Maria Amaral Gaspar
Licenciada em Ciências de Engenharia do Ambiente

Policy analysis: Does the WFD works with regard to CEC in aquatic environments? Case study: The Netherlands

Dissertação para obtenção do Grau de Mestre em
Engenharia do Ambiente, perfil de Engenharia Sanitária

Orientador: Astrid Fischer, PhD student, TU Delft Faculty of Civil Engineering and Geosciences

Co-orientador: Prof. Doutora Leonor Miranda Monteiro do Amaral, Professora Auxiliar, FCT/UNL

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UNIVERSIDADE NOVA DE LISBOA

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RESUMO

Nos últimos anos, a problemática dos Poluentes Emergentes (PE) presentes nas massas de águas de superfície da União Europeia (UE) e o seu possível impacto na saúde humana e no ambiente têm vindo a ser registados.

A Diretiva-Quadro da Água (2000/60/EC; DQA) é a principal política da UE que estabelece um enquadramento para a proteção dos ecossistemas aquáticos, desde que entrou em vigor. Esta Diretiva exige a monitorização de 45 substâncias prioritárias, de acordo com as respetivas normas de qualidade ambiental, de forma a alcançar, em 2027, o bom estado químico das massas de água. Na última revisão da DQA, em 2015, verificou-se que os Estados Membro ainda não conseguiram cumprir todos os objetivos ambientais exigidos.

A presente dissertação tem como objetivo analisar a eficácia da DQA na proteção dos ecossistemas aquáticos no combate aos PE e avaliar se os objetivos ambientais serão efetivamente cumpridos até à última revisão. A Holanda foi utilizada como caso de estudo.

Foram realizadas entrevistas a 13 colaboradores de diferentes entidades do sistema de gestão de água da Holanda. Com base nos resultados obtidos, verificou-se que, nos últimos anos, a DQA tem sido a principal legislação da UE no domínio da política da água para a proteção dos ecossistemas aquáticos. A diretiva tem vindo a consciencializar e encorajar os Estados Membro a tomar medidas, no entanto, foram identificados alguns problemas.

Concluiu-se que a DQA não tem sido suficientemente eficiente na proteção dos ecossistemas aquáticos com PE. Embora seja difícil prever o seu sucesso em 2027, foram identificados dois cenários possíveis. Por último, foi proposta uma análise consistente dos PE, a integração dos objetivos da DQA na legislação da UE que regula as substâncias químicas, a colaboração entre todas as entidades envolvidas e uma estratégia integrada para a implementação da DQA nos Estados Membro.

Palavras-chave: Diretiva-Quadro da Água, análise de políticas, Poluentes Emergentes, ecossistemas aquáticos.

ABSTRACT

The problematic of Contaminants of Emerging Concern (CEC) in the European Union (EU) surface water has been reported over the last decades as well as CEC's potential impact on human health and the environment.

The Water Framework Directive (2000/60/EC; WFD) is the main EU Directive for the protection of aquatic environments since it came in force. This Directive requires the monitoring of 45 priority substances regarding their environmental quality standards in order to achieve the good chemical status of water bodies until 2027. The last revision of the WFD in 2015 showed that Member States have not met the targets yet.

The present dissertation aims to analyse whether WFD has been efficient enough to protect the aquatic ecosystems against CEC and evaluate if the environmental objectives will be complied until its last revision. The Netherlands was used as the case study.

Interviews were carried out to 13 employees of the different layers in the Dutch water management system. Based on results obtained, it was concluded that the WFD has been the main European water legislation used to protect the aquatic environment from the occurrence of CEC in the last years. The Directive have created awareness and encourages Member States to take actions, however, some issues were identified.

The conclusion is that WFD has not been efficient enough in the protection of aquatic environments against CEC. Although it is difficult to predict its success in 2027, two possible scenarios were identified. In the end, it was suggested a consistent assessment of CEC in aquatic environments, connection of WFD goals with EU's chemicals regulations, collaboration between all interested parties and an integrated strategy to WFD implementation in the Member States.

Keywords: Water Framework Directive, policy analysis, Contaminants of Emerging Concern, aquatic ecosystems.

