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LITERATURE REVIEW ON THE METHODOLOGY FOR DETERMINING THE NEW QUALITY REQUIREMENTS FOR DOMESTIC WATER

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ABSTRACT

The aim of the study was to discover a methodology for determining the new quality requirements for domestic water. The focus was on chemical parameters due to the need from the commissioner.

The research method was a narrative literature review. Literature searches were conducted for chemical parameters and for analysis methods. Data was collected from laws and decrees on both EU and national levels, research articles, standards, and publications and reports by public entities.

EU legislation sets the minimum quality requirements for the new chemical parameters. National legislation sets general requirements for the determination methods for the chemical quality parameters, for example, an obligation to use primarily the SFS-EN standard in the laboratory investigations. As a result of the study the new quality requirements for household water were determined, their analysis methods outlined briefly, and the required equipment was listed.

Keywords: water quality, chemical parameters, domestic water

CONTENTS

1 INTRODUCTION

Water is a prerequisite of life. United Nations' sustainable development goal number six aims to attain clean and accessible drinking water for all and to improve the quality of water (United Nations n.d.). According to the Sustainable Development Goals report 1.6 billion people will suffer from a shortage of safely managed drinking water in 2030 (United Nations 2022, 13).

Domestic water is defined as water intended for drinking, preparation of food or other household purposes in private, public or commercial places (Terveydensuojelulaki 763/1994). High-quality domestic water can be produced using any raw water; the cleaning process differs depending on the characteristics of raw water (Finnish Environment Institute 2021). In 2021 in Finland 42 % of domestic water was produced from groundwater, 40 % from surface water and the rest came from artificial groundwater (Finnish Institute for Health and Welfare 2021, 4).

Water quality describes the suitability of water for its intended purpose (Finnish Environment Institute 2021). In Finland the domestic water quality is good. According to the public authority research conducted in big water supply areas 99.98 % of the results complied with the health-based quality requirements for domestic water (Finnish Institute for Health and Welfare 2021, 2). Domestic water quality requirements consist of both microbiological and chemical requirements which are prescribed in national regulations (Finnish Environment Institute 2021). General indicators for water quality are temperature, one of the basic measurements in water research, odour, taste, colour and turbidity (Finnish Environment Institute 2021).

Drinking water quality is dependent on the source of water supply, disinfection procedure and distribution network. Corrosion, hydraulic conditions of the distribution network as well as the release of substances from the pipe materials contribute to the quality of water. (Feretti et al. 2020.) The quality of water can deteriorate if it stays too long in the water distribution system (Finnish Environment Institute 2021). Disinfection by-products with adverse health effects can occur in the drinking water. The formation of disinfection by-products is consistent with the natural organic matter concentration in the treatable water, particularly if the disinfection is performed with chlorine. However, the sufficient concentration of chlorine is a requisite to decrease the microbial risk. In addition, the reaction between disinfectants and organic matter as well as the microbial growth can be affected by physiochemical characteristics like pH, metals and temperature of water. (Feretti et al. 2020.) In Finland the municipal health protection authority supervises the quality of domestic water regularly; the object is to verify the quality of domestic water and that it does not cause health hazard (National Supervisory Authority for Welfare and Health (Valvira) 2023).

The aim of the study is to discover a methodology for determining the new quality requirements for domestic water set in Decree of the Ministry of Social Affairs and Health amending the Decree of the Ministry of Social Affairs and Health on quality requirements and monitoring studies of domestic water (Sosiaali- ja terveysministeriön asetus talousveden laatuvaatimuksista ja valvontatutkimuksista annetun sosiaali- ja terveysministeriön asetuksen muuttamisesta 2/2023, Appendix 1, Table 2). The study focuses on chemical parameters which are the most relevant parameters in research in the environmental laboratory. The research questions are:

1. What are the new quality requirements for domestic water?
2. Why are these parameters being investigated?
3. What analysis methods can be used to verify compliance with the new quality requirements?

The expected outcome of the study is a literature review on the new quality requirements for chemical compounds, their method of analysis and required equipment to be used in the analysis. This literature review serves Xamk Environmental Laboratory in their different research projects.

2 QUALITY CRITERIA FOR DOMESTIC WATER

Quality criteria for domestic water are composed of quality requirements and quality targets. Quality requirements and targets are set for different parameters. Quality parameters for domestic water consist of microbiological parameters and chemical parameters. Both parameters have their own quality requirements. Quality targets are set for indicator parameters. (Directive (EU) 2020/2184.)

2.1 Microbiological parameters

The microbiological quality of domestic water is monitored by observing the presence of indicator microbes (National Supervisory Authority for Welfare and Health (Valvira) 2020, 5). *E.coli* is under continuous supervision (National Supervisory Authority for Welfare and Health (Valvira) 2020, 7). *E.coli* is considered the best indicator microbe for intestinal contamination and the presence of these indicator microbes in household water denotes the possibility of presence of pathogens (National Supervisory Authority for Welfare and Health (Valvira) 2020, 7–8). Directive (EU) 2020/2184 states the minimum quality requirements for microbiological parameters (Table 1) in domestic water.

Table 1. Minimum quality requirements for microbiological parameters (Directive (EU) 2020/2184)

Parameter	**Maximum value**
Intestinal enterococci	0 cfu*/100 ml
Escherichia coli (E.coli)	0/100 ml

*colony forming unit.

Good quality domestic water does not contain intestinal enterococci nor *E.coli*: the maximum value of intestinal enterococci in domestic water is 0 colony forming unit (cfu) per 100 millilitre of water. The same applies to E.coli: the maximum value of E.coli in domestic water is 0 per 100 millilitre of water.

