costs

There is a common fear amongst the drinking water suppliers that the costs for the WSPs are high, and that they will increase the costs of the drinking water production. A result of implementing WSPs is that the microbial testing decreases and process monitoring increases, and in countries where microbial testing is expensive this can prove beneficial for the economy. There are countries that have microbial monitoring in their legislation, for them the microbial testing cost would stay the same (Davidson, et al., 2005).

According to Davidson et al. (2005), routine monitoring costs could be reduced to one-third in a developing country if WSP is used. The recurring cost of process monitoring (such as turbidity, chlorine, residuals, pH, etc.) will certainly be lower than routine control of E. coli as an operational tool, and this relates to developing countries in particular. In countries like United Kingdom where there are regular monitoring of cryptosporidium it would be beneficial to use process monitoring and cheaper surrogates. WSPs will require an initial investment and the costs will be specific to the area and the existing system (Davidson, et al., 2005).

When a cost-benefit analysis is made the cost of activities like maintenance, cost of capital items and incomes from sale of water, social and environmental changes are considered. The benefits of implementing WSP will come over time, with a larger investment cost in the beginning of the project (Talagi, 2011).

To make a cost-benefit analysis it is necessary to take several parameters into account. The Pacific Islands Applied Geoscience Commission (SOPAC) has made two economic assessments of WSPs, one in Niue (a small island associated to New Zealand) and the other one in Palau (an island country associated to United States), and the parameters that were used are as follow (Talagi, 2011):

- The rate of discount time is critical to estimate the benefits over time, therefore in the SOPAC analysis discount rates of 3, 7 and 10 percent were used; since the discount rates in the Pacific vary between 3 and 12 percent.
- Life span of materials: with time the materials grow weaker and will have to be replaced, therefore the investment has to be considered for a reasonable amount of time.
- Water demand depends on the population and the amount of tourism during some periods of the year. It is also important to know if the water demand is increasing or decreasing.
- Operational costs, water quality testing and fuel for monitoring have to be included in the costs over time.
- Health costs, there is an immediate financial cost if an outbreak would occur, then there are more long-term costs which are how long time the person that is sick has to be at home. In the SOPAC reports the immediate response to outbreak is also included.
- Mitigating actions, if the water has to be boiled or if filters have to be used in case of an outbreak, although in the reports from SOPAC this costs are not known and therefore not incorporated in the cost-benefit analysis.
- Alternative water supply, costs of bottled water is incorporated in the analysis, where the amount of imported water is calculated and analysed.

- Education and awareness costs are calculated, these are for the staff and for the population.
- Leakage, costs for leakage is important to calculate since the percentage of leakage can cost a lot of money. In the leakage calculations the cost for electricity of the pumps are included. And also pipes have to be renewed and this cost is also included in the overall cost.

*Examples of costs that implement Water Safety Plans given by WHO*

In Gold Coast Water (Australia), the cost for making a HACCP was estimated; the HACCP was to be made with ISO 9001 and 14001 as a starting platform. This was made during two months and with help of a water engineer and consultant, the cost was estimated to 11 500 EUR (≈105 000 SEK). Audits were made frequently and the cost was estimated to 1 700 EUR (≈16 000 SEK). The development of HACCP has been regarded as beneficial for the plant (Davidson, et al., 2005).

Melbourne Water (Australia), a bulk supplier that has 3.5 million consumers, developed an HACCP to cover all of their operation. They used an existing staff member and this cost was estimated for 12 months and cost 34 500 EUR (≈320 000 SEK), risk assessment was performed for a cost of 17 200 EUR (≈159 000 SEK) and every three years the risk assessment will be updated for a cost of 5 600 EUR (≈52 000 SEK). There are no additional costs for process monitoring, although auditing costs are estimated to 2 800 EUR (≈26 000 SEK). This has been validated as essential for the safety of the drinking water and has led to several improvements in the drinking water process (Davidson, et al., 2005).

Uganda used consultants from the United Kingdom with a cost of 35 000 EUR (≈323 000 SEK) and local consultant time with a cost of 7 000 EUR (≈65 000 SEK). The total cost of Kampala was 49 000 EUR (≈452 000 SEK) and the risk assessment were made for 11 towns, which gave a total cost of 6 300 EUR (≈58 000 SEK) per town (Davidson, et al., 2005).

*SOPAC Economic assessment of WSP in Niue and Palau*

When SOPAC did the cost-benefit analysis for Niue, the costs were divided into overall costs and government costs. In the Niue project the overall present value of benefit was 863 150 USD (≈7 000 000 SEK) and the overall cost was 714 496 USD (≈5 800 000 SEK), giving a net benefit of 148 654 USD (≈1 200 000 SEK). This gives a ratio of 1,20 USD for every dollar spent. For the government costs the benefits were 600 486 USD (≈4 900 000 SEK) and the costs were 205 849 USD (≈1 700 000 SEK), giving a benefit of 380 960 USD (≈3 100 000 SEK) with a cost-benefit ratio of 2,90 USD for every dollar spent. In the benefits, health improvement is the biggest and the minimizing of the imported water comes second and in third place reduction of leakage. A sensitivity analysis has been made for the different discount rates and it is evident that the return increases the lower the discount rate. For the overall costs with a discount rate of 7 percent the overall return would be 1,50 USD for every dollar spent and for the government the return would be 3,10 USD for every dollar invested. If a discount rate of 3 percent is used the overall return of 1,90 USD and for the government the return rate is calculated to 3,30 USD (Talagi, 2011).

For Palau the cost-benefit analysis showed that the benefit of implementing WSP over 20 years would be 1,34 million USD (≈11 000 000 SEK) and the present costs would be 0,23 million USD (≈2 000 000 SEK), which gives a benefit of 1,11 million USD (≈9 000 000 SEK). For the Palau project the cost-benefit ratio is 5,90 USD for every invested dollar. In the sensitivity analysis it is shown that the return ratio does not vary much with different discount rates. For a discount rate of 7 percent, it gives a return of 6 USD for every dollar spent and for 3 percent discount rate the return would also be 6 USD for every dollar invested (Gerber, 2010).

*Economic estimation in Sweden for costs in case of waterborne diseases*

After the outbreak in Östersund (Sweden) some calculations were done to estimate how much it would cost the society when all the people got sick. The cost that is calculated by Totalförsvarets Forskningsinstitut (FOI) is for an isolated event. Several estimations and assumptions were done: 45% of the population in Östersund got sick, and a sickness period when they can't work was three days, where the production loss was estimated to 2 000 SEK and the cost for medical attention of 7 000 SEK per day. The amount of money people got by having the symptom was 500 SEK. 50 percent of the population that got sick was estimated to have jobs and the other half were estimated to be unemployed, children, students and seniors. The cost for missing work was estimated to 81 million SEK and the cost for health care for 1 percent of the people that got sick was 17 million SEK and finally the cost for feeling bad during the period was 121,5 million SEK. The total cost for the population getting sick was 219,51 million SEK (Lindberg, et al., 2011).

An additional study was made by a consultant company, Tyréns, where two different types of municipalities were used to calculate the cost that waterborne diseases would have on the society. The costs were calculated for two cases, total interruptions in the water supply and contaminated drinking water. The costs were also calculated for a small municipality and a large municipality. In case of interruption in the water supply the cost for the small municipality was 7 million SEK and 80 million SEK for the bigger municipality. In case of contamination in the drinking water, the cost was 37 million SEK (small) and 160 million SEK (large) and in case of sickness and death the cost would increase immensely: for a small municipality the costs would be 136 million SEK and for a bigger municipality the cost would be 415 million SEK (Törneke & Engman, 2009).

## 4.2 Drinking water in Sweden

Swedish legislation and guidelines are presented in this chapter, the regulatory agency are also presented.

### 4.2.1 Water quality regulation agencies

Legislations for drinking water and raw water in Sweden are adopted from the European Union (EU) and are set to maintain a high quality. Rules, guidelines and quality standards are developed by the EU countries in unison and are guidelines for how the European countries should work with water in all aspects from raw water to tap water, how to protect and guide the work in the country but also how countries can work together to maintain a high water quality. The legislations given by the EU are what the countries should achieve, but countries can have higher quality standards in their produced drinking water than those that are set by the EU (Livsmedelsverket, 2015).

Sweden has several regulatory agencies that supervise the municipalities so that the legislation set by the EU is upheld. When it comes to drinking water production the National Food Agency (Livsmedelsverket) is responsible. The regulation agency for raw water is the Swedish Agency for Marine and Water Management (Havs och Vatten myndigheten) and the Geological Survey of Sweden (Sveriges Geologiska Undersökning) (Livsmedelsverket, 2015). Responsible for the distribution network is Livsmedelsverket and the National Board of Housing, Building and Planning (Boverket). Boverket is also responsible for VA-installation.

Although not part of the regulatory agencies, the Swedish Water & Wastewater Association (Svenskt Vatten) is also an important part of the drinking water supply. Svenskt Vatten is an association, made up by the municipalities, in order to "*to assist with technical, economic and administrative issues and to represent the interests of the municipalities in negotiations with authorities and other organisations on regulations, etc.*" (Svenskt Vatten, n.d.(a)). Svenskt

Vatten develops recommendations and guidelines, collects data, and arranges seminars and courses for its members. They also finance applied research in the field of drinking water and wastewater.

### 4.2.2 Drinking water quality regulation agencies

Livsmedelsverket has a central role in the rules and legislation concerning food in Sweden and drinking water is an important part of the food industry and is therefore supervised by Livsmedelsverket (Livsmedelsverket, 2015). Livsmedelsverket is mainly responsible of leading and coordinating the control of drinking water quality in the municipalities in Sweden. They also support the municipalities in their drinking water control.

According to the legislation from Livsmedelsverket, it is the producers and distributors of the drinking water that are responsible for the quality of the water and that it upholds a high drinking water standard that is set in the documents SLVFS 2001:30. The legislation for drinking water production includes requirements within (Livsmedelsverket, 2015):

- Manufacturing and distribution
- Self-monitoring
- Parameters to be studied
- Frequencies of sampling and analysis
- Measures in case of impaired drinking water quality
- Information
- Quality requirements

The legislation for drinking water does not apply for a drinking water plant that supplies less than 50 people or deliver less than 10 $m^3$/day. But if the water is used in the industry it always has to follow the legislation for drinking water.

In Sweden the municipalities have to control that the water quality in the produced drinking water is following the legislation from the Livsmedelsverket. Local surveillance authorities are appointed to handle the external control of the drinking water for the municipality (Miljöförvaltningen, 2013).

### 4.2.3 Source water quality regulation agencies

Havs och Vatten myndigheten is a relatively new national agency (Nylén, 2013), responsible for legislations, guidelines, and give guidance on how the management of lakes and streams in Sweden should be done (Livsmedelsverket, 2015). The government gives the agency goals and budgetary limits, and then the agency works independently, they also have their own priorities that are four focal points outside of the goals set by the government (Nylén, 2013):

- Biodiversity in running water
- Sustainable fishing with focus on landing obligation
- Regulation of fishing in protected areas
- Efforts for a living Baltic Sea

The legislation set by the EU the 23 of October 2000 focuses mainly on how to maintain and manage water resources and water sources in the European countries and is named 2000/60/EG. The directive says that the water as a raw resource has to be protected for the future generations and that eutrophication, acidification, floods and other problems should be contained so that they do not burden the natural chemical processes (Livsmedelsverket, 2015). According to the legislation from the EU the water is given a status that corresponds to different conditions at the present time. The status varies from poor to high water status (Vattenförvaltningen, n.d.).

Sweden is divided into five water authorities: Baltic Bay, Baltic Sea, North Baltic, South Baltic and Skagerakk and Kattegat. The water authorities have to assure that the water legislation from the EU is upheld (Vattenförvaltningen, n.d.).

The water authorities work with the whole drainage area which is the natural boundaries between water systems. The work also creates a need to organize the work with other countries, since the natural water boundaries in some parts of the country overlaps with the neighbouring countries. The goal of the water authority is that all of Sweden´s water should achieve at least the status adequate water by 2015. The water management is carried out in several recurring elements that are carried out in a six-year period (Vattenförvaltningen, n.d.).

### 4.2.4 Distribution network regulation agencies

Boverket handles construction, housing and urban planning in the municipalities. Their main goal is to work as a regulatory agency for the urban areas of the country and they have four main focus areas (Boverket, 2015).

- Developing regulations and guidelines for urban areas in the municipality.
- Responsible for overseeing energy assessments and that the Building Act is followed in the planning stage of a building project.
- Administrate assistance and grants that are issued from the state.
- Investigate and analyse issues that can arise in urban planning and construction.

Concerning drinking water, Boverket is responsible that the planning of the distribution network and the VA- installations follow the legislations and the guidelines given by the state (Boverket, 2015).

### 4.2.5 Further challenges in Swedish drinking water production

Climate change can have a short-term impact on the water supply, rendering the raw water source unusable for a short period of time. It also can have a long-term impact on the raw water source causing high contamination, making the source useless for future drinking water production. According to Svenskt Vatten, the extreme changes in flows caused by climate change will have a great impact on the drinking water production. With high rain quantities and floods the risk of contaminated water running into the catchment area and finally contaminating the raw water source is high. The contamination areas are assessed to be roads, contaminated soil, sewers, pasture and other sources. Therefore microbial and chemical contamination will continue to be a challenge in the future (Svenskt Vatten, 2007).

Livsmedelsverket has conducted during 2012 a study around the microbial challenges in drinking water supply, where 66 drinking water suppliers answered questions. 40 of the 66 suppliers are during 2012 making changes to their drinking water processes due to future microbial hazards in the raw water source. The suppliers consider that there is information and experience lacking in the area of microbial hazards, which can be a problem in the future. New methods and tools are necessary to identify and estimate the microbial risk in the raw water. Good Disinfection Praxis, Microbiological Risk Assessment and HACCP are some of the methods used in some of the plants (Säve-Söderbergh, et al., 2013).

Climate change has a huge impact on the economy. To gradually customize Swedish drinking water processes and distribution to handle increased risks and new conditions during a period 2011-2100, the estimated cost is 5,50 billion SEK for a whole municipality to upgrade and 2 billion SEK for one drinking water plant. Sweden has low costs for drinking water and the cost are estimated to increase if the drinking water system has to be customized for future challenges (Svenskt Vatten, 2007). According to Swedish suppliers a study should be done where costs for different barriers are analysed with the effectiveness, this could be used in the future challenges when different barriers are to be chosen in a drinking water plant (Säve-Söderbergh, et al., 2013).

The distribution network is an essential part in the drinking water supply chain. Even though the water quality leaving the drinking water plant is high, different disruptions in the distribution system can decrease the quality of the drinking water. Heavy rains can cause landslides, which in turn can damage part of the pipe system, and they can also cause flooding where the wastewater blends with the drinking water. Other types of disturbances in the pipe systems are pressure losses due to electrical problems or leakage of the pipe system (Svenskt Vatten, 2007).

### 4.2.6 Guidelines for drinking water in Sweden

Livsmedelsverket is responsible for the Swedish drinking water guidelines and in those the HACCP has been incorporated. It is important that a description of the water plant is accessible and up to date (SLVFS 2001:30, n.d.).

In the Swedish guidelines risk assessment is included as Faroanalys och kritiska styrpunkter, here it is required that the drinking water supplier integrate the risk based approach (SLVFS 2001:30, u.d.):

1. Establish, implement and maintain a permanent procedure or procedures based on HACCP
2. Ensure that any documents describing the procedures developed in accordance with paragraph 1 is always current.
3. Retain all other documentation and all other records for an appropriate time.

The legislation also states that the drinking water process has to have an appropriate amount of security barrier against microbiological contamination. The drinking water distributed cannot contain high levels of chemicals used in the process and a list is given for the levels and chemicals that can be used (SLVFS 2001:30, n.d.).

Drinking water quality is high when the drinking water does not have any microorganisms, parasites or other high chemical levels that can endanger human health. In the legislation there are a list with parameters and what levels they cannot exceed. Quality regulations are for all drinking water leaving the plant, but also for water that comes from tanks and that are used in businesses (SLVFS 2001:30, n.d.).