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LIST OF ABBREVIATIONS

BAT	Best Available Techniques
BOD5	Biochemical Oxygen Demand
CEC	Contaminants of emerging concern
COD	Chemical Oxygen Demand
COMMPS	Combined Monitoring-based and Modelling-based Priority Setting
DWTP	Drinking water treatment plant
EC	European Commission
EDC	Endocrine Disruptor Compound
EE2	17α-ethinylestradiol
EINECS	European INventory of Existing Commercial Substances
EKF	Ecological Key Factor
EQS	Environment Quality Standards
EU	European Union
I&M	*Ministerie van Infrastructuur en Milieu*
IPO	*Interprovinciaal Overleg*
MBR	Membrane Bioreactor
NSAID	Nonsteroidal anti-inflammatory drug
PBDE	Polybrominated diphenyl ether
PBT	Persistent, Bioaccumulative and Toxic
PCP	Personal Care Product
PE	*Poluentes Emergentes*
PPP	Plant Protection Product
RBD	River Basin District
REACH	Registration, Evaluation, Authorization and Restriction of Chemical
RIVM	*Rijksinstituut voor Volksgezondheid en Milieu*
RIWA	*Vereniging van Rivierwaterbedrijven*
RWS	*Rijkswaterstaat*
SVHC	Substances of Very High Concern
TAPES	Transnational Action Program on Emerging Substances
TSS	Total Suspended Solids
TU Delft	*Technische Universiteit Delft*
UvW	*Unie van Waterschappen*
VEWIN	*Vereniging van drinkwaterbedrijven in Nederland*
VNG	*Vereniging van Nederlandse Gemeenten*
WFD	Water Framework Directive
WHO	World Health Organization
WWTP	Wastewater treatment plant

1. INTRODUCTION

1.1. Framework

Chemicals have become indispensable substances of daily life (EEA, 2011). According to the European Inventory of Existing Chemical Substances, 30 to 70% of around 100000 chemicals registered in the European Union (EU) are used every day (Schwarzenbach, et al., 2006). In spite of their benefits for today's society, some chemicals have potential to cause harmful effects on human health and the environment (Molander, et al., 2012).

The occurrence of chemicals in water resources has been increasing since the nineteenth century due to human activities and the demands of a growing and industrialized population (Houtman, 2010; Viladomat, 2010). In Europe, over 1000 micropollutants were measured in aquatic ecosystems and are listed as current emerging pollutants (Sauvé & Desrosiers, 2014; NORMAN, 2016). Part of these micropollutants are Contaminants of Emerging Concern (CEC) and this group of chemical substances are the focus of this thesis.

CEC are chemicals of synthetic or natural origin which have been found in the environment and where their fate, behavior and/or toxicological effects are not all known yet, which might be a potential risk to human health and the environment (Sauvé & Desrosiers, 2014; Naidu, et al., 2016a). The CEC includes pharmaceuticals, personal care products, plant protection products, food additives, biocides and numerous other chemicals that are widely used in today's society (Stuart, et al., 2012). Domestic wastewater, hospital effluents, agriculture and industry are some of the sources of these chemicals (De la Cruz, et al., 2012).

CEC can be found in aquatic ecosystems (surface water, groundwater or seawater) as well as in wastewater treatment plant (WWTP) influent and effluent and in drinking water (Conerly & Ohanian, 2010; Tol, 2013). In most cases, they are found in the aquatic ecosystems at very low concentrations (from ngL^{-1} to μgL^{-1}). Substances that are not regular found in conventional WWTP are often not removed, as these were not designed to remove them in the first place. Advanced treatment techniques in WWTPs have been efficient to eliminate CEC (Yin, 2014; Luo, et al., 2014; Ribeiro, et al., 2015a; Barbosa, et al., 2016). The occurrence of CEC in aquatic ecosystems could cause adverse effects not only in the aquatic organisms, such as feminization of male fish and liver and kidneys damage in fish but also in humans, examples are endocrine disruption and resistant bacteria (Richardson & Ternes, 2011; Yin, 2014; van der Grinten, et al., 2015; Hamza, et al., 2016). Many authors have reported the potential risk of CEC in aquatic ecosystems even at low concentrations (Kolpin, 2002; Barnes, 2008; Houtman, 2010; Stuart, et al., 2012; García, et al., 2013; Carvalho, et al., 2014; Luo, et al., 2014; Muis, 2015; Hamza, et al., 2016; Meador, et al., 2016).