2.2 Chemical parameters

The chemical parameters that are examined from the domestic water consist of parameters resulting from raw water, disinfection by-products, parameters resulting from water treatment chemicals, from materials used in supply network, and parameters that are affected by the piping of buildings (Sosiaali- ja terveysministeriön asetus talousveden laadusta ja valvonnasta sekä rakennusten vesilaitteistojen riskienhallinnasta 1352/2015). Chemical disinfectants are utilized in drinking water treatment to eliminate pathogenic microorganisms; the disadvantage is the formation of chemical by-products (World Health Organization (WHO) 2022, 5–6). Constant, long-lasting exposure to chemical substances through domestic water can cause health hazards (National Supervisory Authority for Welfare and Health (Valvira) 2020, 5). Nonetheless, the risk resulting from deficient water disinfection is greater than the risk from disinfection by-products (World Health Organization (WHO) 2022, 6). The quality requirements for chemical parameters in domestic water are set as approximate total intake from water, food and air (which is 2 litres of domestic water per 24 hours). The quality requirements for carcinogenic substances are founded on mathematical risk assessment. (National Supervisory Authority for Welfare and Health (Valvira) 2020, 5.) The new quality requirements for chemical parameters are discussed more in detail in the results section.

2.3 Indicator parameters

Indicator parameters are used for monitoring purposes and quality targets are set for them. Indicator parameters include inter alia colour, conductivity, odour, taste, colony count 22 °C and turbidity. Although the indicator parameters do not influence public health directly, they should be supervised since they can serve to discover inadequacy in water treatment or distribution network. (Directive (EU) 2020/2184.)

2.4 Example of quality parameters commonly examined from domestic water

Directive (EU) 2020/2184 comprises a long list of parameters addressing the quality of domestic water. However, it is not required to examine all the parameters but select the parameters to be monitored based on a risk assessment (Directive (EU) 2020/2184). Table 2 shows one example of quality parameters examined from domestic water in Helsinki region.

Table 2. Quality parameters (collated from Helsingin seudun ympäristöpalvelut (HSY) 2023 & Sosiaali- ja terveysministeriön asetus talousveden laadusta ja valvonnasta sekä rakennusten vesilaitteistojen riskienhallinnasta 1352/2015)

Parameters for continuous quality control	**Parameters for periodical quality control**	**Quality target parameters**	**Parameters to be notified for users**
Aluminium, Al	Cadmium, Cd	Chloride, Cl	Calcium, Ca
Coliform bacteria	Chromium, Cr	Sodium, Na	Magnesium, Mg
Conductivity	Copper, Cu	Sulphate sulphur, SO_4-S	Permanent hardness
Flavour	Fluoride, F	Temperature	Potassium, K
Heterotrophic plate count 22 °C	Lead, Pb	Total organic carbon, TOC	
Iron, Fe	Escherichia coli	$KMnO_4$-index	
Manganese, Mn	pH	Ammonium nitrogen, NH_4-N	
Odour			
Turbidity			
Escherichia coli			
pH			

From these parameters aluminium, coliform bacteria, conductivity, flavour, heterotrophic plate count 22 °C, iron, manganese, odour and turbidity are parameters to be determined in continuous quality control whereas cadmium, chromium, copper, fluoride and lead are parameters included in the periodical quality control. *Escherichia coli* and pH are determined in both monitoring schemes. (Sosiaali- ja terveysministeriön asetus talousveden laadusta ja valvonnasta sekä rakennusten vesilaitteistojen riskienhallinnasta 1352/2015.) In addition, Helsinki Region Environmental Services (HSY) monitor the household water quality by examining quality target parameters: chloride, sodium, sulphate sulphur, temperature, total organic carbon (TOC), $KMnO_4$-index and ammonium nitrogen (Helsingin seudun ympäristöpalvelut (HSY) 2023). Furthermore, calcium, magnesium, permanent hardness and potassium are parameters that are examined for water user notification purposes (Sosiaali- ja terveysministeriön asetus talousveden laadusta ja valvonnasta sekä rakennusten vesilaitteistojen riskienhallinnasta 1352/2015).

2.5 Legal framework

Directive (EU) 2020/2184 states the minimum quality requirements for water intended for human consumption in European Union Member States and it came into effect on 12 January 2021. Finland among other Member States had the obligation to enforce the quality requirements in national laws by 12 January 2023 (Directive (EU) 2020/2184). Public health act (Terveydensuojelulaki 763/1994), Health protection regulation (Terveydensuojeluasetus 1280/1994) and Decree on the quality and control of household water and risk management of water installations in buildings (Sosiaali- ja terveysministeriön asetus talousveden laadusta ja valvonnasta sekä rakennusten vesilaitteistojen riskienhallinnasta 1352/2015) among others were modified to correspond to the EU Directive (Vesilaitosyhdistys 2023).

Private wells are regulated by Decree on household water requirements and monitoring studies for small units (Sosiaali- ja terveysministeriön asetus pienten yksiköiden talousveden laatuvaatimuksista ja valvontatutkimuksista 401/2001); individual households that utilize private wells for domestic water supply are responsible for the quality of their own water.

3 MATERIAL AND METHODS

The methodology of the study is a narrative literature review. The selection of the most appropriate methodology was based on the purpose of the review and the literature type (Xiao & Watson 2017). The literature review is planned by recognizing the need for its completion, defining the aim and establishing the review protocol (Xiao & Watson 2017). The need for the literature review came from the amendments to national legislation concerning the quality requirements for domestic water. A clear and compact code of practice would save time and effort from the environmental laboratory when the information is searched. The literature review can be useful in current and near future projects in Xamk Environmental Laboratory.

The aim of the study was defined considering the usefulness of its results for the Xamk Environmental Laboratory. The review protocol was established based on the research questions. To answer the first research question “What are the new quality requirements for domestic water?” laws and decrees on both EU and national levels were investigated: in particular the Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (Directive (EU) 2020/2184), the Decree on the quality and control of household water and risk management of water installations in buildings (Sosiaali- ja terveysministeriön asetus talousveden laadusta ja valvonnasta sekä rakennusten vesilaitteistojen riskienhallinnasta 1352/2015) and the Public Health Act (Terveydensuojelulaki 763/1994) were examined. To answer the second research question “Why are these parameters being investigated?” a literature search was conducted. To answer the third research question “What analysis methods can be used to verify compliance with the new quality requirements?” the Directive (EU) 2020/2184 and the Decree on the quality and control of household water and risk management of water installations in buildings (Sosiaali- ja terveysministeriön asetus talousveden laadusta ja valvonnasta sekä rakennusten vesilaitteistojen riskienhallinnasta 1352/2015) were examined to revise whether there were any requirements for the analysis methods. According to the national decree (1352/2015 Appendix III), SFS-EN standard must be used in the determination method for chemical parameters, and so a search for analysis method was performed in SFS Online service.