According to the legislation, drinking water suppliers, companies that produce bottled water and other companies that produce their own drinking water have to draft a programme for regular surveys and extended surveys. In these surveys, the sampling points have to be included and also the frequency of the surveys. All analyses from the surveys have to be analysed in an accredited laboratory (SLVFS 2001:30, n.d.).

If the quality is not met, or if the drinking water for any reason poses a health risk for the population, the suppliers of drinking water must immediately investigate the cause. In the investigation the suppliers must investigate if the decrease in quality will endanger human health. In case of contamination, the surveillance authority must be informed. The supplier has to also notify the consumers if any actions has be taken against contamination in drinking water (SLVFS 2001:30, n.d.).

#### *Advice and guidance from Svenskt Vatten*

The suppliers have a big responsibility since the legislations requires self-monitoring. And according to the reports from Livsmedelsverket there is 1 to 13 cases of contamination with a median of 918 people sick (Svenskt Vatten, n.d.(b)).

Svenskt Vatten has taken the WSP concept and revised and simplified it so that drinking water suppliers have an easier time understanding the different steps and what has to be done to meet the legislation. Svenskt Vatten has some key words that describe the system from source to tap (Svenskt Vatten, n.d.(b)):

- Vattenskyddsområde (Water protection area) – The municipalities of Sweden have to, before 2012, establish a water protection zone according to the legislation Ramdirektiv för vatten.
- Vattenförsörjningsplan (Water supply plan) – Municipalities have to develop a plan for how to uphold a high water quality. In the plan all water resources are identified.
- Råvattenkontroll (raw water control) – Producers of drinking water must know the quality of the raw water source, sampling must be continuous and samples must be taken during extreme weather conditions as well.
- Microbiologiska controller och bariärer (Microbiological controls and barriers) – There should be enough barriers to secure a healthy drinking water. The microbial sampling only samples a small part of the whole water body, which means that they only give an estimation of the quality. To make a risk analysis, some crucial parts of the drinking water system must be known. There are two tools that are effective to evaluate if the process has enough amount of barriers, these are Optimal Disinfection Praxis (ODP) and QMRA.
- Distribution (Distribution) to ensure a good distribution network there has to be frequent control of reservoirs, routines for reservoirs and a hydraulic model. Reservoirs are a last vulnerable part of the drinking water system.

WSPs are viewed as an effective and systematic approach to view the risks in the drinking water system. A complete WSP contains different steps and those are (Svenskt Vatten, n.d.(b)):

- Self-control programs with HACCP
- Water protection areas
- Supply water plan
- Emergency handling plan

Svenskt Vatten has developed a checklist to make it easier for the supplier to implement WSP.

### 4.2.7 Site description of drinking water systems

#### *Gothenburg, Alelyckan & Lackarebäck*

The raw water source for Gothenburg's drinking water is the River Göta älv, which runs from Norway through the east of Sweden. The quality of the raw water in the river is under normal circumstances good, and the oxygen depletion shows that the river has a good quality enhancement for the future. Extensive overflow in the sewage pipes, sewage plants and the drainage of the soil causes the microbiological raw water quality to decrease, which is caused by substantial changes and variations in precipitation. The quality of the raw water source is regularly measured and changes are reported to the Miljöförvaltningen (Kretslopp och Vatten, 2014). In Gothenburg it is Kretslopp och Vatten that manages the drinking water plants and the waste water plants, and have the responsibility for the processes and that the drinking water distributed to the population has a high standard (Göteborg Stad, 2015).

The raw water intake in River Göta älv is situated in Lärjeholmen and from there the raw water is distributed to the two drinking water plants, Alelyckan and Lackarebäck. Raw water is transported to Lackarebäck by raw water tunnels that distribute the water to Delsjöarna and from there the raw water is taken into the drinking water plant to be treated further. The total amount of raw water used for drinking water during 2013 is 63.5 $Mm^3$, during 2013 only 29 abnormalities have been registered. Furthermore the raw water intake has been shut down for 1 857 hours during 76 occasions (Kretslopp och Vatten, 2014).

In Lackarebäck the raw water is first treated with chlorine and limestone, chlorine is used as pre-disinfection and limestone is used to adjust pH and alkalinity of the raw water (Kretslopp och Vatten, 2014). Thereafter the water is treated with aluminium sulphate and is transported to big basins which is the flocculation step. During the flocculation step the particles, organic material and microorganisms accumulate into flocks and sink to the bottom of the basin, where they build a sludge that is later scraped and transported to the waste water plant. To minimise the odour and taste the water runs through 1,5 meters of active carbon. In the last treatment step limestone, sodium hydroxide and carbon (kolsyra) are added to prevent corrosion in the pipes, adjust the water pH and increase the hardness of the outgoing drinking water. Chlorine is also added in this step to prevent bacteria from growing in the distribution network (Mehner, u.d.). Ultra-filters are a new treatment step that is being incorporated into the drinking water process, to increase the capacity of the drinking water plant to remove microorganisms (Kretslopp och Vatten, 2014).

When the drinking water processes are completed the water is transported to the population by 1740 km of water pipes that are connected to households. During peak hours, water from 13 reservoirs are used to compensate for the higher consumption of drinking water. Reservoirs also minimise the risk for the lack of water during power outage. Production of drinking water is lower during the night and therefore the reservoirs are filled (Mehner, n.d.).

### Long-term goals for Kretslopp och Vatten

Kretslopp och Vatten have long-term goals and four main goals that they continually work with to secure the quality of the drinking water for the consumers of Gothenburg. The long-term challenges for the drinking water are waterborne diseases that can be transported with the drinking water, long-lasting quality disturbance in the drinking water process and collapse of the raw water tunnels that lead the raw water to Delsjöarna. Costs for the production of the drinking water is also an important parameter and is dependent of the current system and how it is being administrated, the cost for investments are to be paid during a minimum of 50 years and have to secure a drinking water process that will deliver safe drinking water with a high quality. The four goals are (Kretslopp och Vatten, n.d.):

- Healthy water
- Good water
- Safe distribution
- Long-term sustainability

Safe water is the most important of the goals, since the population's health is directly affected by the quality of the drinking water. In Sweden an infection with more than 10 000 consumers in unacceptable, the quantification has been made by the Environmental Protection Agency (EPA) in the United States. According to the Swedish legislation an E. coli level of 10/100 ml is an evident indication of contamination and a third barrier is needed in the process. For the raw water source, old requirements are used and state that an E. coli level of 50/100 ml over 5 percent of the time is unacceptable and in occurrence the raw water can't be used for production of drinking water (Kretslopp och Vatten, n.d.).

Smell and odour are the parameters that are taken into consideration when the goal good water is to be fulfilled. Consumer complaints are constantly and systematically registered and compared with the areas in Gothenburg, and if an area has several complaints the state of the distribution network is assessed (Kretslopp och Vatten, n.d.).

To have an interruption in the delivery of drinking water to the population is acceptable, but not when the time exceeds four hours. The consumers find interruption that are long lasting and that affects a larger percentage of the population as serious, and the capacity and ability of the drinking water plant is questioned. Therefore safe distribution of the drinking water is of the outmost importance, especially the distribution to hospitals and other public services (Kretslopp och Vatten, n.d.).

Sustainability is also an important goal for Kretslopp och Vatten. Therefore the costs are an economic and social factor and all consumers have to be able to pay for the drinking water costs. Chlorine is highly used in the drinking water process, nevertheless the rest-product is not good for the environment and has to be minimised. Leakage in the distribution network costs 0,80 SEK/$m^3$ and is a small cost, nonetheless they have to be repaired so that polluted ground water doesn't mix with the treated drinking water (Kretslopp och Vatten, n.d.).

### *Alingsås, Färgen*

The municipality of Alingsås has one surface water treatment plant – Hjälmared – and four minor groundwater plants – Sollebrunn, Magra, Gräfsnäs and Ödenäs (ABVA, 2009). The major raw water source for the municipality of Alingsås is the Lake Lilla Färgen (Göteborgsregionen, 2013), from which 93% of the water produced for the municipality is taken from. The raw water intake is located in the northern part of the lake and from there it is fed, through a raw water line, to a pumping station (Sweco, 2015). Afterwards, it is pumped to the water treatment plant in Hjälmared.

The water is treated by adding sodium bicarbonate when it enters the plant and, subsequently, aluminium sulphate during the flocculation and precipitation step. It is then filtered using rapid sand filters. The water's pH is increased with a combination of sodium bicarbonate and carbon dioxide. Finally, the disinfection process is performed with sodium hypochlorite and UV-light. The treated water is then distributed to the consumer through 230 km of pipes (ABVA, 2009). Approximately 2.8 $Mm^3$ of drinking water per year is produced for 29 100 consumers.

The plant currently produces an average of 7 071 $m^3$ per day, although it has a maximum capacity of 12 000 $m^3$ per day. In the event that Lake Lilla Färgen cannot be used as a source, the municipality can withdraw water from the Lake Ömmern. However, it is only allowed to withdraw a maximum of 60 480 $m^3$ per year.

### *Östersund, Minnesgärdet*

For the municipality of Östersund the raw water source is Storsjön, which is the fifth biggest lake in Sweden. Storsjön is also a part of Indalsälvens catchment area. The raw water in the lake is clear, rich in oxygen and is low on nutrient concentration. With the future climate changes the quality of the raw water is expected to change as well. With increase in precipitation the microbial growth is expected to increase in the lake, thereby decreasing the water quality. The raw water intake is situated only a couple of hundred meters from the shore. Thereafter the raw water is transported to Östersund's biggest drinking water plant, Minnesgärdet, that supplies to 50 000 people which correspond to 95 percent of the population of Östersund (Klimatanpassninsportalen, 2014).

At the moment Östersund does not have a secondary raw water source, which in case of a devastating accident to the existing raw water source would render 95 percent of the population without any drinking water. Östersund has six drinking water facilities and four of them use groundwater as their raw water source and the other two use surface water, but the groundwater facilities cannot by themselves supply Östersund, therefore actions are being taken to secure the drinking water quantity in Minnesgärdet (Klimatanpassninsportalen, 2014).

Minnesgärdet has three barriers and all of them are to inactivate the microbes, but no barrier is installed that aims to separate the microbes from the drinking water. Ozone is the first barrier in the facility and the water is treated with Ozone ($O_3$), the particles in the water flocculates and are easily separated, this step improves odour and taste. UV-light is the second step in the drinking water facility and aims to inactivate or kill the microorganisms in the water with the energy. The third step is chlorination and aims to kill the last of the microorganisms in the outgoing drinking water. The facility has the capacity to produce a higher quantity of drinking water (up to 60 000 $m^3$), today the facility produces 17 000 - 18 000 $m^3$ of drinking water, therefore the capacity of the plant is not an issue for the near future (Östersunds Kommun, 2013).

Östersund had an outbreak of cryptosporidium in 2010 where 45 percent of the population, which corresponds to 27 000 people, were infected with a pathogen that is transported through drinking water. After the cryptosporidium outbreak in 2010 several extensive studies have been made to secure the drinking water quality of Östersund. Membrane filters have been tested in the drinking water facility of Minnesgärdet and in 2015 it will be decided which one is installed (Klimatanpassninsportalen, 2014). There are also several changes that have to be made on the other facilities as well. The municipality of Östersund aims to establish a water protective zone around the raw water source, since the biggest threats are perceived to be microbial contamination and chemical contamination originated from cars, trains and industries in the area. They also aim to analyse the drinking water quality and establish a proper plan to supervise the quality of the raw water source (Östersunds Kommun, 2013).

The drinking water is distributed to the population by 430 km of distribution pipes. The age of the distribution network varies through the system and the oldest pipes are around 100 years old. Old pipes need to be exchanged for newer pipes, and some new pipes also need to be exchanged to prevent infiltration from the ground water into the distribution network (Östersunds Kommun, 2013).

#### Long term goals for the drinking water

Östersund long term goals for the drinking water of the municipality are listed below. The contamination of cryptosporidium during 2010/2011 has led to a greater insight in how to prevent future contamination and what measures have to be taken to secure the drinking water quality.

- Clean water - the water has to have a high quality and be cleans so it can be used for drinking water, as part of different processes in industries and for recreational activities.
- Healthy water – drinking water in the tap has to be fresh and healthy.
- Good water – the population choses water from the tap as their main drinking water.

The municipality of Östersund has also selected more specific changes to the drinking water supply chain, they want to constantly estimate the status of the water plant with the method Good Disinfection Praxis (GDP). Possibilities to build an additional drinking water plant that can deliver water to the municipality in case of an accident in Minnesgärdet is being reviewed in the municipality (Östersunds Kommun, 2013).

## 4.3 Drinking water in Latvia

Latvia currently possesses enough water resources to satisfy the total domestic, industrial and agricultural demand. Available groundwater resources are approximately 1.4 $Mm^3$ per day, which is four times higher than the groundwater output (Feldmane, 2010). Moreover, the current trend in Latvia for drinking water use is that consumption is decreasing. From 1991 to 2000, consumption plummeted from 200 $Mm^3$ per year to 80 $Mm^3$ per year. A three-fold decrease in industrial and agricultural consumption was also experienced in the same time frame. The losses in the distribution network are high, exceeding 30 $Mm^3$ per year.

Legislation for drinking water and raw water in Latvia has been adopted from the European Union. The main regulatory agency responsible for surveillance and control of the drinking water is the Health Inspectorate of Latvia, a subordinate institution of the Ministry of Health. Local municipalities have the primary responsibility for their drinking water and raw water sources. More on the guidelines governing drinking water in Latvia is discussed in the following section.

### 4.3.1 Guidelines for drinking water in Latvia

The main document detailing the requirements for drinking water quality in Latvia is the Regulations of the Cabinet of Ministers No. 235, approved in 2003. These requirements were created to comply with the Council Directive 98/83/EC on the quality of water intended for human consumption. A special normative can be assigned for selected parameters that are naturally elevated in the groundwater. This provides the possibility to specifically monitor and implement measures to solve these issues. The special normative covers iron, sulphates, ammonium, chlorides and manganese. Currently, 535 drinking water systems out of 1528 have been assigned a special normative, usually for high iron content (Feldmane, 2010).

The Regulations of the Cabinet of Ministers No. 736 states that a special permit is required if water abstraction exceeds 10 $m^3$/day or the system serves more than 50 persons. In order to apply for a permit, a series of documents with technical information on the water network and the wells must be provided. The location of a well that is intended for drinking water must be agreed with the Inspectorate of Health and includes an evaluation of possible contaminants present at the site, which must be eliminated as part of the process. The process to create water protection areas for both groundwater and surface water sources is found in the Regulations of the Cabinet of Ministers No. 43 from 2004.

The national regulations also require washing, cleaning and disinfection of water pipes before starting operations or after repair works have been carried out in the system. Prophylactic disinfection is encouraged to be performed yearly (even two times a year) to improve the microbial quality of the drinking water (Feldmane, 2010).

### 4.3.2 Site description of drinking water system Riga, Daugava

The Daugava is the most important river in Latvia, as it is used as for energy production and raw water source (Halla, u.d.). The quality of the river has been heavily impacted by anthropogenic sources and usually contains high concentrations of organic matter (Juhna & Klavins, 2001). However, due to reduced industrial activity and use of fertilizers, the environmental pressure exerted over the Daugava is decreasing.

The Daugava water treatment plant in Riga is the only plant that uses surface water as a source; all other suppliers use groundwater or artificial recharge. Water is pumped from the Riga Hydropower Station to the plant via two pipelines, which are 14 km long and 1 200 mm in diameter (Halla, u.d.). The treatment process consists of (Brombal, et al., 2009):

Pre-ozonation > Coagulation (aluminium sulphate) > Flocculation and sedimentation > Rapid sand filtration > Second ozonation > Biofiltration > Chlorination

The treated water is then distributed to the city through 1 300 km of pipes. The plant purifies more than 100 000 $m^3$ per day (Juhna & Klavins, 2001), serving 40-50 percent of the demand from Riga.