The protection of aquatic ecosystems from the presence of CEC has been a challenge for the EU. Many regulations, directives and other policies have been developed not only to regulate the chemicals production and use but also to protect the environment. However, the political awareness of the CEC problematic in aquatic environments might have started with the implementation of Water Framework Directive (WFD).

The WFD is the main directive used to protect the aquatic environment from chemical substances in the EU (Fürhacker, 2008; Muñoz, et al., 2008). It dictates that EU Member States should achieve a good ecological and chemical status of their surface and groundwater bodies, by 2015 (EEA, 2013; Araújo, et al., 2015; Brack, et al., 2017). Another aim of this directive is to measure the concentration of substances with significant risk to the aquatic environment and/or human health under a monitoring programme to be adopted by Member States (Ribeiro, et al., 2015a). Therefore, 33 priority substances and/or groups of substances were identified by the Directive 2008/105/EC and Environmental Quality Standards (EQS) were set for these (Pinto, 2015). In 2013, WFD was amended by Directive 2013/39/EU and 12 substances were added with their respective EQS (Barbosa, et al., 2016). Recently, the first EU Watch List with 10 substances and/or groups of substances was defined by Decision 2015/495/EU to support future prioritization of chemicals and complement the EU data base (Ribeiro, et al., 2015b).

The WFD promotes the integration of other EU directives with the aim of ensuring the protection of human health and the environment. EU water directives, namely the Urban Wastewater Directive (EU, 1991), the Drinking Water Directive (EU, 1998) and the Directive on Integrated Pollution Prevention and Control (EU, 2010), all are referred to in the WFD as directives which should be taken into account by Member States to control water pollution (EU, 2000; European Commission, 2008b). EU environmental directives, particularly the Registration, Evaluation, Authorization and Restriction of Chemical substances (REACH) (EU, 2006), the Directive on Plant Protection Products (EU, 2009b) and the Biocidal Products Directive (EU, 2012b) are focussing on chemicals production and their distribution on the EU market (European Commission, 2008a). The connection between environmental and chemicals EU Directives is a challenge for the EU and water authorities who aims to protect aquatic environments and a large proportion of CEC are still unregulated (Lopez, et al., 2015).

The Netherlands have made an effort to protect the aquatic environment from CEC with the WFD implementation. The Dutch water management system is very complex and organized in order to meet the goals for the protection of their water quality, including the WFD objectives required (Beunen, et al., 2009). However, it is not clear whether the Netherlands will be able to achieve the WFD targets (EQS) by 2027.

The efficiency of the WFD to protect aquatic environments from CEC is not well known as well as if it is actually working in the Member States.

1.2. Objectives and research scope

The present thesis was developed within the scope of a PhD project on how is the best approach to manage CEC in the urban water cycle, integrated in the EU Intereg project TAPES (Transnational Action Program on Emerging Substances).

This thesis is focussed on the Water Framework Directive (WFD) analysis because it is considered the main tool for water protection more precisely surface water protection against CEC. The aim of this dissertation is to analyse whether the WFD is efficient enough to protect the aquatic ecosystems against CEC and evaluate its future success in the last revision, in 2027, by discussing what is missing and what needs to be achieved for the WFD to succeed in the Member States. Since the implementation of the WFD differs in each country, the Netherlands will be used as the case study.

The main goal of this thesis is to contribute to the protection of water resources against chemical substances and gather more information about the current EU policies and the occurrence of CEC in the environment.

1.3. Research question

Based on the objectives of this study, the main research question is developed:

Is the Water Framework Directive protecting the aquatic environments with regards to CEC?

To answer this question, the following six sub-questions are formulated:

Q1: What legislation is in place to regulate chemicals in the EU and does this take the aquatic environment into account?
Q2: What legislation is in place to protect the aquatic environments in the EU?
Q3: What is the WFD role in the Dutch water management system and how is it used?
Q4: What measures have been taken in the Netherlands and other Member States based on the WFD to protect the aquatic environment with regards to CEC?
Q5: Will the targets be complied in 2027 and will WFD be successful?
Q6: What are the recommendations for the WFD success?