The literature review is conducted by gathering, analyzing and combining data, and lastly the findings are reported (Xiao & Watson 2017). Data was collected by two separate literature searches: one for gathering information on the new water quality parameters and the other for the determination methods. Lastly data was combined from different research articles, standards, laws and other publications.

3.1 Literature search for new water quality parameters

The following databases were used: Science Direct and Directory of Open Access Journals (DOAJ). Material was searched for in the Kaakkuri, customer interface of the Library of South-Eastern Finland University of Applied Sciences. The literature search was done separately for each chemical parameter (see Figures 1 to 5). The searches were narrowed down by the year of publication between 2018–2023 to keep the data as current as possible. Only peer reviewed articles with access to full text were included. Articles written in other language than English or Finnish were excluded. The search terms appeared in the abstracts of the articles. The first screening of the articles was done either by examining the titles (Figure 1) or by examining the titles and abstracts (Figures 2, 3, 4 and 5). The literature search for bisphenol A is demonstrated in Figure 1 (the diagram is adapted from Xiao & Watson 2019).

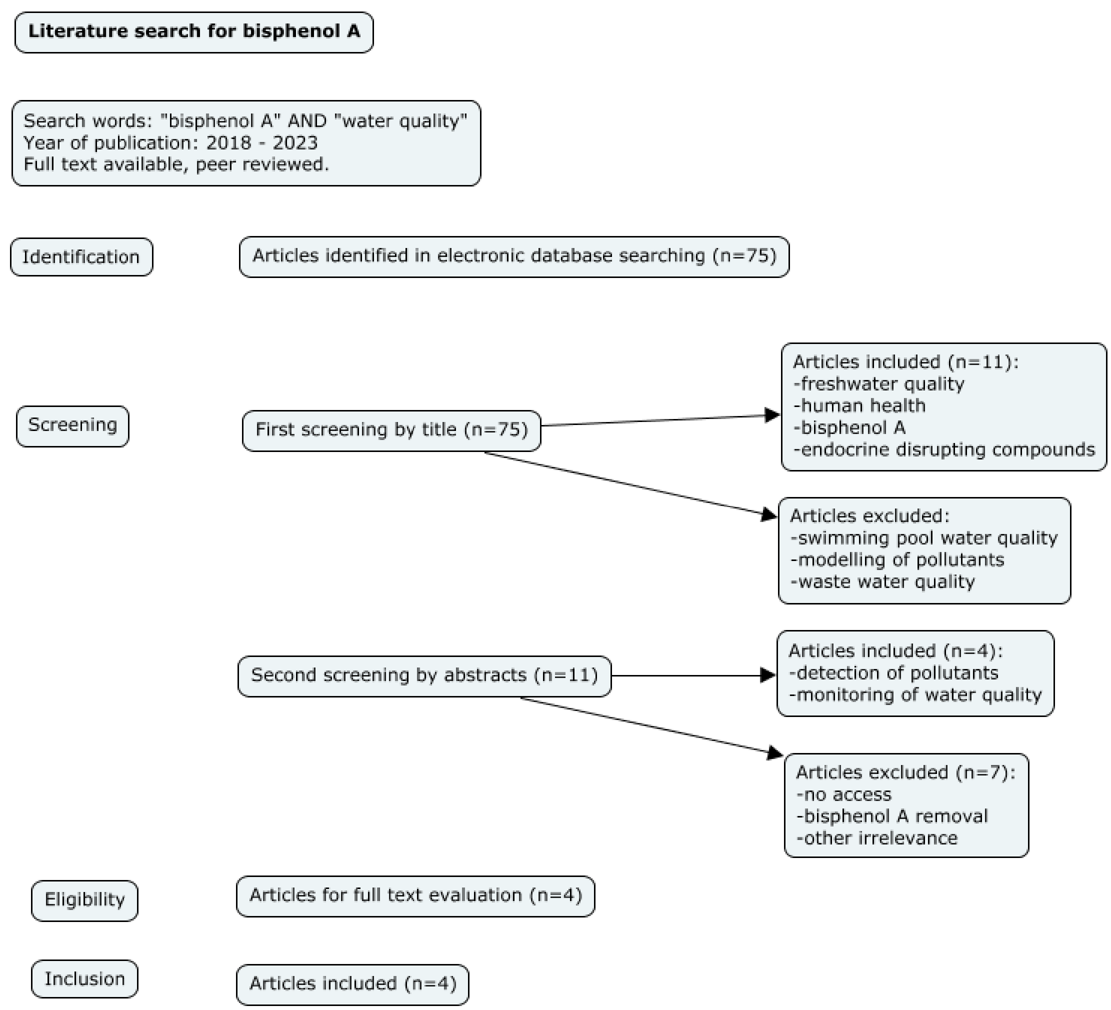

Figure 1. Literature search for bisphenol A

The total of 75 articles were identified from the search criteria. The inclusion and exclusion criteria varied in the different screening phases. In the first screening articles were included to the next phase if they dealt with freshwater quality, human health, bisphenol A or endocrine disrupting compounds. In the second screening articles were included to the full text evaluation if they dealt with detection of pollutants or monitoring of water quality. Four articles were included in the review.

Figure 2 shows the literature search for chlorate. 13 articles were identified in electronic database searching. After the first screening seven articles were included in the full text evaluation.