# 5. Results

In this chapter, result for the literature studies will be presented in a table to illustrate the countries that have WSP. Interviews with Swedish authorities and suppliers, and the Latvian Water and Waste Water Works Association will be described and presented as well. Finally, the levels of WSP implementation in the Swedish drinking water plants are presented in a table.

## 5.1 Summary of WSP Implementation in the World

A complete list of the countries with well-documented cases of WSP being implemented in any of their water supply is presented in the following table. The countries in bold are the ones that could be determined to require WSP from a regulatory level.

*Table 5 - List of countries with WSP. Countries in bold are the ones that have WSP implementation as a legal requirement.*

| Region | Countries |
|---|---|
| Africa | Ghana, Kenya, Morocco, **South Africa**, **Uganda** |
| Americas | Argentina, **Bolivia***, Brazil, **Canada**, Colombia, Ecuador, El Salvador, Guyana, Honduras, Jamaica, Peru |
| Asia & Oceania | **Australia**, **Bangladesh**, Bhutan, China, India, Indonesia, Japan, **Republic of Korea**, Lao PDR, Malaysia, Mongolia, **Nepal**, **New Zealand**, **The Philippines**, Singapore, Thailand, Vietnam |
| Europe | Austria, **Belgium**, France, Germany, **Hungary**, **Iceland**, Ireland, Lithuania, **The Netherlands**, Portugal, Spain, **Switzerland**, **United Kingdom** |

*Requirement is only for urban water systems

## 5.2 Interview Authorities Sweden

There are two levels of audit and surveillance of drinking water in Sweden: central and local. Livsmedelsverket is Sweden's central authority and therefore has the responsibility to coordinate and control the guidelines and legislation for surveillance of drinking water for all the drinking water suppliers in the country. Torbjörn Lindberg works at Livsmedelsverket and states:

> "Livsmedelsverket is the central authority of drinking water, and are responsible for legislation from the water works to almost the tap … Should lead and coordinate the official control and official surveillance of drinking water…"

In a local level it is Miljöförvaltningen in Gothenburg and Miljöskyddskontoret in Alingsås that uphold, control and monitor that the legislation is followed in different ways. The quality of drinking water is an important part of their work, which is stated by Alingsås Miljöskyddskontoret:

> "The role is to control that the water that goes out to the consumers is safe and that the suppliers follow the legislation set by Livsmedelsverket. This is done by checking the test protocols..."

Though it is important to remember that the WSPs or risk assessment are not done by the municipalities, their role is to control that there is a risk assessment done by the supplier, but the main responsibility for the risk assessment lies on the drinking water supplier. Miljöförvaltningen in Gothenburg says:

> "They [Miljöförvaltningen] do not make the WSP, but control that they [WSP] are done and that they are functional. They [Miljöförvaltningen] assess them [WSPs] in the control, [there are] no guidelines on how to assess that the legislation is followed [by the supplier]."

When a drinking water supplier is going to start operating the drinking water plants, first they have to submit a document called "Provtagningsprogram" (Sampling Program), where the frequency of all the tests and process parameters are stated. An approval from Miljöförvaltningen and Miljöskyddskontoret is necessary and Alingsås explains:

> "When starting the operation, a drinking water plant has to submit a Provtagningsprogram, here all the tests and frequency are listed and Miljöskyddskontoret has to control and approve the plan. Changes can be made in the test plan if the supplier or Miljöskyddskontoret finds it necessary due to changes in the [drinking water supply] system or other changes…"

The controls from the municipality depends on the size and the capacity of the municipality. In Alingsås there are 4 people working in the agency and that implies that there might be a lack of resources to take samples to assure the drinking water quality, although this does not mean that the result from the self-assessment in the drinking water plant are not checked by the municipality. If irregularities are found in the supervision of the process monitoring results, contact is established and further discussions are made to ensure that the potential problem is remediated.

When Alingsås supervises and visits the plan, it is mainly the practical aspect of the plant and sanitary aspects that are revised. Reports with the results are written and if there are any potential problems that need to be remediated, a deadline is set up for the changes that have to be made by the drinking water suppliers. Alingsås Miljöskyddskontoret do not take their own samples of the drinking water to assure that the momentary water quality is upheld. Alingsås Miljöskyddskontoret explains what they do in the interview:

> "During controls in the drinking water plant the practical aspect are examined so that they follow the legislation, the alarms are checked and routines are reviewed. When the controls are done, reports are written with conclusions and observations.
>
> Results from the [water sampling] test made in the water plant are sent directly to Miljöskyddskontoret and there the result are reviewed and if a results deviates [from the Sampling Program], contact is established with the water plant to follow up the results."

Gothenburg municipality has a more extensive monitoring frequency for the drinking water suppliers compared to Alingsås. The frequency of the visits to the drinking water plants varies; normally Miljöförvaltningen visit the plant between 8-10 times in a year and if it is necessary, or indications of a decrease in water quality are documented, the frequency can increase. Kretslopp och Vatten delivers documentation for the operation in the drinking water distribution system and the drinking water plant, so that Miljöförvaltningen can assess their normal operation and changes in the water quality.

When visits to the plans are made different parts of the systems are monitored and assessed and Miljöskyddskontoret in Gothenburg does take samples of drinking water to ensure that the quality is high. The methodology used to do the assessment varies and there are no routines established on how to carry out the assessment of the drinking water plant and the distribution system. It all depends on the capacity and creativity of the officer that assesses the system, as Daniel Eek explains in the interview:

> "Control every part of the [drinking water supply] system, … use some checkpoints to verify if the system is functional, and the control points depend on what is being assessed in that visit. The [water] sample taken in the controls are only a peephole in the reality and assess if the system works right now, in the moment. If the system is functional when [water quality] test are made then it will be functional even when Miljöförvaltningen is not there. How to control if the system is good is very hard, since you get a momentary glance of it…

> …The methodology in which the [drinking water supply] system is being assessed depends on the officer's creativity. When they are checking the system they have to find a way that gives them the truth about the system. It is up to every officer how the control is done, nothing is fixed, and good ideas can be implemented into the checking, [officers] have to dig as far as they can."

### View of risk assessment

The general opinion about implementing risk assessments in the drinking water plants is positive. Livsmedelsverket has introduced risk assessment requirements into the regulations by using a method called HACCP. HACCP is a requirement of the legislation and all drinking water suppliers should have or started implementing this method. When comparing HACCP with the WSP approach they are very similar and the only part that the Swedish legislation does not handle are the raw water quality parameters. The companies that have adapted to the legislation has almost implemented the whole WSP approach. Drinking water suppliers can also use the general hygienic requirements and according to the Livsmedelsverket this should be enough to have a safe drinking water. Torbjörn Lindberg explains in the interview:

> "…If the WSP is compared with HACCP they are similar, but mainly the same. You can say that Sweden has already implemented WSP or big part of the WSP [framework]…
>
> HACCP is mandatory and all drinking water suppliers have to have it. There are two tracks to produce safe drinking water and one is HACCP and the other one is to use the general hygienic requirements and this is enough to produce safe drinking water. There is a certain flexibility on how far you have to go in the hazard principle work. In paragraph 2 A and B [in Swedish legislation SLVFS 2001:30] the basic requirements are given to produce safe drinking water… "

The municipalities also find the risk assessment approach to be a good approach because it implies that the vulnerabilities in the drinking water and distribution system can be found easier and can function as motivation for smaller municipalities to invest in solutions that will ensure a high drinking water quality. In smaller municipalities investments in the drinking water system can be hard to motivate since Sweden has a good quality of raw water and in many cases municipalities do not find it necessary to make changes to a system that has worked well for a long time.

The bigger drinking water supplies have, according to Torbjörn Lindberg, more resources, capacity and knowledge to comply more easily with the drinking water legislation and adapt more effectively to changes in the legislations.

The general opinion for the smaller municipalities are that the implementation of a risk-based approach and WSP is expensive and will require much work, which not all the smaller municipalities are not able to provide. In many cases, smaller municipalities and smaller companies that provide their own drinking water do not have the knowledge to implement and establish a risk assessment, therefore a consultant company has to be employed and this costs money. Alingsås Miljöskyddskontoret says:

> "In the municipality, Good Disinfection Praxis is used and a lot of work is being done with WSP at the moment, maybe not [as] structured and systematic as the WHO guidelines.
>
> In [a] small municipality it is important to make risk analysis so that an investment can be made in drinking water quality.
>
> An opinion is that WSP is very important, since there can always be threats to the drinking water and its quality. In Sweden we are very spoiled with the availability and quality of the water. Although implementation of WSPs are important, they are costly to make and time consuming."

The extent of risk assessment implementation in Sweden, according to Torbjörn Lindberg in Livsmedelsverket, is that the risk assessment based approach is rather new in Sweden. The risk-based approach was introduced in 2012, which is rather early to see results now in 2015, since results in water projects are often seen after a period of 10-15 years. The Swedish drinking water companies are far from done, although it is expected that most of the companies owned by the municipalities have started with their work.

In Europe the level of implementation of risk-based approach varies, in the western part of Europe countries have worked much longer with the risk-based approach and some countries, like the United Kingdom, have even used WSP as their model for risk assessment. An important fact is that all countries that are implementing the Water Directives from the European Union are starting a national water department that handles and regulate the drinking water, whilst three countries in Europe use the food legislation as a central regulatory agency. The newer countries that are members of the European Union have probably not started their work with the water directives, as Torbjörn Lindberg says:

> "Most of the larger and western part of Europe are working with the water regulations set by the European Union, the newer members in the east have not yet adapted to the European Union legislations, they will probably wait until the new regulations with risk assessment approach integrated are released and this will take at least five years. Sweden was very late 2012, England had it in 2005 and use more of the risk-based approach than Sweden. Norway also use the food legislation as a regulator. Only three countries that use the food legislation as a regulation for drinking water are Sweden, Norway and Austria. "

### Education in the regulatory agencies

Education is important to understand and implement a risk-based approach to the drinking water production. Different levels and education backgrounds are needed when working with the regulatory agencies. Livsmedelsverket provides education in two different ways to the drinking water suppliers, mainly by providing guides to facilitate the understanding of the legislations. Suppliers and agencies can always turn to the food agency to gain information, if technical information is needed the suppliers can turn to Svenskt Vatten that provide more technical help. Torbjörn Lindberg explains about how they provide education in the interview:

> "Two kind of supports are provided to the drinking water suppliers, guidance documents are provided and is information on how to understand the regulations. The second support is individual support, suppliers are always welcome to contact Livsmedelsverket if there are any questions. Collaborations are made with Svenskt Vatten where they put together information for the suppliers, and have more or less a regular dialogue with Svenskt Vatten. Always inform to the suppliers to use the information from Svenskt Vatten since they are the technical experts and complement Livsmedelsverket. "

In the local regulatory agencies the education can vary, larger municipalities has staff that have education in different areas. Smaller municipalities do not always have the capacity to employ people with drinking water as a basis in education. One common ground is that all officers are educated in food supply science and it is required of all agency workers to participate in a two week education provided by Svenskt Vatten. Daniel Eek says in the interview:

> "The officers are educated in food supply science, and have some knowledge of the drinking water operations."

The municipality agencies are also responsible for their own education and to uphold a high standards of education within the department. Miljöskyddskontoret is always finding ways to participate in different courses that can increase knowledge of drinking water and other areas. Miljöskyddskontoret also organise their own courses and information evenings where important people in the business are invited to participate. Jennie Eriksson from Miljöskyddskontoret in Alingsås says:

> "Employees in Miljöskyddskontoret in Alingsås have different backgrounds as inspectors, since water is not their only concern. The staff has been to courses that Livsmedelsverket arranges, and they have organised their own courses where important people in the business has been invited."

There are also meetings two times a year where regulatory agencies have the chance to meet and exchange experiences with each other. Problems for the future are discussed and solutions in different problematic areas that other agencies have used, can be beneficial and good knowledge if the municipality encounters similar problems.

## 5.3 Interview Water Suppliers Sweden

All of the interviewed suppliers performed some kind of risk assessment in the different components of their system: source water, treatment plant and distribution. The most common type of analysis was a qualitative assessment of the risks, which involved identifying potential hazards and consequences, and determining which risks were acceptable and which had to be handled. Gothenburg also had a specific assessment done as part of a case study (see Lindhe et al. (2008) for more information), where a probabilistic fault tree was used to analyse their system from source to tap. Additionally, Thorwaldsdotter (2006) tested QMRA as a complement to HACCP in the Gothenburg plant.

All the suppliers used HACCP to assess the risks at the treatment plant and agreed that it was important to conduct this type of analysis. For example, Alingsås stated:

> "…this [HACCP] method has been used two times and was last updated in 2013; it is an easy method that is done by the DRIFT workers in the [water treatment] plant. The HACCP is a good method where the risks in the plant are easily evaluated and can be remediated almost at once."

For their source water, the three interviewed suppliers had water protection areas. In Alingsås, the water protection area for Färgen Lake and potential risks in the source water was reassessed this year. Östersund is currently working in updating their water protection areas as well. Gothenburg has up-to-date protection areas around their main sources (River Göta älv and Delsjö Lakes) and emergency sources.

Monitoring programs are similar between the different systems, since they follow the national guidelines. The three of them use a combination of online systems and laboratory testing to verify the quality of the drinking water. Parameters like pH, turbidity and chlorine are monitored online in all of the treatment plants. The plants with UV-disinfection also monitor that this system is functioning correctly. Additional sampling occurs in the source water and distribution system. In Gothenburg's case, they also have online monitoring along the River Göta älv. Gothenburg's goal with their monitoring program was described in the interview as:

> “The [process] parameters are monitored frequently with online instruments that measure all the essential parameters for the [water treatment] plant to function properly. Every three days more [water] samples are taken than the ones regularly monitored to analyse. One of Gothenburg’s goals is that all test results have to be below the national guidelines. None of the samples taken of the drinking water should be classified as unsuitable (otjänligt), and 99,9 percent of the samples should be suitable (tjänligt) with no observations (anmärkning). A parameter that Gothenburg still control is the raw water quality, since it is essential for the drinking water processes in the plant.”

Raw water quality emerged in all the interviews conducted. The following phrase summarizes the main idea being expressed by the interviewees:

> “Raw water quality limits for the raw water source should be established… ”

The outdated Livsmedelsverket requirements for source water quality are still used in Gothenburg and Östersund. There was consensus among the interviewees about the importance of having a guide for raw water quality. However, they also indicated that it would be beneficial if an updated version was made available for the suppliers.

All the interviewed suppliers have done similar work to create different plans to manage the system and to have procedures on how to handle different issues. Drift routines are in place in the drinking water plant for normal operation in all locations. Gothenburg has a “Verksamhetshandboken”, or Operations Manual, which encompasses all the routines and maintenance for their water treatment plant during normal operation and during malfunctioning. A contingency plan, called “Beredskapsplan”, has been developed to manage serious problems in the water treatment plant (e.g., criteria to shutting down the plant) by Gothenburg and Östersund. Alingsås is working with the municipality to come up with its own plan.

Crisis management plans are currently in development in Alingsås and Östersund. These plans are being done in collaboration with the municipality. While the procedure for how to deal with an e.g. outbreak has not been clearly defined, a chain of contact has been established for both cities.

“Vattenförsörjningsplan”, or water supply plans, are an important document with the goal of ensuring the long-term availability of water resources for drinking water supply. Alingsås and Gothenburg have the same plan, since they belong to the Greater Gothenburg region. It was first drafted in 2003 and the latest review was done in 2014. Östersund’s plans are currently being developed by the municipality. Östersund itself has completed water supply plans for their small plants and are now working with the larger plant’s (Minnesgärdet) plan.

Concerning education, staff is required to take Svenskt Vatten courses relevant to drinking water. However, the educational profile of the staff is mostly selected during the recruitment phase. Gothenburg also has internal education to increase the knowledge and competence of their staff, in addition to the Svenskt Vatten courses. It is worth noting that none of the interviewed suppliers had any internal education or courses related to WSP.