1.4. Dissertation Structure

This dissertation consists of five chapters. **Chapter 1** presents the context of this thesis, providing a brief explanation of the subjects studied and its relevance as well as the objectives, the research scope and research question of the dissertation. **Chapter 2** provides the theoretical context of the study through a comprehensive review of literature regarding CEC. This chapter contains three subchapters which clarifies the current situation of CEC in the environment namely their sources, impacts on human health and the environment and the available removal techniques. Also, a description of the occurrence of CEC in EU water resources and the relevant EU legislation with regards to CEC in the aquatic environment are included. **Chapter 3** describes the methodology used in this study, the research approach and which steps will be taken to answer the research question, including analytical instrument (interviews of stakeholders), sampling used and how the results were analysed. **Chapter 4** is the case study analysis and it is divided into four subchapters The first provides an overview of the situation in the Netherlands, including the characterization of the country and the occurrences of CEC in the Dutch water bodies. The Netherlands has a complex water management system. Hence an overview of the Dutch water management system is given in second subchapter in order to understand how it works institutionally and how EU legislation, particularly the WFD, is implemented in the Netherlands. The third and fourth subchapters present the analysis and discussion of the interview results, respectively. Finally, **Chapter 5** presents the main conclusions and recommendations for future research in this area.

2. LITERATURE REVIEW

2.1. Contaminants of Emerging Concern

2.1.1. Definition

Currently, the awareness of the potential impacts of chemical substances on human health and the environment is increasing and many different definitions of emerging substances were published (Houtman, 2010; Richardson & Ternes, 2011; Geissen, et al., 2015; Lopez, et al., 2015; Barbosa, et al., 2016; Meador, et al., 2016).

In this study, we use the term Contaminants of Emerging Concern (CEC) defined as "*naturally occurring, manufactured and manmade chemicals or materials witch have now been discovered or are suspected present in various environmental compartments and whose toxicity or persistence are likely to significantly alter the metabolism of a living being*" (Sauvé & Desrosiers, 2014). CEC are not necessarily new chemicals. They can already be known but their harmful effects were not previously detected (Naidu, et al., 2016b).

CEC includes but are not limited to pharmaceuticals, hormones and steroids, personal care compounds, pesticides, surfactants, artificial sweeteners, perfluorinated compounds, drugs of abuse, industry chemicals, water treatment by-products and flame retardants (Richardson, 2010; Richardson & Ternes, 2011; Stuart, et al., 2012).

2.1.2. Sources and pathways of CEC

Rural areas (greenhouses and livestock), urban areas (household and healthcare) and Industry represent a large part of CEC sources that could introduce these substances into the surface water (Tol, 2013).

In the **rural areas**, several CEC such as Plant Protection Products (PPP) and veterinary medicines are used to protect the crop and livestock. This sector has many diffuse sources that contributes to water chemical pollution, particularly with the introduction of PPP and veterinary medicines (Schwarzenbach, et al., 2006). PPP are mainly applied to crops for pests and weed control (Pinto, 2015). Veterinary medicines, particularly antibiotics, are used in livestock to prevent animal diseases and can be introduced to the environment by the use of manure or leaching of pasture (Tol, 2013). Therefore, the CEC used in agriculture may end in aquatic environment by soil erosion, interflow and surface runoff (Fischer, et al., 2017).

The **urban areas** are the source of CEC from housing areas and hospital emissions (Muis, 2015). The use of household products, Personal Care Products (PCP), pharmaceuticals for instance antibiotics and steroidal hormones, biocides and flame retardants is very common in urban areas

(Ong, 2016). In the urban areas, the major route of these substances into aquatic ecosystems is the wastewater treatment plant (WWTP) effluents and sludge (Fischer, et al., 2017; Muis, 2015).

Industry is responsible for CEC production, including the ones used in agriculture and urban sectors (Tol, 2013). Industry is strongly associated to a point source because of the industrial discharges which are an important emission route of CEC to the aquatic environment.

The CEC sources and pathways of aquatic environment are briefly shown in Figure 2.1.