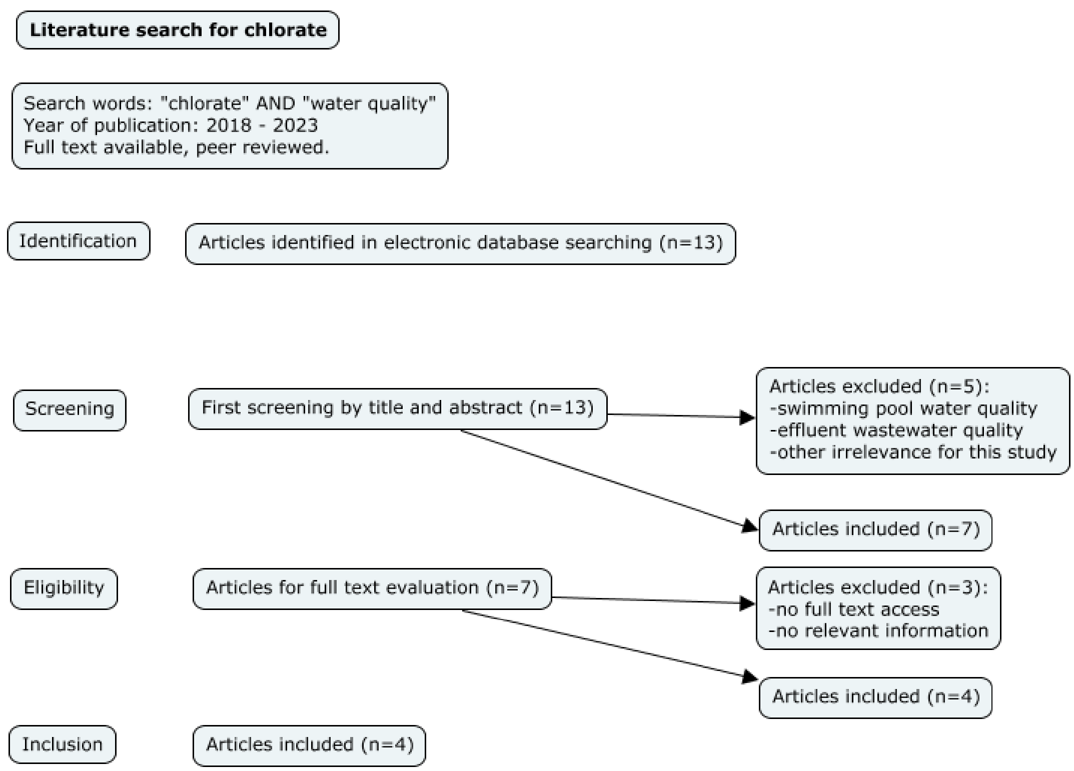

Figure 2. Literature search for chlorate

In the end 4 articles were included in the review. Additional information on chlorate was searched and included from the website of Finnish Institute for Health and Welfare (2023b).

The literature search for chlorite is demonstrated in Figure 3. From 30 articles resulted in the search only three articles were screened for the full text evaluation. However, relevant information was not found from these articles, and the search terms were changed to “chlorite” AND “health effects”.

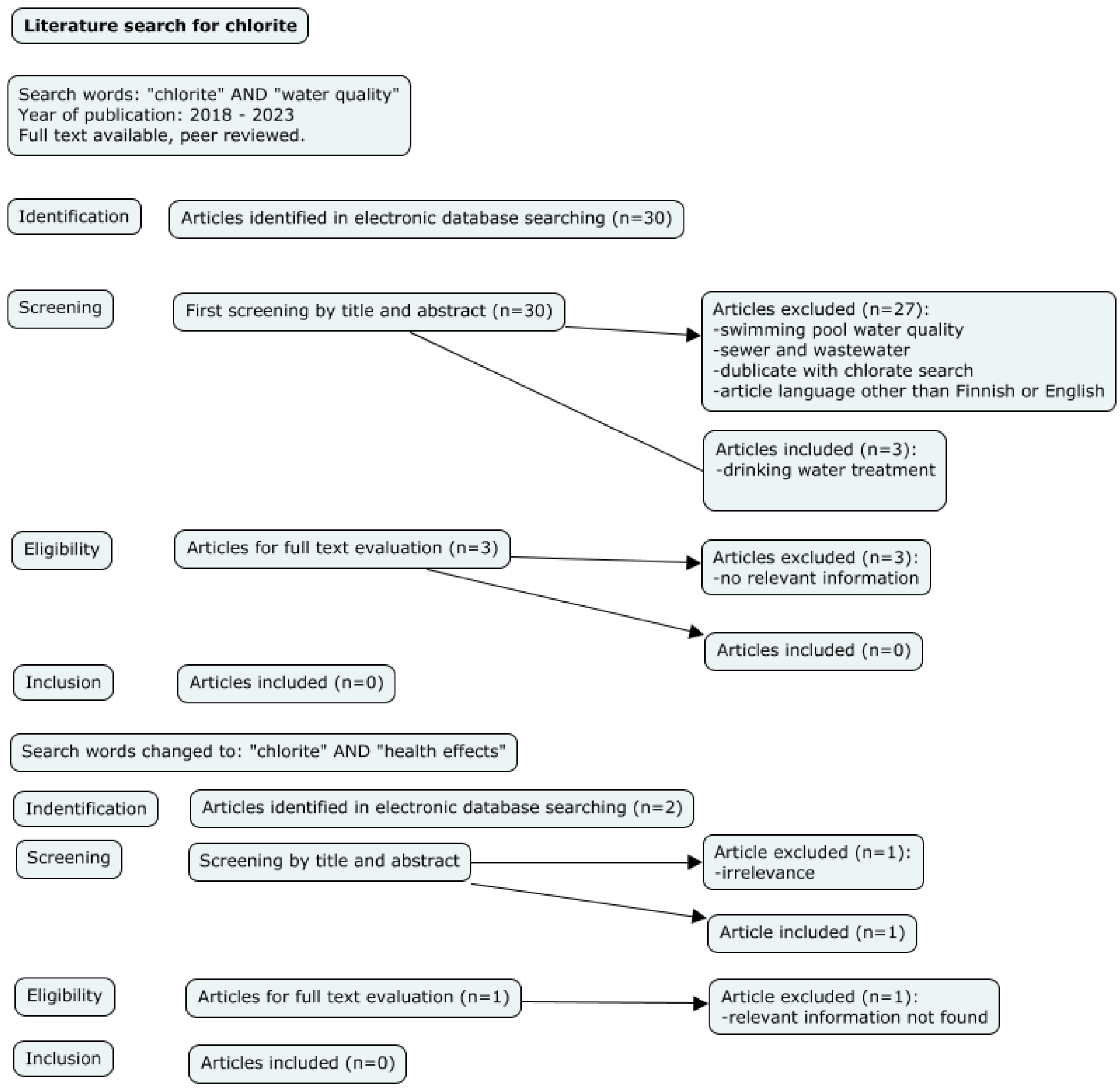

Figure 3. Literature search for chlorite

The new search resulted in two articles which were not relevant for this study. Additional information on chlorite was searched from the website of Finnish Institute for Health and Welfare (2023b).