The use of risk assessments to identify current risks and future risks has helped shape the decisions for improvements in each of the water supply systems. For example, Gothenburg presented during the interview:

> “There are several major risks that have been identified in the drinking water supply system. The first one is the capacity of the water treatment plants. If one of the drinking water plants would have problems and would have to shut down, then other water plant would not be able to supply the rest of the population. Therefore an increase in capacity of both drinking water plants are planned and underway.

> The second risk are microbiological hazards; therefore UV-light has been installed in Alelyckan but are going to be exchanged for ultrafiltration within the next 10-15 years and ultrafiltration are being installed in Lackarebäck to prevent contamination in the drinking water.
>
> A third identified risk are the raw water tunnels that lead the raw water from Lärjeholmen to Delsjöarna, if the tunnels would collapse there would be no secondary source to Alelyckan and the amount of raw water in Delsjöarna that can be used for drinking water production would be limited, therefore an increase in production capacity would be a solution."

Östersund has no issues with capacity, but microbial hazards are present at their intake. As explained by the interviewee:

> "The water level at Storsjön varies during the year, but the raw water intake is at an appropriate depth. Microbial quality is also varying, occasionally being problematic on the surface of the lake. Microbial quality at the intake is sometimes affected. For this reason, improvements [membrane filtration] are being tested at the [water treatment] plant."

Both Gothenburg and Östersund have chosen membrane filtration as an acceptable solution for their microbial hazard. Alingsås has few risks in their water source, but they have identified a road that has vehicles with dangerous goods transiting as a major one. For this reason, a secondary source has been selected as an appropriate measure.

Climate change is a major risk for the future for all the suppliers. Östersund says:

> "Climate change will likely affect us eventually. At the moment there have not been much consequences, but there might be in the future. That's why the [membrane] filtration system should be installed as soon as possible. To be ahead of the problems that may arise."

Alingsås has also given some thought to possible consequences of climate change:

> "Future challenges for Färgen water plant can be climate change that increases the humic substances in the raw water. The plant has no active carbon filters to give the water a better taste, and if the quality of the raw water decreases, investments might have to be directed towards carbon filters."

## 5.4 Effects of Outbreak

One event associated with the drinking water supply that was also addressed during the interviews was the waterborne cryptosporidiosis outbreak in Östersund in 2010. During the interview, Östersund recognized:

> "Because of the recent outbreak, water quality is a more relevant issue in the eyes of the public. It has made authorities more aware of the need to protect their water source and the importance of implementing measures to this effect."

The outbreak case in Östersund was also brought up by the rest of the interviewees. They referred to the event as "eye opener" and a "wake-up call" to increase the awareness of the risks in their system. Gothenburg said during their interview that one important reason for the installation of the ultrafiltration system was to have a barrier against parasites.

During the interview with Torbjörn Lindberg, a study of the consequences and costs of the Östersund outbreak ordered by Livsmedelsverket was discussed (see Lindberg et al., 2011). In the report, it was determined that Östersund had no microbiological barrier against cryptosporidium. Concerning the effects in the water supply system, Östersund responded:

> "As for the water supplier, it is hard to say the effect it has had since they are trying to continuously improve all parts of the water system. One measure that was taken during the outbreak was the installation of UV-disinfection.

> Turbidity has a two-flag alarm system, which was installed after the outbreak. There was only one flag before."

In Livsmedelsverket's report, it was recognized that the short time that it took for Östersund to install the UV-disinfection limited the effects of the outbreak.

## 5.5 Interview Latvian Water and Waste Water Works Association

Drinking water companies are owned by the municipality, and are regulated by the water legislation in Latvia. The Ministry of Health is the organization that has the central role of enforcing and adapting the legislation set by the European Union. All municipalities have a local monitoring agency. The Ministry of Health are trying to adapt the risk assessment approach and WSP into the legislation. The drinking water suppliers also have to pay a tax to the central authorities. Baiba Gulbe, who is the head of the LWWWWA, says in the interview:

> "Water companies are owned by the municipalities, and only one company in Latvia is a private company…. We have governmental level, Ministry of Health, in charge of implementing the Drinking Water Directive. This organization makes legislation about drinking water safety and quality."

All drinking water companies in Latvia have to apply for a licence before the drinking water plant is allowed to start operations. When the license is issued it implies that the water legislations have to be upheld and followed by the drinking water suppliers. The license is issued once, and has to be renewed if changes are to be made in the drinking water process or if there are changes in the legislations that make it necessary to make larger changes in the processes. From the interview with Baiba Gulbe, she states:

> "All water companies have a license. That means they have to follow certain rules on how to operate, and what to do with the water resources. They also have to pay a water resource tax. Water suppliers are only required to renew their certification if there are any amendments in the regulations or changes."

At the same time that the license is issued a document called monitoring program has to be issued (similar to the document called "Provtagningsprogram" issued in Sweden). Here all the monitoring point and sampling points are given together with the frequency, the process monitoring is included and microbial tests are also included. This plan has to be approved by the local monitoring agency before the plan can operate. Baiba Gulbe tells in the interview:

> "Every water company makes their monitoring program every year. Reservoirs, some places chosen in water mains, water in wells, points before treatment and after treatment are monitored. In Latvia, it is called a measurement plan. The plan includes quality checks on what you need to measure, how often, and suggested activities if there are some problems. Parameters are chosen based on the regulations."

The amount of drinking water needed in society has decreased. During the last 15 years the drinking water consumption has decreased from 180 to 65 litres per person a day. The decrease of the drinking water consumption has several reasons: one of them is the increase of water prices (during the Soviet regime, drinking water was virtually free) and the other reason is the reconstructions in the distribution network, which decreases the leaks in the distribution network. Due to the decrease of the amount of water in the distribution network, all of the pipes are today oversized and are dimensioned for a higher capacity. This causes a decreased flow and velocity in the pipes leading to problems in the network. Baiba Gulbe says:

> "Usage of water decreased dramatically. For example, in the 2000s, [it was] 180 litres per day and now it is 65 litres per day. Due to increase in water prices and reconstruction of the system [reduction of leaks]…. Water companies need to follow firefighting rules, which increases the diameter [of the pipes]. Velocity in the mains is low. That is why water companies do some flushing, annual flushing."

### Overview of Daugava drinking water plant

The drinking water plant in Daugava is the only plant that uses surface water as raw water source. All the other plants that used surface water as a raw water source have been shut down since the consumption of drinking water has decreased. The rest of the plants take their water from groundwater.

In the Daugava plant the process monitoring parameters are taken from the legislations and an online monitoring system is used, where parameters like turbidity and pH are monitored continuously. The parameters that show if there is a microbial contamination are also monitored every day, together with other parameters that the process monitoring does not monitor. Baiba tells in the interview:

> "Some are monitored online [e.g., pH, turbidity] but daily check for parameters that are not online. They use the laboratory inside the Daugava plant to perform the testing. They check the pipe system maybe once a week or once a month."

There are differences between the different drinking water plants, although the smaller plants use groundwater as a raw water source they should have a process monitoring and many of them do not have it at all. In many cases the smaller plants do not have the education, experience and competence to operate a drinking water plant properly. From the interview with Baiba Gulbe:

> "In smaller plants, online monitoring is not advisable because they [operators] do not have the experience or competence. They usually hire a laboratory to do their testing. They also do not have such a staff to do the monitoring, some even have just one person to check both water and wastewater treatment plants."

### Risk Assessment situation in Riga and in Daugava drinking water plant

Talis Juhna, a professor from RTU, states that the initiative to work with WSPs and risk-based assessments comes from the universities and central ministries but that it is not actively introduced by the water suppliers:

> "In terms of water safety planning there have been some initiatives from the ministry level and academic institution to initiate the WSP process. Though it has not been actively introduced and there is reluctance due to two major factors."

The major factor that contributes to the reluctance shown by the drinking water suppliers is that the risks in groundwater are low and therefore the drinking water quality is relatively high. The flooding problem in Latvia is low, therefore the risk of microbial contamination in the distribution network is also low. The risks that are found in the quality of the groundwater is that the metal levels are rather high according to the guidelines. Financing is also an issue. The cost to implement WSPs is rather unknown, which generates averseness amongst the suppliers. HACCP has been introduced in the food industry and has been beneficial. Talis Juhna believes that the reluctance to implement HACCP or WSPs in the drinking water area is due to lack of information and education.

To reinforce the importance of WSPs and their implementation, Talis Juhna gave these interesting examples on the use and efficiency of WSPs:

> “An example is, if a contamination is introduced in the middle of the [water supply] system, the probability of finding the source of contamination with sampling is less than 5%; therefore it will not be possible to detect the source of the contamination due to the fact that no risk assessment has been done. And if the risks can be identified, it is more probable that the contamination source is found. When risks are not known, the investments are spent in the wrong area [of the water supply system]. When risks are defined [i.e., properly identified], investments [to improve the drinking water system] can be [justified].
>
> Quantity is also a risk, since the city has an aging system and replacements are on-going all the time. There are high leakage rates in the distribution system and the risk in the distribution is intrusion into the drinking water pipes. This can be a major risk if flooding would occur. The decrease of water consumption also affects the distribution network, since there is less water going into the system the flow in the system is not what it should be. ”

In the Daugava drinking water treatment plant there are no risk assessments made for the processes of the plant. A general risk assessment has been made for the whole municipality, where some risks in the drinking water distribution system and raw water source have been assessed. Water suppliers in Latvia have made some minor risk assessments, where they assess small problems that they encounter. Another way to share experience with other municipalities have been done, but not periodically. Kamila Gruskevica tells in the interview:

> “We had project that included dissemination, where we invited all the people from the water companies and we had a discussion of the risks and what can we do about them. The workshop was a one-time event, but Baiba usually goes to conferences where experience can be shared.”

Baiba Gulbe added:

> “[Water] Companies have studies of specific cases of risks, for example, of flooding. They have investment projects to change the location of the water fields, due to the high risk of flooding.”

### Education

Education in the risk-based assessment area is not extensive in the drinking water industry of Latvia. The impression given is that the university is more interested in the method, but the suppliers are not interested in adapting their systems to WSPs or any other risk-based assessment tool.

The larger drinking water suppliers hire employees with different backgrounds and below Baiba Gulbe gives an example on this. The operators of the drinking water plants receive training in operating a drinking water plant, but no education is given concerning risk assessment, such as courses related to WSP, as stated in the interview:

> “If you work in the lab, you need to go through courses related to microbiology and about [water] sampling standards. [Water treatment plant] Operators are selected based on recruitment. We have staff training, where they go and learn from the operation of other [water treatment] plants. No education related to WSP is currently given.”

In smaller drinking water treatment plants there is no possibility for training or education when it concerns the risk-based approach, in some plants there is one person monitoring both the drinking water plant and the wastewater plant. This implies that there are no resources to spend on further education or implementing WSPs.

## 5.6 WSP Implementation by Swedish Suppliers

The following table presents a summary of the status of WSP implementation within the interviewed drinking water supply systems in Sweden. It is based on the responses obtained during the interview.

All the interviewed water suppliers have at least one of the steps fully implemented (see Table 6). All of them had integrated HACCP into their operations, as well as having a functioning water protection area. Water supply plans for Gothenburg and Alingsås was fully implemented; since they are both part of the Greater Gothenburg region, their plans are the same. Östersund had plans for their small water plants and is currently working in the large plant. Gothenburg is the only supplier with a fully implemented crisis management plan. The other two suppliers have established a chain of contact, and are still currently working with their respective municipality in developing a crisis plan.

*Table 6 - Summary of the status of WSP implementation in Sweden.*

| **Parts of a WSP** | **Gothenburg** | **Alingsås** | **Östersund** |
|---|---|---|---|
| Self-monitoring programme with HACCP | | | |
| Water Protection Areas with regulations | | | |
| Water supply plan | | | |
| Crisis Management Plan | | | |

Fully implemented   Partially implemented   Not implemented

# 6. Discussion

In this chapter, the results are discussed in more detail. A comparison between the large and small water suppliers in Sweden is performed. Additionally, a comparison between Sweden and Latvia is also carried out. Possibilities of improving the Swedish system with measures implemented in other countries on WSP are studied. The costs associated with implementing a WSP are explored. Limitations encountered during this project are presented and further investigations are proposed.

## 6.1 Swedish perspective of risk assessment

Based on the responses from the interviews with the Swedish authorities, one can see that there is a positive attitude to the use of risk assessment in the drinking water supply. Both the national and local authorities agree about the benefits of implementing risk-based approaches e.g., easier to identify the vulnerabilities of the system, allowing municipalities to prioritize investments. The fact that there's a legal requirement for water suppliers to apply HACCP in their systems confirms that the authorities consider a risk-based approach as necessary for the production of safe drinking water.

All the authorities interviewed in this project agree upon the significance of their independent surveillance work, to ensure that the water distributed to consumers is of good quality. In addition to their national role as a regulatory agency, Livsmedelsverket also acknowledges the importance of working closely with institutions like Swedish Water and Wastewater Association ("Svenskt Vatten"), to provide competence and knowledge to suppliers so they can comply with the regulations. This work is an important element to ensure that the law is complied in a satisfactory manner and that suppliers then are able to adapt their systems in accordance to the requirements stated by the national authority.

The interviewed suppliers also seem to share the same opinion as the authorities regarding risk assessment. Alingsås made some remarks about the extra cost of implementing HACCP, but in general all the responses from suppliers were positive. Even though the use of HACCP is mandatory, they can see that it is a useful tool for the operation and planning of their system. All the suppliers also responded that they had been working with assessing the risks to their supply before the introduction of the HACCP requirement. This indicates that the topic of risk assessment was relevant enough for them to initiate studies voluntarily, and not only performing these assessments because they are required by law.

### Comparison between large and small supply systems

To explore if the size of a municipality would affect the methodologies used by both the suppliers and local authorities, a comparison between the responses obtained from Gothenburg and Alingsås was performed. The methodologies from the Gothenburg and Alingsås suppliers were found to be quite similar. Both of them had used HACCP to evaluate risks and identified measures to take. Water protection areas were created around the sources, to restrict the activities that could potentially contaminate the water bodies. Contingency plans and monitoring programs were set according to the guidelines and the requirements of each municipality.

However, from the responses it is obvious that Gothenburg has a broader monitor system in place. For example, they have several upstream sampling locations with regular sampling at their sources and also online monitoring at their main source (River Göta älv), whereas the smaller supplier only does sampling at the raw water intake. This can evidently be justified due to the fact that River Göta älv is covering a long distance, with many municipalities disposing their wastewater upstream to Gothenburg's raw water intake. Alingsås uses Lake Färgen, which has lesser impact from industrial and wastewater discharges than River Göta älv.

Another difference found was that Gothenburg seemed to have done more work analysing their risks than Alingsås. They were the only supplier that had performed a quantitative risk assessment in their system (quantitative fault tree analysis of water disruptions). Quantitative methods are considered to be less subjective than qualitative assessments (Wasewar & Kumar, 2010), therefore it can be said that they have a better overview of the risks in their system. However, it is possible that this perception is skewed since the analysis done by each supplier was not reviewed thoroughly in this study.

Gothenburg has carried out considerable work on securing a continuous supply of drinking water. Their increase in the capacity of the two treatment plants, so that they are able to satisfy the demand of the city by only one plant, if the other is out of service, has been considered of utmost importance based on the risks identified. Alingsås has also secured an alternative raw water source (Lake Ömmern), in case they cannot extract water from the main source. In conclusion, one can consider that both the suppliers have taken the actions needed based on the risk assessments and supply needs.

The main difference at the authority level is the local authorities' way of surveillance. Alingsås Miljöskyddskontor does not take water samples on their own due to lack of resources. On the contrary, Gothenburg Miljöförvaltning usually collects samples, normally 8-10 times a year; although more samples can be taken if they have reasons to suspect that the water quality is not complying with the standard. The fact that Alingsås does not take samples on their own might restrict the ability of the municipality to be able to perform the surveillance of the drinking water supply in full, which would undermine their role as a local regulatory agency.