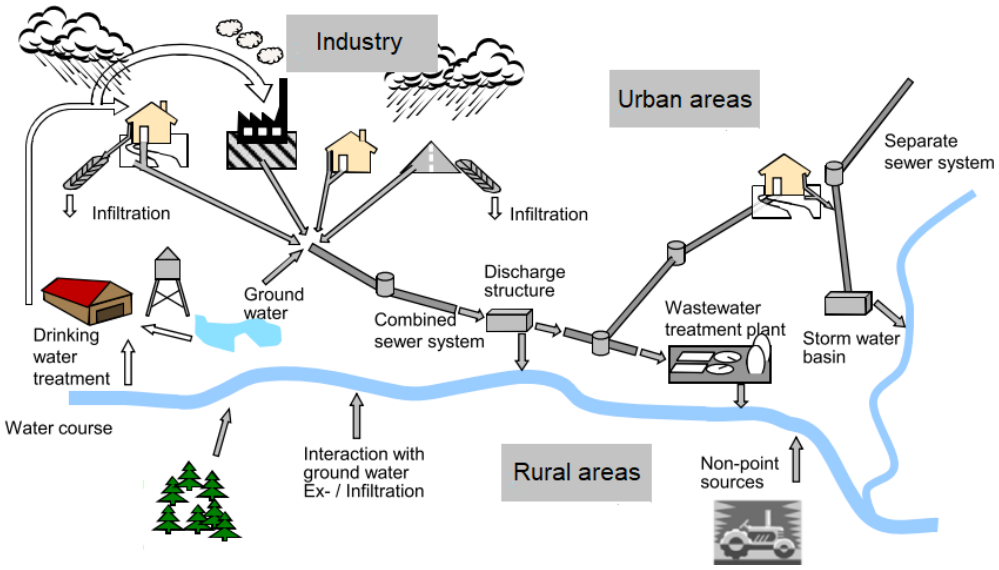

Figure 2.1- Sources of CEC and their pathways to the aquatic environment (Fischer, et al., 2017).

2.1.3. Treatment Techniques for CEC

The several point and diffuse CEC sources and their occurrence at very low concentrations in aquatic environments makes their identification more difficult. The conventional WWTP are not design to remove all of these compounds and it has been considered one of the sources of the occurrence of CEC in aquatic environments (Yin, 2014; Luo, et al., 2014). CEC are mainly removed during the secondary treatment at WWTP by conventional activated sludge or membrane biological reactors. **Activated carbon adsorption** (powdered activated carbon or granular activated carbon) has been an alternative technique to improve WWTP and in general it is effective to remove organic compounds if the matching pore size/shape and non-polar characteristics were suitable (Barbosa, et al., 2016). **Advanced oxidation processes** and **ozonation** has a high potential to remove CEC, such as endocrine disruptors, although there is a risk of environmental pollution from the residual oxidant (Aris, et al., 2014; Barbosa, et al., 2016). **Nano filtration** and **reverses osmose (RO)** are the most efficient membrane processes to remove CEC (Barbosa, et al., 2016).

Luo et al. (2014), analysed three types of treatment processes of WWTP to compare their CECs removal rate: low-cost (e.g. aerated lagoon) conventional and advanced (e.g. reverses osmose)

(Table 2.1). It is verified that advanced treatment techniques have better removal ranged although, the high costs and by-products associated to these techniques are a disadvantage.

Table 2.1 Comparison of three types of WWTP (Luo, et al., 2014).

	Removals (%) in different types of WWTPs		
Compounds	Conventional[1]	Low-cost[2]	Advanced[3]
Ibuprofen	71 – 99	38 – 99	>35 – 99
Diclofenac	5 – 81	~0 – 88	78 – >99
Ketoprofen	11 – 94	~0 – 88	83 –99
Carbamazepine	10 – 59	~0 – 51	68 – 99
Estrone	75 – 87	60 – 78	>50 – >99
Bisphenol A	60 – 95	23 – 73	>58 – >98
Nonylphenol	22 – 93	56 – 85	48 – >99

2.1.4. Impacts of CEC on living organisms

The available treatment techniques might not respond to the constantly introduction of CEC in aquatic environment. In fact, although the existing knowledge of CEC in general is still limited, their potential for environmental effects have been increasingly detected and documented in many research papers (Graymore, et al., 2001; Richardson, 2010; Richardson & Ternes, 2011; Bedoux, et al., 2012; Daghrir & Drogui, 2013; Aris, et al., 2014; Lonappan, et al., 2016; Naidu, et al., 2016a; Adeel, M., et al., 2017; Yang, 2017).