The literature search for haloacetic acids (HAAs) (Figure 4) resulted in 63 articles. The articles were screened by title and abstract and articles were included for more in-depth evaluation if they dealt with water disinfection by-products, drinking water, analysis of HAAs or health concerns regarding HAAs. Two articles were included in the review.

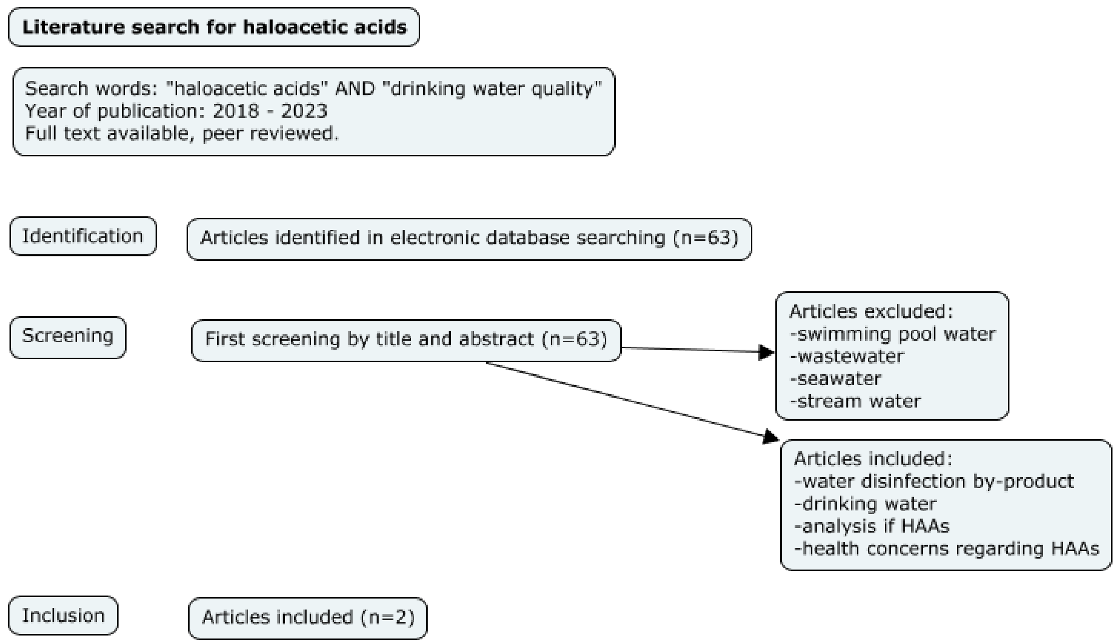

Figure 4. Literature search for haloacetic acids

Literature search for microcystin-LR (Figure 5) resulted in 20 articles. The screening of the articles was done by titles and abstracts and only one article was included in the review.

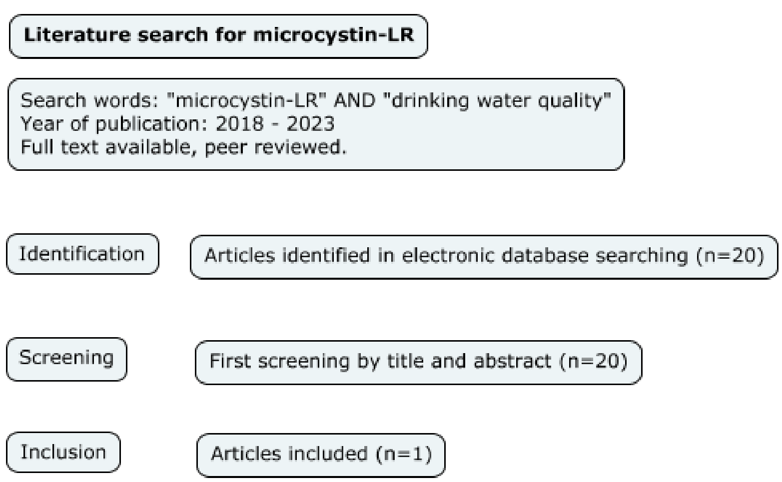

Figure 5. Literature search for microcystin-LR

Additional information was found from World Health Organization’s (2020 & 2022) publications related to drinking water quality guidelines.

3.2 Literature search for determination methods

As the national decree (1352/2015 Appendix III) requires SFS-EN standard in the determination method for chemical parameters the search for determination methods was conducted in SFS Online service. The search was conducted separately for each parameter.

Search for determination method for bisphenol A was conducted on 11 April 2023. The keyword used for the search was “bisphenol A” and it gave four results. Three of the given results were excluded due to irrelevance and the standard SFS-EN ISO 18857-2 was chosen.

Search for determination method for chlorate was conducted on 11 April 2023. The keyword used for the search was “chlorate” and it gave nine results of which three were duplicates of Finnish and English. The duplicates were excluded due to irrelevance (industrial use) as well as the other two (pyrotechnic articles and sodium chlorate). The standard SFS-EN ISO 10304-4 was chosen. The same determination method resulted in chlorite.

Search for determination method for haloacetic acids was conducted on 12 April 2023. The keyword used for the search was “haloacetic acids” and it gave one result: SFS-EN ISO 23631.

Search for determination method for microcystin-LR was conducted on 2 May 2023. The keyword used for the search was “microcystin-LR” / “microcystin” and it did not give any result. Determination methods for microcystin-LR were searched from World Health Organization’s (WHO) guidelines for drinking water quality.

Search for determination method for per- and polyfluoroalkyl substances (PFAS) was conducted on 2 May 2023. The keyword used for the search was “PFAS” and it gave two results. However, these standards were intended for determination of PFAS in textile materials and coated fabrics, not in water, and they were excluded. Search with keyword “per- and polyfluoroalkyl substances” did not give any result. A suitable determination method was found in United States Environmental Protection Agency’s (EPA) website.