Torbjörn Lindberg, from Livsmedelsverket, commented during his interview that large water suppliers have a greater possibility to invest time and money in developing competence to manage their drinking water supply effectively. Smaller municipalities have a harder time due to limited resources. This statement correlates well with the responses obtained from Gothenburg and Alingsås.

### Effects of an outbreak

During all the interviews, one aspect of the drinking water supply that was focused on was the lessons learned from the outbreak that occurred in Östersund in 2010. Our main interest was to understand how the event changed the mentality of the stakeholders involved in the drinking water supply system. Any changes in the water supply system that could be attributed to the outbreak were also of interest.

Based on the response received from the Östersund interviewee, the largest effect experienced of the outbreak was in the public opinion and on the politicians. Some modifications to the supply system in Östersund were performed due to the outbreak: adding a UV-disinfection step and introducing a two-flag alarm system for turbidity. The new alarm system warns when the turbidity value is high, but within an acceptable range, and higher than permitted. This allows the supplier to take precautionary measures at an earlier stage than with the previous alarm system, which only indicated turbidity above permitted range. The addition of UV-disinfection can be attributed to the fact that Östersund did not have microbiological barrier against Cryptosporidium (see Lindberg et al., 2011). Moreover, the outbreak in Östersund accelerated the planned installation of UV disinfection in Alingsås. All of the interviewed actors agreed that after the outbreak, there was an increased awareness of the risks in the drinking water supply. These responses are in line with previous research on the consequences of the outbreak in Sweden e.g., Widerström et al. (2014).

It is important to acknowledge that the outbreak is a sensitive topic from several perspectives. Bratanova et al. (2013) indicate that, after a water-borne outbreak, the public's trust on the supplier influences the public's apprehension of risk and the acceptance of continuing use of tap water. The responses of the Östersund supplier could be shaped by this reasoning, to minimize any concern the population might have with their water supply system. Therefore, it is possible that the statements about the consequences of the outbreak in the drinking water system of Östersund are conservative.

## 6.2 Sweden and Latvia comparison

In Sweden, there is a consensus amongst the drinking water suppliers and municipalities that risk-based assessments are the best way of ensuring drinking water of good quality, and that minimizing the risk of different hazards have a large impact on the drinking water supply. In Latvia, however, the same enthusiasm was not as obvious: the researchers are more enthusiastic about implementing a risk-based approach, but the suppliers are more sceptic, seemingly because they associate the implementation as time consuming and costly. The general opinion amongst the suppliers is that the drinking water quality is good in Latvia and therefore it is not necessary for their current methodologies to change.

The situation concerning education also differs in the different countries. The interviews with the Swedish drinking water suppliers show that they are very interested in education and information, participating in different workshops that can help them solve different problems. Even small municipalities are working to gain knowledge by themselves making their own courses and using people with knowledge in risk-based methodologies to teach them. Livsmedelsverket in Sweden is also very interested in helping and promoting knowledge to the municipalities, by writing guides to the guidelines and collaborating with Svenskt Vatten to spread more information. When speaking to the Latvian suppliers the same enthusiasm for education is not found, this in turn can be due to the lack of information about the benefits of WSP. According to Professor Talis Juhna, at RTU, universities and municipalities have worked with informing and introducing to WSPs, but the information has not reached all the way down the chain to the drinking water suppliers. This could be remediated by introducing a course similar to the one that Svenskt Vatten has in Sweden, where the risk-based methodology can be introduced. Another possibility would be to introduce the methodology in the Latvian regulations, in conjunction with the courses.

In Latvia the central regulatory agency is the Ministry of Health, while in Sweden the central regulatory agency is Livsmedelsverket that control also the food industries in Sweden. This can have different implications on the regulatory aspects from a central and local point of view. In Sweden, smaller local regulatory agencies feel that it can be hard to keep up with all the sampling that might be needed to ensure that the drinking water suppliers are complying with the regulations.

The regulations in Sweden and Latvia are both adopted from the Drinking Water Directive established by the European Union. In the Directive from the European Union it is possible to find all the parameters that have to be regulated by the legislation in each country. In the existing Drinking Water Directive, the risk-based approach is not included (there are plans to include them in a revised edition of the directive). The countries in Europe that use a risk-based approach have done so voluntarily, demonstrating higher ambitions than the directive. Countries have to adapt the legislation to their own national legislation and in some cases have made their own adaptations and set their own levels, e.g. in Sweden perfluorated compounds found in high levels have been regulated.

The WSP and a risk-based approach have to be adapted to the local circumstances and will vary depending on which country you make them in. Sweden and Latvia have some similarities and differences in the risks to their drinking water supply. Flooding is a problem in the two countries although in different rates. Sweden has more problems with flooding therefore becoming a greater risk for the drinking water. Problems in the raw water source and groundwater source also differs in the countries: in Latvia the metal levels in the raw water is generally higher and something they have to work with.

## 6.3 Implementation of WSP in Sweden

Based on the global literature review on WSP, it was found that Sweden had not implemented the WSP approach. However, after conducting the interviews to the different actors of the Swedish drinking water supply, it is clear that many of its parts already are in operation. This inconsistency shows that more work should be done in determining the level of implementation of risk-based approaches to drinking water supply. It is important to note that suppliers and local authorities are more familiar with WSP through Svenskt Vatten than the WHO Guidelines; so it is possible that this lack of information in the international literature is due to differences in the terminology used in Sweden and internationally.

The literature review also revealed some measures taken by other countries that have implemented WSP, which could be useful to apply to the Swedish water supply system. For example, the HACCP requirement in Sweden makes no distinction between sizes of the supplier. This is a potential inconvenience since implementation of the method in small water supplies might be limited by resources. In Iceland, a simplified 5-step HACCP has been developed specifically for this case. This simplification enables the supplier to gain all the advantages of a risk-based method with a reduced cost. The introduction of different levels of requirements based on the size could aid the different suppliers in improving their system within what is feasible for them to realize.

The province of Alberta (Canada) has made all of the documentation and templates necessary to carry out a WSP available on their website. This facilitates the process for the operator producing the WSP. Additional assistance can be solicited to the Environment and Water department if necessary. This is somewhat similar to the aid provided by Svenskt Vatten and Livsmedelsverket, however, having all the documentation available online could prove helpful for the suppliers that might want to compare the methodology with their own. This comparison could lead to the supplier introducing parts of the WSP methodology to improve their current one.

In South Africa, an incentive-based method is used to secure a high quality of drinking water. This is achieved through a certification program called Blue Drop. Some aspects of this approach might prove beneficial to use in Sweden, as to create a greater incentive to improve the water supply system. A good score and the certification itself could be seen as something desirable by the supplier, and these two goals could only be achieved if the supplier has a well-performing system. Consumers might also feel motivated to require their local water supplier to obtain the certification, which could be a further incentive.

Also, consumers can access online summaries of the main findings from the Blue Drop assessment of water suppliers. One can review the score received by the supplier, general comments on the drinking water supply system, and a rating on whether the quality is good or not. Even though in Sweden municipalities compile statistics and information about their drinking water system for the public, a tool like this could be helpful to provide the general public with an instrument to quickly evaluate their system. General alerts e.g. boiling recommendations, could also be posted in this tool, so that users can stay up-to-date with the information provided by the supplier.

Vietnam was one of the countries that tested a tool called Water Safety Investment Plan. This tool allows the supplier to prioritize investments and identify where economic resources can be obtained. Providing a similar tool to suppliers in Sweden would help them use their resources more efficiently and determine which areas need to be prioritized. More about the costs of implementing a WSP will be discussed in the following section.

## 6.4 Costs

Financial resources have been a topic that has been brought up in many of the interviews, often as an obstacle for WSPs to be implemented. Cost-benefit analysis of implementing WSPs or risk based approaches in water supply systems have not been performed in Sweden, therefore the municipalities and the suppliers can only speculate about the WSP implementation costs. From the information provided by the WHO, it is possible to estimate that the cost for implementation will vary from 100 000 SEK - 400 000 SEK. In the cases given as an example from WHO the calculations are coarse estimations, but the main costs in that estimation are the risk assessment performed by a consultant, audits, monitoring and risk assessment updates. The highest cost is the hiring of a consultant to perform the risk assessments. Monitoring costs are not high in comparison to the total cost. Although the cost to implement WSP is low, the consequences and changes that are caused by implementing WSP can be very high, since WSP can lead to major changes in the drinking water processes and in the distribution network.

In Sweden two studies can be found regarding the cost to society of a microbial outbreak and how much a total interruption in the drinking water distribution would cost. Östersund have had the largest microbial outbreak in Sweden and FOI estimated a cost of 220 million SEK (Lindberg, et al., 2011), when 45 % of the population got sick; what would happen if more people got sick is an interesting scenario. In another study, made by Tyréns, the cost is also estimated to be high for waterborne diseases: around 160 million SEK for a small municipality and 415 million SEK for a large one (Törneke & Engman, 2009). In many cases the outbreak could have been avoided if proper barriers in the drinking water plant had been in use or if the risk had been assessed beforehand. Even though the cost to implement and change the drinking water plants to secure a high quality of drinking water would have a high cost, it would probably be lower than the cost for an outbreak. According to Törneke & Engman (2009), the cost for an interruption in the drinking water distribution is not as high as for a microbial outbreak: 7 million SEK for a small municipality and 80 million SEK for a large one. However, this implies that it is better to keep up the maintenance of the drinking water distribution network.

SOPAC (in the Pacific) has made two more extensive analysis of the benefit that implementing WSP would have on the economy. The costs and benefits have been calculated over a period of 20 years with different discount rates. From both studies it is evident that the WSP implementation would be beneficial for the municipality: in Niue the lowest cost-benefit ratio had a profit of 1,20 USD for every dollar invested in improving the drinking water supply system (Talagi, 2011), and in Palau the lowest cost-benefit ratio was 5,90 USD for every dollar invested (Gerber, 2010). This shows that the amount of money that can be saved by using a WSP varies and has to be calculated for each individual case to get a proper picture of the cost. Although the cost-benefit ratio varies considerably, it is important to point out that in all cases there is a profit from implementing WSP.

## 6.5 Limitations

For this project, Östersund was chosen to represent a municipality affected by an outbreak, Alingsås was chosen to represent the smaller municipalities and Gothenburg was chosen to represent the larger municipalities. The perspectives gained from the interviews can be misleading in some cases, since the interviews were conducted in only three municipalities. To gain a more accurate picture of the general point of views from the smaller municipalities as well as the larger ones, complementary written surveys could have been sent and analysed within this project. Also, more municipalities could have been contacted for interviews.

Alingsås is part of the Greater Gothenburg region, and therefore benefits somewhat from lying close to a large water supplier e.g., water supply plans are up-to-date, possibility of exchanging information. Thus, it might not represent the true level of progress achieved by a small municipal water supplier. It would have been interesting to analyse a smaller municipality that does not have a large municipality close by, to see if the development in implementing the legislation and risk-based methods would have come as far along as in Alingsås. It is more likely that the larger municipalities are at the same level as Gothenburg, since the larger municipalities have the competence, economy and knowledge.

The information about the suppliers in Sweden was hard to acquire, since there is not much information that can be found on the Internet and several documents of importance for this project were not available to the public. Information had to be collected from the different suppliers during the interviews. Information from Latvia was also difficult to assimilate to us, since the legislations and all the important documents concerning drinking water are all in Latvian and had to be translated for us. Ideally more interviews with suppliers and municipalities would have been good to get a general overview of the situation in Latvia. Therefore in further studies more information about Latvia would be valuable to gain.

## 6.6 Further studies

Risk-based methodologies are a relatively new concept in Sweden; from the interviews it was evident that it was added into the legislation in 2012. From this thesis it is evident that in order to gain more knowledge about implementing HACCP or WSP, a cost-benefit analysis would be helpful. The analysis has to be made specifically for Sweden and the conditions in the Swedish drinking water plants. A cost-benefit analysis for the different technical barriers that could be used to prevent water-borne pathogens from contaminating the drinking water would be of great use for the smaller municipalities. These solutions would be compared with each other so that the best solution could be chosen. In the calculations the size of population served should be a factor.

In Sweden a large part of the population uses private wells, which are not regulated by Livsmedelsverket unless water is used for production of food intended to be sold. Latvia also has a large part of their population not connected to centralized water supply. The private wells are harder to control and the drinking water quality is often low and unhealthy for the users in Latvia. In order to manage the wells properly some technical knowledge is usually required, which the general population might not possess. A study that aims to make risk-based approach understandable and easier to use (sort of "how to guide") for the part of the population that uses private wells could be of interest.

A methodology to incorporate quantitative analysis in the planning of a drinking water plant would be extremely useful for both Sweden and Latvia. Also, exploring the possibility of adding a quantitative analysis to the HACCP, similar to the work done by Thorwaldsdotter (2006) in Gothenburg, would also be useful for other drinking water plants; the more methods used to assess the risks in the drinking water supply the better. Quantitative analyses give a statistical perspective of the risk occurring which can be helpful in identifying where investments will have the greater impact.

The drinking water source in Latvia is mainly groundwater, therefore a study regarding the risks that are present in drinking water plants that use groundwater as a raw water source could be of use to make a better comparison between the countries. Quantitative analyses focused on groundwater, e.g., QMRA or QRCA in wells, could be of use in both countries. Since suppliers in Latvia see WSPs as costly, a cost-benefit analysis could also be very beneficial to have a more accurate picture of the benefits of introducing risk-based approaches into the Latvian system.

# 7. Conclusion

In this thesis project, a comparison between methods and views of risk assessment in drinking water supply systems of Sweden and Latvia was done. The main findings were:

- *Sweden has a regulatory requirement for HACCP in the drinking water supply system, while Latvia does not.*
- *Authorities and suppliers in Sweden view risk assessment/WSPs as positive and useful, while in Latvia the suppliers consider RA/WSPs as costly and unnecessary.*

Furthermore, three Swedish water suppliers were analysed in-depth to identify their progress in the RA/WSP area. From this, it can be said that:

- *Gothenburg, as a large water supplier, has all the parts of a WSP fully implemented.*
- *Alingsås, as a small water supplier, is still working in its crisis management plan.*
- *Östersund is still working on their water supply plan and crisis management plan.*
- *Sweden's awareness of microbial hazards has increased since the cryptosporidium outbreak in Östersund. Drinking water supply systems have been reviewed and upgraded to take parasites into account.*

Interesting approaches implemented in the world that could be of use in Sweden and Latvia were identified. These measures include:

- *Simplified HACCP method for small water suppliers (Iceland)*
- *Incentive-based certification, Blue Drop, to motivate suppliers to improve their systems and an information web tool to publish the results (South Africa)*
- *Availability of template and guidance documentation to carry out WSPs in the municipality webpage (Canada)*
- *Water Safety Investment Plan to determine the viability of WSPs (Vietnam)*

Based on the responses of the interviewees and the assessment of the collected information, further investigations are proposed:

- *Quantitative risk assessments in both Sweden and Latvia, since most of the work done has been of qualitative nature.*
- *Cost-benefit analyses of implementing WSPs, to provide support for further integration of risk-based approaches in the normal operation of drinking water supplies.*
- *Studies of groundwater supply systems and their risks*

## Bibliography


Abu-Zeid, M. A., 1998. Water and sustainable development: the vision for world water, life and the environment. *Water Policy,* 1(1), pp. 9-19.

ABVA, 2009. *Vatten och Avlopp- Råd och anvisningar ,* s.l.: Alingsås kommun.

ASC, 2014. *Water in Africa.* [Online]
Available at: http://www.ascleiden.nl/content/webdossiers/water-africa
[Accessed 21 February 2015].

Asit, K. & Biswas, D., 1991. Water for sustainable development in the 21st century: a global perspective. *GeoJournal ,* 24(4), pp. 341-345.

Barrington, D., Fuller, K. & McMillan, A., 2013. Developing water safety plans in rural Nepal. *Journal of Water, Sanitation and Hygiene for Development,* 3(3), pp. 392-401.

Baum, R., Amjad, U., Luh, J. & Bartram, J., 2015. An examination of the potential added value of water safety plans to the United States national drinking water legislation. *International Journal of Hygiene and Environmental Health.*

Boverket, 2015. *Boverket.* [Online]
Available at: http://www.boverket.se/sv/om-boverket/boverkets-uppdrag/
[Accessed 16 Febuary 2015].

Bratanova, B. et al., 2013. Restoring drinking water acceptance following a waterborne disease outbreak: the role of trust, risk perception, and communication. *Journal of Applied Social Psychology ,* 43(9), pp. 1761-1770.

Brombal, M. et al., 2009. *Risk Assessment of Riga Water Supply,* Deliverable no. D 7.5.3: TECHNEAU.

Burgman, M., 2005. *Risks and Decisions for Conservation and Environmental Management.* Cambridge: Cambridge University Press.

Byleveld, P. M., Deere, D. & Davison, A., 2008. Water safety plans: planning for adverse events and communicating with consumers. *Journal of Water and Health ,* 6(S1), pp. 1-9.

Davidson, A. et al., 2005. *Water Safety Plans - Managing drinking-water quality from catchment to consumer,* Geneva: World Health Organization.

DWA, n.d. *Blue Drop Handbook - version 1,* South Africa: Department Water Affairs.

DWI, 2010. *The Water Supply Regulation 2010.* s.l., Drinking Water Inspetorate.

DWI, 2015. *Drinking Water Inspectorate.* [Online]
Available at: http://dwi.defra.gov.uk/
[Accessed 22 April 2015].

DWQR, n.d.(a). *Drinking Water Quality Regulator.* [Online]
Available at: http://www.dwqr.org.uk/
[Accessed 25 April 2015].

DWQR, n.d.(b). *Drinking Water Quality Regulator.* [Online]
Available at: http://www.dwqr.org.uk/information/regulatory-framework/the-cryptosporidium-scottish-water-directions-2003/
[Accessed 14 April 2015].

DWQR, n.d.(c). *Drinking Water Quality Regulator.* [Online]
Available at: http://www.dwqr.org.uk/information/regulatory-framework/
[Accessed 14 April 2015].

Environmental & Engineering Managers Ltd., 2008. *Lessons Learnt from the Development of the WSP for the Spanish Town Water Supply System in Jamaica,* Kingston: Environmental & Engineering Managers Ltd..

ES Ministry of Health, 2012. *Plan de Seguridad del Agua: Ministerio de Salud de El Salvador (Water Safety Plan: El Salvador Ministry of Health).* [Online]
Available at: http://usam.salud.gob.sv/index.php/component/content/article/584
[Accessed 15 February 2015].

Feldmane, J., 2010. *Summary Report Under the Protocol on Water and Health.* [Online]
Available at:
http://www.unece.org/fileadmin/DAM/env/water/Protocol_reports/reports_pdf_web/Latvia_summary_report_en.pdf
[Accessed 19 May 2015].

Fundación Sumaj Huasi, 2011. *Planes de Seguridad de Agua en Ciudades Fronterizas de Bolivia, Perú, Argentina y Brasil,* La Paz: Fundación Sumaj Huasi.

Gelting, R., 2009. Water Safety Plans: CDC's Role. *Journal of Environmental Health,* 72(4), pp. 44-45.

Gerber, F., 2010. *An Economic Assessment of Drinking Water Safety Planning Koror-Airai, Palau,* s.l.: SOPAC.

Gherardi, C., 2009. Water Safety Plans in Lao PDR: serious about scaling up. *Water21,* Issue 01102, pp. 33-34.

Gunnarsdóttir, M. J., Gardarsson, S. M. & Bartram, J., 2012a. Icelandic experience with water safety plans. *Water Science & Technology,* 65(2), pp. 277-288.

Gunnarsdottir, M. J., Gardarsson, S. M., Elliott, M. & Sigmundsdottir, G., 2012b. Benefits of Water Safety Plans: Microbiology, Compliance, and Public. *Environmental Science & Technology,* 46(14), pp. 7782-7789.

Göteborg Stad, 2015. *Göteborg Stad.* [Online]
Available at: http://goteborg.se/wps/portal/enheter/fackforvaltning/kretslopp-och-vatten
[Accessed 3 April 2015].

Göteborgsregionen, 2013. *Förslag till regional vattenförsörjningsplan,* s.l.: Göteborgsregionen.

Halla, T., n.d. *Water Management in Riga and in Copenhagen.* [Online]
Available at: http://www.helsinki.fi/envirohist/seaandcities/articles/CopRig.pdf
[Accessed 12 May 2015].

Hokstad, P. et al., 2009. *Methods for risk analysis of drinking water systems from source to tap - Guidance report on Risk Analysis,* Deliverable no. D 4.2.4: TECHNEAU.

Hulsmann, A. & Smeets, P., 2011. *Towards a Guidance Document for the implementation of a Risk Assessment for small water supplies in the European Union: Overview of best practices ,* Nieuwegein: Watercycle Research Institute (KWR).

Juhna, T. & Klavins, M., 2001. Water quality changes in Latvia and Riga: possibilities and problems in 1980-2000. *Ambio,* 30(4-5), pp. 306-314.

Kama, K., 2010. *Water Safety Plan: Facilitation Guide,* Bhutan: Department of Public Health.

Klimatanpassninsportalen, 2014. *Klimatanpassninsportalen.* [Online]
Available at: http://www.klimatanpassning.se/atgarda/exempel-pa-anpassning/rent-dricksvatten-ostersund-fordjupning-1.75353
[Accessed 3 April 2015].

Kretslopp och Vatten, 2014. *Kretslopp och Vatten Årsberättelse 2013,* Gothenburg: Göteborg Stad - Kretslopp och Vatten.

Kretslopp och Vatten, n.d. *Långsiktiga mål för Kretslopp och Vatten,* Gothenburg: Kretslopp och Vatten.

Kunikane, S., 2009. *Recent progress in WSP application in Japan.* Las Vegas, US EPA.

K-Water, 2013. *The Development of Water Safety Plans in Korea,* Republic of Korea: Water Supply Operations & Maintenance Department.

LAC WSP, n.d. *About the Network.* [Online]
Available at: http://www.bvsde.paho.org/wspnetwork/aboutredlacpsa.html
[Accessed 24 February 2015].

Lillian Amegovu, I., 2011. *Water Safety Plan Policy, Provisions and Status of Implementation in Uganda,* Nairobi: Ministry of Water & Environment.

Lindberg, A., Lusua, J. & Nevhage, B., 2011. *Cryptosporidium i Östersund vintern 2010/2011,* Sweden: Livsmedelsverket.

Lindberg, T., 2015. *Faroanalys och kritiska styrpunkter (HACCP).* s.l.: Livsmedelsverket.

Lindhe, A., 2010. *Risk Assessment and Decision Support for Managing Drinking Water Systems,* Gothenburg: Chalmers University of Technology.

Lindhe, A. et al., 2008. *Risk assessment case study – Göteborg, Sweden,* Deliverable no. D 4.1.5a: TECHNEAU.

Livsmedelsverket, 2015. *Livsmedelsverket.* [Online]
Available at: http://www.livsmedelsverket.se/produktion-handel--kontroll/produktion-av-livsmedel/dricksvattenproduktion/foreskrifter-om-dricksvatten/
[Accessed 05 March 2015].

Mahmud, S. G. et al., 2007. Development and implementation of water safety plans for small water supplies in Bangladesh: benefits and lessons learned. *Journal of Water and Health,* 5(4), pp. 585-597.

Martel, K., Kimeyer, G. & Hanson, A., 2006. *Application of HACCP for Distribution System Protection,* s.l.: Awwa Research Foundation.

Maynilad, 2012. *WATER SAFETY PLAN: Managing Drinking Water Quality from Catchment to Consumer,* Manila: Maynilad Water Services, Inc..

Mehner, H., n.d. *Göteborg Stad.* [Online]
Available at: http://goteborg.se/wps/portal/invanare/bygga-o-bo/vatten-och-avlopp/dricksvatten/dricksvattenberedning
[Accessed 23 January 2015].

Miljöförvaltningen, 2013. *Göteborg Stad.* [Online]
Available at:
http://goteborg.se/wps/portal/enheter/fackforvaltning/miljoforvaltningen/!ut/p/b1/04_Sj9Q1NDA3NTI3MTU31o_Qj8pLLMtMTyzJzM9LzAHxo8zijUy9A52MvIwN_N0CXQyMQtwcwwJCfJxMfQ2BCiKBCgxwAEcDQvr9PPJzU_Vzo3IsAHQitkA!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/
[Accessed 4 March 2015].

NGO Committee on Education, n.d. *Our Common Future: Report of the World Commission on Environment and Development.* [Online]
Available at: http://www.un-documents.net/ocf-02.htm#I
[Accessed 19 February 2015].

Nylén, K.-J., 2013. *Havs och Vattenmyndigheten.* [Online]
Available at: https://www.havochvatten.se/hav/uppdrag--kontakt/vart-uppdrag.html
[Accessed 09 March 2015].

NZ Ministry of Health, 2014. *A Framework on How to Prepare and Develop Water Safety Plans for Drinking-water Supplies,* Wellington: New Zealand Ministry of Health.

O'Meally, S., 2011. *Uganda's Story: Rural water supply in Uganda - Major strides in sector coordination and performance,* London: Overseas Development Institute.

PAHO, 2011. *Pan American Health Organization.* [Online]
Available at:
http://www.paho.org/MEX/index.php?option=com_content&view=article&id=448:curso-taller-sobre-planes-seguridad-agua-psa&catid=827:noticias&Itemid=499
[Accessed 23 February 2015].

Pérez Vidal, A., Torres Lozada, P. & Cruz Vélez, C. H., 2009. Water safety plans. Fundamentals and prospects for implementing them in Colombia. *Ingeniería e Investigación ,* 29(3), pp. 79-85.

Petterson, S., Signor, R., Ashbolt, N. & Roser, D., 2006. *QMRA methodology,* s.l.: Microrisk.

Pollard, S. J., 2008. *Risk Management for Water and Wastewater Utilities.* 1st ed. London: IWA Publishing.

RASHON, 2009. *Guía para la implementación de Planes de Seguridad de Agua en el Sector Rural de Honduras ,* s.l.: Red de Agua y Saneamiento de Honduras, RASHON.

Reid, D. C. et al., 2014. Implementation of Alberta's drinking water safety plans. *Water Quality Research Journal of Canada,* 49(1), pp. 5-9.

Rosén, L. et al., 2007. *Generic Framework and Methods for Integrated Risk Management in Water Safety Plans,* Deliverable no. D 4.1.3, D 4.2.1, D 4.2.2, D 4.2.3: TECHNEAU.

Rowley, J., 2012. Conducting research interviews. *Management Research Review,* 35(3/4), pp. 260-271.

Saeijs, H. & Van Berkel, M., 1995. Global water crisis: the major issue of the 21st century, a growing and explosive problem.. *PubMed,* 4(Eur Water Pollut Control), pp. 26-40.

Scottish Governments, 2013. *The Scottish Governments.* [Online]
Available at: http://www.gov.scot/Topics/Environment/Water
[Accessed 15 March 2015].

SEPA, n.d. *Scottish Environment Protection Agency.* [Online]
Available at: http://www.sepa.org.uk/regulations/water/
[Accessed 14 Febuary 2015].

SLVFS 2001:30, n.d. *Livsmedelsverkets föreskrifter om dricksvatten,* s.l.: Livsmedelsverket.

South African Government, 2015. *About SA: Water Affairs.* [Online]
Available at: http://www.gov.za/about-sa/water-affairs
[Accessed 1 March 2015].

Sutherland, D., 2013. *Water Safety Plans: Efforts in Asia Pacific,* Nagpur: World Health Organization.

Sweco, 2015. *FÄRGENSJÖARNA VATTENSKYDDSOMRÅDE- TEKNISKT UNDERLAG MED FÖRSLAG TILL VATTENSKYDDSOMRÅDE OCH SKYDDSFÖRESKRIFTER,* s.l.: Alingsås kommun.

Svenskt Vatten, 2007. *Dricksvattenförsörjning i förändrat,* s.l.: Svenskt Vatten.

Svenskt Vatten, n.d.(a). *About Us: The Swedish Water & Wastewater Association, SWWA.* [Online]
Available at: http://www.svensktvatten.se/Om-Svenskt-Vatten/Om-oss/In-English/
[Accessed 20 Junio 2015].

Svenskt Vatten, n.d.(b). *Råd och riktlinjer för ansvariga inom dricksvattenproduction,* s.l.: Svenskt Vatten.

Säve-Söderbergh, M., Dryselius, R., Simonsson, M. & Toljander, J., 2013. *Behovsanalys för svensk dricksvattenförsörjning - sammanställning av intervjuer och workshop,* s.l.: Livsmedelsverket .

Talagi, D., 2011. *An Economic Assessment of Water Safety Planning: NIUE,* s.l.: SOPAC.

Thorwaldsdotter, R., 2006. *Use of Quantitative Microbial Risk Assessment (QMRA) as a Tool in the Hazard Analysis and Critical Control Point (HACCP) Management System for Water Treatment Plants - Especially for Development of Critical Limits,* Lund: Lund University.

Tuhovcak, L. & Rucka, J., 2009. Hazard identification and risk analysis of water supply systems. In: H. Alegre & M. d. C. Almeida, eds. *Strategic Asset Management of Water Supply and Wastewater Infrastructures.* London: IWA Publishing, pp. 287-297.

Törneke, K. & Engman, M., 2009. *Samhällskostnader vid störningar i dricksvattenförsörjningen,* s.l.: Tyréns AB.

UNBS, 2013. *Administrative Directives On Implementation Of Water Standards Requirements,* s.l.: UNBS.

Wasewar, K. & Kumar, M., 2010. Quantitative Risk Assessment. *i-Manager's Journal on Future Engineering and Technology,* 6(1), pp. 33-39.

Vattenförvaltningen, n.d. *Vattenförvaltningen.* [Online]
Available at: http://www.vattenmyndigheterna.se/Sv/om-vattenmyndigheterna/vattenforvaltningens-arbetscykel/miljokvalitetsnormer/Pages/default.aspx
[Accessed 8 March 2015].

WHO: Europe, 2007. *Support for the Development of a Framework for the Implementation of Water Safety Plans in the European Union,* s.l.: WHO.

WHO: Europe, 2014. *Water Safety Plans in eastern Europe, the Caucasus and central Asia,* Copenhagen: World Health Organization.

WHO, 2011. *Guidelines for drinking-water quality - 4th ed.,* Geneva: World Health Organization.

WHO, 2014a. *Progress on sanitation and drinking-water - 2014 update,* Geneva: World Health Organization.

WHO, 2014b. *Water for Life Decade: Africa.* [Online]
Available at: http://www.un.org/waterforlifedecade/africa.shtml
[Accessed 23 February 2015].

WHO, 2015a. *About WHO.* [Online]
Available at: http://www.who.int/about/en/
[Accessed 20 February 2015].

WHO, 2015b. *About: Millennium Development Goals.* [Online]
Available at: http://www.who.int/topics/millennium_development_goals/about/en/
[Accessed 20 February 2015].

WHO, 2015c. *Countries: World Health Organization.* [Online]
Available at: http://www.who.int/countries/en/
[Accessed 20 February 2015].

Widerström, M. et al., 2014. Large Outbreak of Cryptosporidium hominis Infection Transmitted through the Public Water Supply, Sweden. *Emerging Infectious Diseases,* 20(4), pp. 581-589.

WSP, n.d. (a). *Water Safety Plan in Lao PDR: Water Safety Portal.* [Online]
Available at:
http://www.wsportal.org/templates/ld_templates/layout_1367.aspx?ObjectId=30319&lang=eng
[Accessed 5 February 2015].