4 RESULTS

Directive (EU) 2020/2184 sets the minimum quality requirements for the new chemical parameters – that is the maximum concentration of chemical compound in one litre of water (Table 3). Bisphenol A, a parameter that may be affected significantly by the piping of the buildings, has a maximum concentration of 2,5 µg/l. Chlorate and chlorite have a maximum concentration of 0,25 mg/l and yet a maximum concentration of 0,70 mg/l is accepted if chlorine dioxide, or other disinfectant that forms these by-products, is utilized. The maximum concentration for haloacetic acids is 60 µg/l. For microcystin-LR, which is mainly resulting from raw water, the maximum concentration is 1,0 µg/l. Sum of PFAS has a maximum concentration of 0,10 µg/l.

Table 3. Minimum quality requirements for the new chemical parameters (Directive (EU) 2020/2184) and their determination methods

Parameter	**Maximum value**	**Determination method**
Bisphenol A	2,5 µg/l	SFS-EN ISO 18857-2 Solid-phase extraction, solvent elution, derivatization and gas chromatographic-mass spectrometric detection
Chlorate & chlorite	0,25 mg/l	SFS-EN ISO 10304-4 Liquid chromatographic separation, conductivity detection
Haloacetic acids (HAAs)	60 µg/l	SFS-EN ISO 23631 Extraction (magnetic stirrer and microseparator or separation funnel), concentration (rotary evaporator or nitrogen stream), derivatization, and gas chromatography analysis
Microcystin-LR	1,0 µg/l	- Mass spectrometry, liquid chromatography or their combination
Sum of PFAS	0,10 µg/l	EPA Method 533 Solid phase extraction, elution, concentration (nitrogen & heated water bath), analysis with liquid chromatography-mass spectrometer, calculation with isotope dilution technique

Directive (EU) 2020/2184 states that the determination method should be verified and recorded compliant with EN ISO/IEC 17025 standard or other globally acknowledged standard. The directive does not specify a certain determination method for chemical parameters, as it specifies for microbiological parameters, yet a minimum performance criterion is required for any method of analysis.

As for the national decree on the quality and control of household water and risk management of water installations in buildings (Sosiaali- ja terveysministeriön asetus talousveden laadusta ja valvonnasta sekä rakennusten vesilaitteistojen riskienhallinnasta 1352/2015), it sets general requirements for the determination method for the quality parameters, for example, an obligation to use primarily SFS-EN standard in the laboratory investigations. However, in the absence of SFS-EN standard an ISO-standard can be used (1352/2015 Appendix III). The main determination methods are compiled in Table 3 and discussed more in detail in the following chapters.

4.1 Bisphenol A

Bisphenol A is utilized in the manufacturing of epoxy resin lining and polycarbonate plastics (Cserbik et al. 2023; Rosenfeld & Feng 2011). It is used in products like water supply pipes, toys and medical tubing (Rosenfeld & Feng 2011). Due to its extensive use bisphenol A is commonly observed in the environment to where it ends up from inefficient treatment of wastewater or industrial effluents (Valcárcel et al. 2018). Bisphenol A can leach at high temperatures and acidic and basic state (Rosenfeld & Feng 2011). Bisphenol A has a short half-life in human body and for that reason it is not regarded as persistent (Cserbik et al. 2023).

Bisphenol A is an endocrine disruptor which can disturb children’s neurodevelopment. In addition, it may augment the risk of cardiovascular problems, infertility and diabetes as well as prostate and breast cancer. (Cserbik et al. 2023; Rosenfeld & Feng 2011.) Daily intake and person’s dose response affect the toxicity of bisphenol A (Rosenfeld & Feng 2011).

Human exposure routes come from drinking water and food: bisphenol A can originate from lining resins in drinking water distribution network, food packing and plastic drinking water bottles (Penserini et al. 2023). In addition, weak removal during the treatment of drinking water may lead concentrations of bisphenol A in tap water (Valcárcel et al. 2018). However, the consumption of fruit and vegetables as well as cereals pose greater risk for bisphenol A exposure than the consumption of tap water (Penserini et al. 2023).

Analysis method: SFS-EN ISO 18857-2

The determination method includes solid-phase extraction, solvent elution, derivatization and gas chromatographic-mass spectrometric detection. The lower range value is contingent on the accuracy of the mass spectrometric detection unit as well as the matrix and the compound in question. For bisphenol A the measurement range is from 0,05 – 0,2 μg/l. (SFS-EN ISO 18857-2:en 2009.)

Equipment for analysis of bisphenol A are a pressure or vacuum assembly needed in the extraction phase, a rotary evaporator with water bath and vacuum stabiliser, a temperature-programmable gas chromatograph which can be utilized in electron impact mode over the relevant mass range, and which contains data system with selected ion monitoring (SFS-EN ISO 18857-2:en 2009).

The minimum performance criterion that is required for the method of analysis of bisphenol A is an uncertainty of measurement of 50 % of the parametric value, resulting in 1,25 μg/l (Directive (EU) 2020/2184).

4.2 Chlorate and chlorite

Chlorate and chlorite are water disinfection by-products often resulting from the disinfection with chlorine dioxide (ClO_2) (Kurajica et al. 2021). Formerly chlorates were utilized as pesticides (Gadelha et al. 2019). Chlorate can be found in domestic water and further in different fresh cut products washed with that water and so it may present a health risk for humans (Banach et al. 2018; Gadelha et al. 2019). Critical effect of long-term exposure to chlorate is that it can preclude the absorption of iodine into the thyroid gland and lead to goitre, whereas the critical effect of long-term exposure to chlorite is decreased liver size (Finnish Institute for Health and Welfare 2023b). In addition, exposure to very high concentrations of chlorate and chlorite may result in oxidative stress and reduce red blood cells and haemoglobin (Feretti et al. 2020; Finnish Institute for Health and Welfare 2023b).

Chlorate ions can be quantified with various analytical equipment: spectrophotometer, chromatography, ion-selective electrodes and flow injection analyzers (Asakai 2018).