WSP, n.d.(b). *Water Safety Plans in Vietnam: Water Safety Portal.* [Online]
Available at:
http://www.wsportal.org/templates/ld_templates/layout_1367.aspx?ObjectId=30322&lang=eng
[Accessed 5 February 2015].

Östersunds Kommun, 2013. *Plan för Vatten- och avloppsförsörjning,* u.o.: Östersunds kommun.

# APPENDIX A – INTERVIEW QUESTIONS: NATIONAL AUTHORITY

**Risk assessment**
Does Livsmedelsverket integrate Risk Assessment requirements for water suppliers in their guidelines?
**Yes**

- What are those requirements?
- What sections of the system are covered?

**No**
Does the organization promote Risk Assessment?

- How?

Is there a consensus in the organization about risk assessment or WSPs?
Is it a positive consensus?

**Education**

- Do you provide any type of support to water suppliers with education in risk assessment/routines/monitoring or other related fields?
- Svensk Vatten has a lot of handbooks and advice for safe water supply. Are these done in a collaboration with Livsmedelsverket?

**Perspective**
Performance of large water suppliers in implementing WSPs
Small water suppliers?
Sweden?
Future challenges

- Role of risk assessment for solving future challenges
- Role of WSP for solving future challenges
- Opinion of water suppliers regarding RA/WSP

# APPENDIX B – INTERVIEW QUESTIONS: LOCAL AUTHORITY

What role does the institution play in the drinking water chain?

What kind of assessments do you carry out?

Revisions to testing Scheme?

Who is responsible for water safety?

Parameters that you monitor? What? How? When?

Hazards or factors that affect the monitoring?

Procedure for drinking water control: Guideline or norm?

Control points?

Documentation?

Education? Needs for the job, internal education, specific education in risk assessment?

Views on risk assessment?

Communication with suppliers?

Role in case of an outbreak or emergency?

# APPENDIX C – INTERVIEW QUESTIONS: WATER SUPPLIER

Introduction: Brief description of the institution, objectives

- Introduction of the person
- Description of the institution
- Organizational structure
- Description of the system

1) WSP
    a) Are you familiar with WSP and related terms?
    b) Do you use WSP or any similar framework?
    c) Health-based targets
        i) Do you follow national guidelines to the letter or have you modified some parameters?
        ii) Major challenges due to source water.
        iii) Are any actions taken to protect source water (primary and secondary sources)?
        iv) Is there any parameter that is missing in the guidelines?
        *v) How do the targets influence your treatment system?*
        *vi) Are there any other factors that affect the treatment system?*

    d) Risk assessment
        vii) Do you perform any kind of risk assessment in your system?
        viii) **Yes:**
            (1) What tools/methodology do you use?
            (2) What areas of the system are covered in the assessment?
            (3) When was it implemented and why?
            (4) How frequent are assessments conducted?
        ix) **No**:
            (1) Is there a reason for not using RA?
            (2) Are there any plans to implement in the future?
        x) What is the official stance of the supplier regarding risk assessment?

    e) Operational monitoring
        xi) How are the operational monitoring parameter chosen?
        xii) Which parameters are essential to monitor to prevent contamination of the drinking-water?
        xiii) Frequency of the operational monitoring?
        xiv) Have you followed the national guidelines for choosing the operational monitoring parameters?
        xv) Have you any parameters outside the national guidelines?

f) Management plans, documentation and communication
   xvi) Are there control measures established for any potential problems arising in the water supply system?
      (1) **Yes**: Brief overview of them
      (2) **No**: How do you solve these problems?
   xvii) Procedure for an outbreak case: during and after it has occurred.
      (1) Line of communication between agencies
      (2) Are there any changes made to the system after an outbreak has occurred?
   xviii) Extent of the documentation of the water supply system: during normal operation, during emergency situations (e.g., outbreak)?
      (1) What kind of reports do you prepare for Miljöförvaltningen?
   xix) How do you manage "false alarms" during monitoring?
      (1) Are there any adjustments that need to be done if a false alarm occurs?
   xx) When and how are the consumers notified if there's a problem?

b) Perspective
   i) Do you perform comparisons (i.e., benchmarking) between your water supply system and other cities', in Sweden and abroad, systems?
      (1) **Yes**:
         (a) Are there areas that need to be improved?
         (b) How are the improvements and upgrades determined?
      (2) **No**:
         (a) How do you measure the performance of the system?
         (b) How are the improvements and upgrades determined?
   ii) Education
      (1) Requirements to work at the plant: do you need special education, certification.
      (2) Is there internal education to learn WSP or other framework?
b) Conclusion:
   i) Short remark on present state, future improvements and challenges.
      (1) WSP: possibilities and limitations for implementation in your system

# APPENDIX D – INTERVIEW TRANSCRIPT: LIVSMEDELSVERKET

**Role**

Livsmedelsverket is the central authority of drinking water, and is responsible for legislation from the water works to almost the tap, the domestic installation is not in their jurisdiction, so have to stop before the domestic installation. Should lead and coordinate the official surveillance of drinking water. Some of the drinking water suppliers are under the surveillance of the LIVSMEDELSVERKET, there are only small food business that have their own drinking water, and otherwise the municipalities are the ones that have the surveillance responsibility for the drinking water suppliers.

**Risk assessment**

Integrate risk assessment requirements in the regulations, the requirement are based upon the hazards and are part of the food legislation. Food legislation has a basic way of making risk assessments. If the water safety planning is compared with HACCP they are mainly the same. You can say that Sweden has already implemented water safety planning or big part of the water safety planning. It is not possible for the NFA to regulate the quality of the raw water, since it is not in the jurisdiction and this component is the one left to have a complete water safety planning.

HACCP is mandatory and all drinking water suppliers have to have it. There are two tracks to produce safe drinking water and one is HACCP and the other one is to use the general hygienic requirements and this is enough to produce safe drinking water. There is a certain flexibility on how far you have to go in the hazard principle work. In paragraph 2 A and B the basic requirements are given to produce safe drinking water.

**Support in education**

Two kinds of support are provided to the drinking water suppliers; guidance documents are provided and information on how to understand the regulations. The second support is individual support; suppliers are always welcome to contact Livsmedelsverket if there are any questions. Collaborations are made with Svenskt Vatten where they put together information for the suppliers, and have more or less a regular dialogue with Svenskt Vatten. Always inform to the suppliers to use the information from Svenskt Vatten since they are the technical experts and complement Livsmedelsverket.

**How integrate knowledge in the field into the guidelines.**

One of the basic processes is that Sweden has to rely on the European Union and has to look and apply the regulation for drinking water directive. It is possible to make national rules, but that is more difficult and have to be based on knowledge that is collected in Sweden which is not always the case. Perfluorated compounds in the drinking water in Sweden is an example and has to be handled in some way, and was handled with information in the internet and surveys and where in the rules this information could be found. Limits for different perfluorated acid where decided and put on the website to help the suppliers to assess the risk and lower the amounts. Livsmedelsverket can be generic and Svenskt vatten can be very detailed.

There is no fixed periodic assessment of the rules, but there are always an ongoing assessment of what works and not works with the rules, it is a combination of unknown events that triggers what has to be done by Livsmedelsverket and the suppliers, and what information has to be added into the legislation. They are constantly changing the rules and adapt to the circumstances.

Ex. Last year a new directive concerning levels of radioactivity in drinking water was issued, this is regulations that have existed since 1998 but further guidelines for how to regulate radioactivity in the water was not given. And now the legislation has to be added into the Swedish legislations before November 2015.

**Challenge for the small water suppliers**

It is a technical challenge for the smaller water suppliers to follow the legislation, especially when it comes to regulations in perfluorated acids for example. Carbon filtration can be used to remove perfluorated acids, but have to be regenerated after a couple of months and this is expensive for the smaller water suppliers. A general challenge is the economy, and all changes in drinking water is a challenge to be able to adapt. Competence is also a challenge in smaller municipalities.

**Future**

The local authorities that are the local representatives, use comparably more resources on smaller suppliers to educate and help them with the drinking water. Bigger suppliers comply with the legislation much easier and they have an effective level. They have the capacity and the knowledge, while smaller suppliers have problems with basic things.

**Perspective with the level of risk assessment implementation**

Rules on HACCP are new and was applied first of January 2012, results are seen in 10-15 years. He expects everybody to have started with the risk assessment work. They are far from finished and consultants are often used to make the risk assessments, which is good if the water suppliers do not have the knowledge or the capacity, but it is important to understand and use the documents.

Risk assessment is an important tool and basic to be able to secure a high and good quality of drinking water. HACCP and WSP is the only way to assure that the quality is good all the time and not only during small periods. The water directive on European level has not been revised since 1998, but the commission will probably decide to revise the water directive and add the risk management and risk assessment approach in the drinking water directive this year.

The smaller non municipality suppliers find WSP very complicated and academic, and do not see the need of using HACCP. The larger suppliers are well aware and agree that this is the way to move forward and is considered one of the most important tolls to achieve good drinking water quality.

Some cost calculations have been done, but there are not many.

Most of the larger and western part of Europe have implemented rules about risk assessments that goes beyond the water regulations set by the European Union, the newer members in the east have not yet adapted to the European Union legislations, they will probably wait until the new regulations with risk assessment approach integrated are released and this will take at least five years. Sweden implemented HACCP in 2012, England had rules about risk assessment around 2005 and use more of the risk based approach than Sweden. Norway also use de food legislation as a regulator. Only three countries that use the food legislation as a regulation for drinking water Sweden, Norway and Austria.

# APPENDIX E – INTERVIEW TRANSCRIPT: GOTHENBURG AUTHORITY

Main goal for Miljöförvaltningen is to ensure that the drinking water supply is fulfilling national legislation. They do not make the WSP, but control that the supply system is functional. Officers are educated in food supply science and have some knowledge in risk assessment. The legislation is in some ways detailed on what to control, they also have guidelines from the NFA and they use these to assess the system's compliance.

- **What part of the system is controlled?**
  They check every part of the system (e.g., distribution network). Control points depend on the parameter being assessed. *They are aware of limitation: how to control if the system is good is very hard, since you only get a momentary glance into the system*.
- **How often?**
  They are out controlling different parts of the system at least 8-10 times per year. Water supplier has an internal revision that revises the system all the time and Miljöverket functions as an external controller.
- **Are there any external factors that influence how often you check?**
  If there are any indications that there is a problem in the drinking water they can do checks every day if justified. If there are any problems with the water supply and distribution network, they get reports from the Kretslopp och Vatten.
- **Methodology**
  Methodology followed to conduct the check varies between control points and parameters being determined. Officers carrying out the control have to be creative, to be able to assess the system in the most representative way. It is up to every officer how the control is done, nothing is fixed, and good ideas can be implemented into the checking.
- **Work Methodology**
  They usually do not work with documents on how to do the assessments; they work with an ongoing dialog. Hold meetings frequently to talk to each other and try to learn from each other in a systematic way.

# APPENDIX F – INTERVIEW TRANSCRIPT: GOTHENBURG SUPPLIER

The raw water comes from River Göta älv and the intake lies in Lärjeholm and from there the raw water is transported to Gothenburg's two drinking water plants Lackarebäck and Alelyckan. The raw water quality in River Göta älv is supervised by 7 online instruments. Lackarebäck uses water from Delsjöarna.

The two drinking water plants have an annual production volume of 30 Million cubic metres each, hence the city cannot be supplied by only one functioning drinking water plant. Today the capacity of Lackarebäck is increased by installing 8 active carbon filters when construction of the ultrafiltration is ongoing.

There are several major risks that have been identified in the drinking water supply system, the first one is the capacity of the water plants, if one of the drinking water plants would have problems and would have to shut down, then other water plant would not be able to supply the rest of the population, therefore an increase in both drinking water plants are planned and underway. The second risk are microbiological hazards and therefore UV-light has been installed in Alelyckan but are going to be exchanged to ultrafiltration during  the next 10-15 years and ultrafiltration are being installed in Lackarebäck to prevent contamination in the drinking water ( 50 % is installed and  today and the other 50 % is planned to in late 2015). A third identified risk are the raw water tunnels that lea the raw water from Lärjeholmen to Delsjöarna, if the tunnels would collapse there would be no secondary source to Alelyckan and the amount of raw water in Delsjöarna that can be used for drinking water production would be limited, therefore an increase in production capacity would be a solution.

Difficult to measure the improvement of water quality when it comes to microorganisms, when installing ultrafilters it is possible to use a method called System Viruslika Partiklar. In the method the water is filtrated through and the amount of particles that have a bigger size than the pores in the filters are counted, if the amount would decrease then there can be something wrong with the filters. Usually the water from Delsjöarna has a high quality and normally there are no harmful microorganisms.

Claes Wångsell is familiar with WSP and finds it a good tool to find risks to know where to invest to minimize the risks to the drinking water. Is not familiar in detail with WSP according to WHO, but is familiar with the guidelines that Svenskt Vatten has. In Kretslopp och Vatten a planning instrument called Åtgärdsplan Vatten is used, here the long-term goals for the drinking water are set for the future and every 10 years there goals for drinking water are revised to assure that the goals for drinking water are met.

In Lackarebäck the parameters that are monitored are the ones set by Livsmedelsverket, though the limits of the parameters are lower to assure that no contamination occurs and the water is treated correctly.  Some of the parameters are monitored frequently with online instruments that measure all the essential parameters for the plant to function properly. Every three days more samples are taken than the ones regularly monitored to analyse. One of Lackarebäcks goals is that all test has to be below the national guidelines. None of samples taken of the drinking water should be classified as (otjänligt), and 99.9 percent of the samples should be (tjänligt) with no (anmärkning). A parameter that Lackarebäck still control is the raw water quality, since it is essential for the drinking water processes in the plant.

Several risk assessments have been made in all areas of the drinking water system in Lackarebäck. Both quantitative and qualitative risk assessments have been made, mostly qualitative analysis. Quantitative risk assessment has been made with help of a fault tree.

Chalmers professor Lars Rosen has also been cooperating with Lackarebäck in the risk assessment area.

A contingency plan has been developed in case of any error or malfunctioning in the plant. They also have a document called Verksamhetshandboken where all the routines and maintenance routines for when the plant is operating normally and during mall functioning. In another document called Beredskapsplan the criteria for shutting down the plant are stated and the approach for how to handle a contamination is also included.

All staff in Lackarebäck is required to attend to the courses that Svenskt Vatten provides. And the staff has different background when it comes to education in some cases a higher education is required. Kretslopp och Vatten also have internal education in several areas, where the staff can improve their knowledge and keep a high competence.

# APPENDIX G – INTERVIEW TRANSCRIPT: ALINGSÅS AUTHORITY

Miljöskyddskontoret in Alingsås is an audit and controlling authority and drinking water control is one of their focuses. Their role is to control that the water that goes out to the consumers is safe and that the suppliers follow the legislation set by Livsmedelsverket. This is done by checking the test protocols.  In case of contamination the drinking water plant has the main responsibility.

When starting the operation a drinking water plant has to submit a Provtagningsprogram, here all the test and frequency are listed and Miljöskyddskontoret has to control and approve the plan. Changes can be made in the test plan if the supplier or Miljöskyddskontoret finds it necessary due to changes in the system or other changes. Raw water testing is not included in the test plan. But since the raw water quality is of most importance for the water processes the supplier also tests the raw water although besides the approved Provtagningsprogram.

Results from the test made in the water plant are sent directly to Miljöskyddskontoret and there the result are reviewed and if a results deviates, contact is established with the water plant to follow up the results. The results can be hard to analyse therefore method of presenting the data is discussed, graphs have been discussed so that trends in the water plant become clearer.

During controls in the drinking water plant the practical aspect are examined so that they follow the legislation, the alarms are checked and routines are reviewed. When the controls are done, reports are written with conclusions and observations.

Employees in Miljöskyddskontoret have different backgrounds as inspectors, since water is not their only concern. The staff has been to courses that Livsmedelsverket arranges, and they have organised their own courses where important people in the business has been invited. They also participate actively in Göteborgs Regionens Dricksvatten Grupp, where they meet two times a year to discuss different problems and assessments that have occurred. The department works constantly with upholding the competence in the department.

In the municipality God Disinfection Praxis is used and allot of work is being done with WSP at the moment maybe not structured and systematic as the WHO guidelines. But the terms used are different and from Svenskt Vatten, it would be possible to work more systematically with WSP.

The impression that Miljöskyddskontoret has about Färgens drinking water plant is that it is a well-functioning plant and they have worked actively with the water quality. In small municipality it is important to make risk analysis so that an investment can be made in drinking water quality. In Alingsås the population and politicians are very interested in drinking water quality and safety, which makes decisions and investment easier to get. Right now there are no need for improvement in the drinking water supply chain. And the communication between Miljöskyddskontoret and the supplier is very good.

An opinion is that WSP is very important, since there can always be threats to the drinking water and its quality, in Sweden we are very spoiled with the availability and quality of the water. Although implementation of WSP and the different plans are important, they are costly to make and time consuming.

If a case of contamination would occur, Miljöskyddskontoret would mainly ask the supplier to investigate and analyse the cause of contamination. In the municipality all departments that are concerned with drinking water have to work together in case of contamination a central krishanteringsplan is being developed in within the municipality. Östersund has been an eye-opener for the municipality and has made them more aware of the hazards to the drinking water.

# APPENDIX H – INTERVIEW TRANSCRIPT: ALINGSÅS SUPPLIER

Färgen the drinking water plant in Alingsås serve 26 000 people with water. The plant is very conventional and was built during 1950. The raw water is pumped up to Färgen's water plant and the first step is to adjust the pH with help of soda. Thereafter there is a precipitation step with help of aluminium sulphate, where the big particles are removed, and then the water is filtrated through sand filters and finally goes through UV-light and chlorine is added. So far the drinking water process in place has managed the variations of the raw water quality very well.

The raw water has a really good quality and there is a good quantity of it in the Lake Lilla Färgen Lake. Since the 1970 lime has been thrown into the forest areas around the lake and the streams that lead to Lake Lilla Färgen Lake, consequently the lake has a stable water with a neutral pH. This measure has been taken because of acidification in the lake. The risks around the raw water source are very few, since there are no outlet from industries and no settlement around the lake. One risk that has been established for the raw water source which is a road that is trafficked by vehicles with dangerous goods thus a secondary raw water source has been chosen in case of an accident.

Tommy Blom and Jennie Eriksson are very familiar with WSP and follow the recommendations from Svenskt Vatten when developing the WSP for Färgen. The WSP for the drinking water plant is at this time not finalised and quite some work and resources have been put into finalising and establishing the guidelines for the water protection area.  And a contingency plan is being developed by the municipality in case of an outbreak due to waterborne diseases. Drift routines have been established for the drinking water plant during normal operation.

Samplings carried out in the drinking water plant are all according to the regulations set by Livsmedelsverket. An online system is used to monitor the process in the drinking water constantly, so that no process failure occurs. Raw water quality in the first raw water source is tested and analysed every month and for the secondary raw water source tests are carried out twice a year. Quality limits for the raw water source should be established by Livsmedelsverket is a common opinion. In addition once a year all parameters that are not monitored during normal operations are analysed. Microbiological tests are made once a week and sent to an accredited laboratory.

Risk analysis have been made for the raw water source by consultants, the method used was their own method called Lindholm-Blom. The water protection area was first made 1993 and is updated now 2015, and the risks to the raw water source have been accessed again. In the regulatory document Vattenförsörjningsplanen several risks have been weighed in the whole drinking water system. The risk analysis in the drinking water plant is made by HACCP and this method has been used two times and was last updated 2013, it is an easy method that is done by the drift workers in the plant. The HACCP is a good method where the risks in the plant are easily evaluated and can be remediated almost at once.

Documentation is extensive in a drinking water plant, during normal operation all the parameters measured are online and saved in the hard drive. In the computer programme all false alarms are documented additionally and the supervisory control is documented in the same place. False alarms in the drinking water process are redirected directly to the operating technician.

If the water quality from the drinking water plant has bad quality and the plant has to be shut down there is a long process to follow. The municipality would need to be notified and a conversation is started on how to proceed. The water quality would have to be controlled before boiling recommendations would be issued. A contingency plan for the process is being developed with cooperation from the municipality, but a chain of contact has been decided.

Education for the staff is a certification that is given by Svenskt Vatten, which is a two weeks programme where drinking water is the main topic. The staff in Färgen's drinking water plant are mainly educated in vocational training since the work that has to be done is mostly practical. Färgen has no internal education for the employed and no WSP education is given.

Future challenges for Färgen's water plant can be climate changes that increases the humus halts in the raw water. The plant has no active carbon filters to give the water a better taste, and if the quality of the raw water decreases, investments might have to be directed towards carbon filters. The distribution system will be rebuilt in different areas to increase capacity and to make reparations in the pipes.

# APPENDIX I – INTERVIEW TRANSCRIPT: ÖSTERSUND SUPPLIER

The quality of the drinking water supply system is checked through different sampling and monitoring procedures, all according to the guidelines. At the plant, online monitoring and sampling for laboratory tests validates that the treatment is working correctly. Microbial quality of the source water is also monitored extensively, testing for E.coli, enterococci, clostridium, giardia, among others. Moreover, Livsmedelsverket is currently doing some sampling of their own.

The water level at Storsjön varies during the year, but the raw water intake is at an appropriate depth. Microbial quality is also varying, occasionally being problematic on the surface of the lake. Microbial quality at the intake is sometimes affected. For this reason, improvements are being tested at the plant i.e., they are planning to install a membrane filter.

Existing water protection areas are currently being revised and new ones being planned. Östersund has also worked to improve their stormwater system and wastewater plants. The city has conserved Livsmedelsverket handbook for raw water and done some adjustments to it.

Because of the recent outbreak, water quality is a more relevant issue in the eyes of the public. It has made authorities more aware of the need to protect their water source and the importance of implementing measures to this effect. As for the water supplier, it is hard to say the effect it has had since they are trying to continuously improve all parts of the water system. One measure that was taken during the outbreak was the installation of UV disinfection.

There has been some qualitative risk assessment done, covering from source to tap. It was first done circa 2009, and updates are performed every election year. Risks have been identified and are dealt with in differing ways: some risks are accepted and routines and plans are prepared in the event that they do occur; for others, improvements in the treatment plant or in the distribution system are carried out.

UV dosage is a critical monitoring parameter; water supply will be cut off if a system failure occurs and subsequently, a decision on what to do will have to be made, e.g., indicating the consumers to boil the water. There is an alarm system in place for chlorine, but supply will not be cut off automatically. Turbidity has a two-flag alarm system, which was installed after the outbreak (only one flag previously).

HACCP is used mostly to determine course of action when online measurements deviate from guideline values. Beredskaphandling is used for more serious problems, e.g. failure of UV-disinfection. It details the course of action to take and who to contact. Water supply plans have been partially implemented in the community. The small plants have completed plans, while the one for Minnesgärdet is still in progress. There is not a very detailed plan in case of an outbreak. Authorities, however, are always involved. The municipality possesses a large crisis group and Östersund Vatten also has a crisis group with several functions, such as taking samples.

Documentation of issues arising in the water supply system varies with each case. For example, detections of coliforms in the drinking water are rare; hence, the documentation of such an instance is extensive. Water leaks are mapped in the system and sometimes samples are taken, which is handled in another document. Documenting the problems that occur in the system aids in providing explanations for future problems.

The staff is always informed of corrective measures taken in the system, as well as the authorities. There is a group that is always available outside working hours in case emergencies arise, that are also informed of the measures. The staff is required to take Svensk Vatten's courses, e.g., hygiene, Svenskt Vatten diplomutbildning. Courses are not limited to Svenskt Vatten, they can also be imparted by different instructors. Staff is supposed to attend these courses at least every five years. However, the educational profile is mostly chosen during the recruitment phase, depending on the needs of the plant.

Climate change is one of the major future challenges for Östersund’s drinking water supply. The interviewee believes that the implementation of the filtration system in the treatment plant is of utmost importance to be prepared to manage this issue.

# APPENDIX J – INTERVIEW TRANSCRIPT: LATVIA LWWWWA

**Font**

Baiba Gulbe

Kamila Gruskevica

**Overview**

Water companies are owned by the municipalities, and only one company in Latvia is private company. Latvia implemented the EU Water Directive after 2005, with the Regulations of the Cabinet of Ministers Nr. 235. The water directive is on the way to be implemented. We have governmental level (Ministry of Health) in charge of implementing drinking water directive. This organization makes legislation about drinking water safety and quality.

Water is a social activity, not really economical. Audit procedures regarding quality are done to ensure safety of water. Guidelines and regulations are followed in how to maintain and how to make water wells.

All water companies have a license. That means they have to follow certain rules on how to operate, and what to do with the water resources. They also have to pay a water resource tax. There are regulations of Cabinet of Ministers about monitoring of territories, groundwater, and different parts of the system (mains, treatment plant). Water suppliers are only required to renew their certification If there are any amendments in the regulations or changes.

Every water company makes their monitoring program every year. Reservoirs, some places chosen in water mains, water in wells, points before treatment and after treatment are monitored. In Latvia, it is called a measurement plan. The plan includes quality checks on what you need to measure, how often, and suggested activities if there are some problems. Parameters are chosen based on the regulations. Some are monitored online (e.g., pH, turbidity) but daily check for parameters that are not online. They use the laboratory inside the Daugava plant to perform the testing. They check the pipe system maybe once a week or once a month. For wells, monitoring done once per year. Treatment stage, once per three months. Water reservoirs is 4x week. Some parameters like arsenic, copper, mercury are done once per year. Cities, once per month they check bacteria and turbidity. Checks from the taps, 36 sample places. Sampling places are chosen from health inspection methodology, they suggest choosing schools, hospitals, public places. In smaller plants, online monitoring is not advisable because they do not have the experience/competence. They usually hire a laboratory to do their testing. They also do not have such a staff to do the monitoring, some even have just one person to check both water and wastewater treatment plant.

If there are emergency cases, like a fire, it is a different stage of planning. It involves the entire municipality and it's known as a civil defence plan. The emergency cases are written down, what to do. They make additional checks; they close the mains and deliver the water in trucks. They have a plan on how to inform the government step by step, and how to inform the population and if it is confirmed that people cannot use the water even if it's boiled, then they have large reservoirs where people can collect water. Use public locations to inform, and also social media. To communicate to the public they spread leaflets, give out public information about water quality in homepages.

We have not only self-control systems, but also have state health inspectors that check every year to plans and monitoring to drinking water. They also check complaints about water quality from the users. The health inspectors can make special plans for water companies: by checking how the water affects the health of people, taking additional measurements and set a time limit for the solution to be carried out (this measure is usually related to high iron content).

We have water quality borders (sanitary safety areas for water sources) and it's made by a Cabinet of Ministers. Wells are deep wells, around 150 m deep. From Baltezers Lake, the water is artificially infiltrated. Riga water uses 60% groundwater and 40% comes from the Daugava plant. We have a mixing zone in the centre, and we have about 3-4 different sources in Riga and in case of emergency shutdown of one of the plants, the other plants can cover the demand.

**Risk assessment**

We had a huge project inside the Six Framework (SECURA), we had dissemination, where we invited all the people from the water companies and we had a discussion of the risks and what can we do about them. The workshop was a one-time event, but Baiba usually goes to conferences where experience can be shared.

Companies have studies of specific cases of risks, for example, of flooding. They have investment projects to change the location of the water fields, due to the high risk of flooding.

We don't have a methodology to calculate health costs. We have cost-benefit analysis to the investment project, and we have analysed what would happen if the project is not carried out. But the costs are not related to quality or drinking water.

**Communication**

We have a yearly public report about the water quality problems, solutions, of all the municipalities in Latvia. Five years back, maybe ten years. Usually if you cannot find a specific year, you can contact the supplier and get the information from them. In the report you can also find a summary of the results from the testing, documented facts of the problems and how they solved the problems (e.g., you will find how many % of the population had higher levels of iron than recommended). Companies are required to make the results of the tests public, as part of their certification.

**Benchmarking**

There is no such study for benchmarking, but every water company shares their experience and knowledge on the way. The association organizes workshops on different topics, we have meetings once every three months. They are usually about new regulations, companies presenting new products, etc.

There's a Baltic conference every year, we discuss about our problems, perspectives and what has been done.

**Education**

If you work in lab, you need to go through courses related to microbiology and about sampling standards.

Operators are selected based on recruitment. We have staff training, where they go and learn from the operation of other plants. No education related to WSP is currently given.

**Problems in Latvia**

Groundwater wells usually do not have issues with water quality. The only problems are high iron and manganese and ammonia. Sources of contamination are usually of natural origin.

In Latvia roughly 75% are connected to centralized water systems, which means that a large part of the population relies on private wells for water. This is problematic, cause this wells are usually shallow (higher risk of contamination). There is high turbidity in Daugava, and during warm periods, there may be issues with cyanobacteria. There is also a high load of organic content in the water, which is difficult to remove with the current treatment system.

Usage of water decreased dramatically. For example, in the 2000s, 180 lpd and now its 65 lpd. It's also regarding water prices and reconstruction of the system (reduction of leaks). And that is a big problem in the mains and its safety. Water companies need to follow firefighting rules, which increases the diameter.

Velocity in the mains is low. That is why water companies do some flushing, annual flushing.

**Future challenges:**

Challenge is with individual people that are not connected to municipal drinking water. We need to work on how to inform them about their impact in the environment. Some companies started checking microbiological components of private wells. Focus for the future is rehabilitation of mains and wastewater treatment (optimization of existing treatment). It's a challenge to change the optimistic way of planning. Here we do not have expected population growth; we need to think about amount of water people consume now (65 lpd) but in regulations we assume 150 lpd. We need to adjust to our daily needs and not optimistic estimates.

# APPENDIX K – INTERVIEW TRANSCRIPT: LATVIA RTU

In terms of water safety planning there have been some initiatives from the ministry level and academic institution to initiate the WSP process. Though it is not being actively being introduced and there is reluctantly due to two major factors:

- The risks in Latvia are not so huge compared to the risks in South Africa. Flooding problems are low and the quality of the raw water is relatively good, although they have problems with Iron, Manganese and other metals.
- Money is also an issue, how much will implementing a WSP cost? It is beneficial in other areas like the food industry, but it has to be introduced to the municipality and water management. There is lack of information and education in this area.

When it comes to water management, in general the municipalities handle all the water companies. They are regulated by local regulations; the implementation of water safety planning is less important for them and more important for academics.

An example is, if a contamination is introduced in the middle of the system, the probability of finding the source of contamination with sampling is less than 5%, therefore it will not be possible to detect the source of the contamination due to the fact that no risk assessment has been done. And if the risks can be identified it is more probable that the contamination source is found. When risks are not known the investments are spent in the wrong area, when risks are defined investments can be made wisely.

Raw water source for the drinking water plant is Daugava and can be a risk. Different sources can pollute the raw water, and it is hard to monitor where the pollution is introduced in the water. In Belarus they have sampling sites to monitor the quality of drinking water, but Latvia does not have monitoring stations, but the drinking water plant uses a multiple barrier principle so they should be on the safe side.

Another risk that has been identified is the trihalomethanes that is a by-product of disinfection with chlorine. Another risk is the high amount of organics in the rivers, in the treatment step flocculation will not take all the by-products.

Quantity is also a risk, since the city has an aging system and replacements are on-going all the time, there are high leakage rates in the distribution system and the risks in the distribution is intrusion into the drinking water pipes. This can be a major risk if flooding would occur. The decrease of water consumptions also affect the distribution network, since there is less water going into the system the flow in the system is not what it should be.

The price of water is a big issue in Latvia and regulators are appointed to handle the price surveillance. During the time when Latvia was under the Russian regimen water was almost for free, but that changed when Latvia became independent. The population mostly by bottled water and don't drink from the tap. The consumption has decreased in Riga from 400 litres/ person to 100 litres/person.