Analysis method: SFS-EN ISO 10304-4

The determination method is intended for raw water, drinking water and swimming pool water. The measurement range for chlorate is 0,03 – 10 mg/l using a conductivity detector. (SFS-EN ISO 10304-4:en 2022.)

Equipment for analysis include an ion chromatographic system. Liquid chromatographic separation is performed with separator column; while low-capacity anion exchanger act as stationary phase, an aqueous solution containing weak mono- and dibasic acids is utilized as mobile phase. Conductivity detector can be employed for the detection. Calibration solutions are prepared and analysed chromatographically, and the calibration function is calculated before the measurement of samples. Validity check should be performed between the sample series. The mass concentration of chlorate is calculated with peak heights or peak areas as stated in ISO 8466-1. (SFS-EN ISO 10304-4:en 2022.)

Uncertainty of measurement for chlorate is 40 % of the parametric value, resulting in 0,1 mg/l (Directive (EU) 2020/2184).

The method of analysis for chlorite is the same as for chlorate. However, there are differences in the standard solutions and calibration solutions. In addition, in case of chlorite both conductivity detector, amperometric detector or UV detector can be employed. The measurement range for chlorite is 0,05 – 1 mg/l using a conductivity detector, 0,1 – 1 mg/l using UV detector (λ = 207 – 220 nm) and 0,01 – 1 mg/l using amperometric detector (0,4 – 1,0 V). (SFS-EN ISO 10304-4:en 2022.)

Uncertainty of measurement for chlorite is 40 % of the parametric value, resulting in 0,1 mg/l (Directive (EU) 2020/2184).

4.3 Haloacetic acids

Haloacetic acids (HAAs) are the most frequent chlorination-disinfection by-products together with trihalomethanes (THMs) (Kurajica et al. 2020). The type of natural organic matter and its concentration in the water are the main factors influencing the evolution of HAAs (Gadelha et al. 2019; Kurajica et al. 2020). As a chemical quality parameter HAAs refer to the sum of monochloro-, dichloro-, and trichloroacetic acids, and mono- and dibromo-acetic acids (Directive (EU) 2020/2184). Trichloroacetic acid, dichloroacetic acid and bromochloroacetic acid have been classified as potentially carcinogenic for humans; their long-term, decades of excessive intake may increase the risk of cancer (Finnish Institute for Health and Welfare 2023a). Haloacetic acids are harmful to kidneys and liver (Finnish Institute for Health and Welfare 2023a) and can cause liver tumors in animals (Gadelha et al. 2019). HAAs shall only be examined when drinking water disinfection methods may form haloacetic acids (Directive (EU) 2020/2184).

Analysis method: SFS-EN ISO 23631
The determination method is intended for following haloacetic acids in drinking water and ground water: bromochloroacetic acid, dibromoacetic acid, dichloroacetic acid, monobromoacetic acid, and monochloroacetic acid. The concentration range is 0,05 – 10 µg/l. The usage of mass spectrometry in the detection enables the verification of the analyte whereas detection by electron-capture detector generates lower detection limits. (SFS-EN ISO 23631:en 2006.)

Equipment for analysis include an evaporation assembly, a magnetic stirrer and a microseparator for phase separation, appliance for preparation of diazomethane, and a capillary gas chromatograph with either a mass spectrometric detector or with an electron-capture detector (SFS-EN ISO 23631:en 2006).

The determination method consists of extraction (using either a magnetic stirrer and a microseparator or a separation funnel), concentration (using a rotary evaporator or a nitrogen stream), derivatization, and gas chromatography analysis (SFS-EN ISO 23631:en 2006).

Uncertainty of measurement for haloacetic acids is 50 % of the parametric value, resulting in 30 µg/l (Directive (EU) 2020/2184).

4.4 Microcystin-LR

Microcystin-LR is a toxin produced by cyanobacteria (blue-green algae), extensively spread and is the most examined microcystin (World Health Organization (WHO) 2022, 430). Cyanobacteria may emerge in surface waters both seasonally and year around depending inter alia the climatic conditions, and the blooms are likely to appear continually in the same surface waters (World Health Organization (WHO) 2022, 432). The resulting acute health effects on people can be intrahepatic haemorrhage; also liver damage have been announced (World Health Organization (WHO) 2022, 432). In addition, microcystin-LR could be carcinogenic (Akter et al. 2019; World Health Organization (WHO) 2022, 432).

This parameter shall be examined only if the presence of cyanobacteria in the raw water was likely according to a risk assessment; the total microcystine content may be determined instead of the microcystine-LR (Sosiaali- ja terveysministeriön asetus talousveden laadusta ja valvonnasta sekä rakennusten vesilaitteistojen riskienhallinnasta 1352/2015).

Analysis method

Mass spectrometry, liquid chromatography or their combination is commonly applied as the determination method for microcystins (Akter et al. 2019). The most accurate determination method is liquid chromatography tandem mass spectrometry LC-MS/MS; although the need for reference standards for each microcystin brings challenges to this method. As for liquid chromatography separation and absorbance detection, just a couple of representative microcystin standards are needed; the weak point of this method is the possible overestimation of peaks that are not entirely detached from other substances when utilizing the absorbance detection. When determining the total microcystin content tests that employ biochemical and immunological techniques could be used. (World Health Organization (WHO) 2020, 34.)

Akter et al. (2019) developed lateral-flow immunoassay (LFIA) test for field testing of microcystins which can detect microcystins' concentrations under 4 µg/L. It could be utilized in screening microcystins from surface waters (Akter et al. 2019).

Uncertainty of measurement for microcystin-LR is 30 % of the parametric value, resulting in 0,3 µg/l (Directive (EU) 2020/2184).

4.5 Sum of per- and polyfluoroalkyl substances (PFAS)

Sum of PFAS indicates per- and polyfluoroalkyl substances regarded a concern (Directive (EU) 2020/2184). PFAS consist of over 4700 synthetic chemicals that accumulate eventually in the environment (the short-chain PFAS) and in people, animals and soil (the long-chain PFAS). PFAS have physical and chemical properties like water repellence, chemical and temperature resistance, or oil repellence for which they are extensively utilized in industry and different consumer products. Examples of products in which PFAS are used are paper food wrapping, coatings for frying pans, outdoor clothing, firefighting foams, paints and pesticides. When accumulating in the human body the risk of negative health effects augments: thyroid disease, increased cholesterol levels, liver damage and kidney cancer. In addition, PFAS can cause developmental effects on unborn child, lower birth weight and reduced response to vaccines. Human exposure routes for PFAS are food, drinking water, consumer products and dust. In addition, exposure via skin is possible through cosmetics and creams. (European Environment Agency 2022.) Sum of PFAS, the new chemical quality parameter set for household water in the Directive (EU) 2020/2184, is the sum of concentration of the compounds listed in Table 4.

Table 4. Sum of PFAS (Directive (EU) 2020/2184)

Perfluorobutanoic acid (PFBA)
Perfluoropentanoic acid (PFPA)
Perfluorohexanoic acid (PFHxA)
Perfluoroheptanoic acid (PFHpA)
Perfluorooctanoic acid (PFOA)
Perfluorononanoic acid (PFNA)
Perfluorodecanoic acid (PFDA)
Perfluoroundecanoic acid (PFUnDA)
Perfluorododecanoic acid (PFDoDA)
Perfluorotridecanoic acid (PFTrDA)
Perfluorobutane sulfonic acid (PFBS)
Perfluoropentane sulfonic acid (PFPS)
Perfluorohexane sulfonic acid (PFHxS)
Perfluoroheptane sulfonic acid (PFHpS)
Perfluorooctane sulfonic acid (PFOS)
Perfluorononane sulfonic acid (PFNS)
Perfluorodecane sulfonic acid (PFDS)
Perfluoroundecane sulfonic acid
Perfluorododecane sulfonic acid
Perfluorotridecane sulfonic acid

Analysis method

The EU Commission will compile technical instructions for determination method for both PFAS total and sum of PFAS by January 2024. These instructions will contain detection limits, sampling frequency and parametric values. (Directive (EU) 2020/2184.) Nevertheless, United States Environmental Protection Agency (EPA) (2019) offers a determination method for per- and polyfluoroalkyl substances in drinking water. The analysis method consists of solid phase extraction, elution with methanol that includes ammonium hydroxide, concentration with nitrogen using heated water bath, analysis with liquid chromatography-mass spectrometer in multiple reaction monitoring mode, and the calculation of the concentrations by isotope dilution technique (United States Environmental Protection Agency (EPA) 2019).

The needed equipment for PFAS determination includes solid phase extraction device, a water bath, a laboratory vacuum system, pH meter, and liquid chromatography-mass spectrometer (LC-MS/MS system) which can electrospray ionization in negative ion mode (United States Environmental Protection Agency (EPA) 2019).

Uncertainty of measurement for PFAS is 50 % of the parametric value resulting in 0,05 µg/l (Directive (EU) 2020/2184).

5 DISCUSSION AND CONCLUSION

National legislative and regulatory changes to implement the new Drinking Water Directive (EU 2020/2184) entered into force in January 2023 (Vesilaitosyhdistys 2023). The new chemical quality requirements for domestic water consist of six new parameters and their maximum concentration in one litre of water: bisphenol A 2,5 µg/l, chlorate 0,25 mg/l, chlorite 0,25 mg/l, haloacetic acids 60 µg/l, microcystin-LR 1,0 µg/l, and per- and polyfluoroalkyl substances (PFAS) 0,10 µg/l (Sosiaali- ja terveysministeriön asetus talousveden laatuvaatimuksista ja valvontatutkimuksista annetun sosiaali- ja terveysministeriön asetuksen muuttamisesta 2/2023, Appendix 1, Table 2). These parameters are important to examine since they can cause health problems to humans. Bisphenol A may augment the risk of cardiovascular problems and disturb children's neurodevelopment (Cserbik et al. 2023; Rosenfeld & Feng 2011). Critical effect of long-term exposure to chlorate is that it can preclude the absorption of iodine into the thyroid gland and lead to goitre, whereas the critical effect of long-term exposure to chlorite is decreased liver size (Finnish Institute for Health and Welfare 2023b). Haloacetic acids are harmful to kidneys and liver and some of them are potentially carcinogenic (Finnish Institute for Health and Welfare 2023a). Microcystin-LR could be carcinogenic (Akter et al. 2019). Per- and polyfluoroalkyl substances (PFAS) may cause liver damage, kidney cancer and thyroid disease (European Environment Agency 2022). Standardized analysis methods exist for these chemical quality parameters so that the compliance with the new quality requirements can be verified. The appointed standards can be utilized for detailed procedure of the analysis of chemical compounds when the need arises in Xamk Environmental Laboratory.

In addition to the current quality requirements for domestic water in future other parameters might be examined. Microplastics could be one noteworthy parameter to be examined from domestic water. According to Shen et al. (2020) microplastics can form health risks for humans via drinking water: microplastics have been detected from both bottled water and tap water. According to Wanner (2021), plastics present in agricultural soils can threaten the drinking water supplies when they degrade to smaller particles and transfer from soil to aquifers. Microplastic particles can increase the pesticides moving into groundwater (Wanner 2021). The health concerns from microplastics to humans require more research, however some effects have been indicated (Shen et al. 2020). The Directive (EU) 2020/2184 encourages special attention to risk assessment of microplastics and endocrine-disrupting compounds in areas where drinking water comes from surface waters. Beta-estradiol and nonylphenol are in the watch list of compounds of concern (European Commission 2022).

Reliability and quality of study

The method of narrative literature review has been criticized for unsystematic and subjective information search and data retrieval (Vilkka 2023, Chapter 1.2.1 Narratiivinen kirjallisuuskatsaus). In this study the selection of the research material was influenced by the need of discovering application methods of certain practices in the field. Publications and reports by public entities and government offices were accepted as research material. The responsible conduct of research (Finnish National Board on Research Integrity (TENK) 2023) was followed through this study by respecting other researchers' work by citing properly, data retrieval was performed ethically, and the result of this study is an open publication. However, there were some omissions when recording the literature searches which complicates the repeatability of this study and decreases the reliability.

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