An overview of general groups of CEC and their impacts on human and animal health are shown in Table 2.2 as well as examples of the specific chemical who may cause these adverse effects.

Table 2.2 Impacts in human and animal health reported as consequence of CEC in aquatic ecosystems.

CEC	Example of CEC	Impacts in human health	Impacts in animals	Reference
Solvent	1,2-Dichloroethane	Cancer risk;	Tumours in laboratory animals;	(WHO, 2003)
Biocide	Triclosan	Antibiotic resistance; Effects on central nervous system;	Disruption of thyroid functions in amphibian and mammalian; Reproductive system altered in male rats; Endocrine disruption for aquatic organism;	(Bedoux, et al., 2012)

Table 2.2.1- Impacts in human and animal health reported as consequence of CEC in aquatic ecosystems (Cont.).

Flame retardant	PBDE[1]	Endocrine disruption risk; Carcinogenic;	Endocrine disruption risk; Carcinogenic;	(Richardson, 2010)
Pharmaceutical-Antibiotic	Tetracycline	Bacteria resistance;	Endocrine disruption in fishes; Growth inhibition in aquatic species;	(Richardson & Ternes, 2011; Daghrir & Drogui, 2013)
Pharmaceutical-EDC[2]	EE2[3]	Breast cancer; Testicles and prostate cancer; Altered immune system;	Reproductive system altered in male and female fishes; Decrease of egg and sperm production in fishes;	(Aris, et al., 2014; Adeel, M., et al., 2017)
Pharmaceutical-NSAID[4]	Diclofenac		Damage of renal system and gastrointestinal tissue in vertebrates (e.g. fish) Damage of gill, liver and kidney in fishes;	(Lonappan, et al., 2016)
Pesticide	Atrazine	Cancer risk; endocrine disruption and reproductive dysfunction;	Gill and kidney damage, changed behavior and growth decrease in fishes; Growth decrease algae;	(Graymore, et al., 2001)

[1] PBDE- Polybrominated diphenyl ethers

[2] EDC- Endocrine Disruptor Compounds

[3] EE2- 17α-ethinylestradiol

[4] NSAID- Nonsteroidal anti-inflammatory drugs

Biocides are disinfectants that prevent the bacterial growth and protect human health. These substances are active substances included in personal care products such as soaps, deodorants, mouthwash, toothpaste, skin creams as well as plastics, textiles, household cleaners and other products used every day. Biocides' toxic effects in aquatic organism can occur in endocrine (e.g. whelks), nervous and reproductive system as well as bacteria resistance to biocides (Germany, 2010; Bedoux, et al., 2012).

Flame retardants are applied in electronic equipment, textiles, furniture, car industry, among others to protect the materials from fire risk (Segev, et al., 2009). These chemicals are lipophilic,

bioaccumulating and persistent in the environment and human health therefore, concerns about their effects have emerged (Richardson & Ternes, 2011). They are potentially carcinogenic and may cause disruption of the endocrine and nervous systems of living beings (Houtman, 2010).

Pharmaceuticals are a wide group of chemicals used to protect human and animal health. Antibiotics (e.g. Tetracycline), nonsteroidal anti-inflammatory drugs (e.g. Diclofenac) and endocrine disrupting compounds (EDC) (e.g. EE2) are some of these chemicals who are part of the CEC:

- **Antibiotics** are one of the most used pharmaceuticals worldwide and are used to treat and control diseases in livestock, aquaculture and hospitals. Bacterial resistance and alteration of liver, kidney and reproductive system of living organisms are some of the main effects of these chemicals on human and animal health (Richardson, 2010; Oliveira, et al., 2013).
- **NSAID** are used as analgesic medicine for several human and veterinary purposes and, consequently, are often found in water environments (Schwaiger, et al., 2004). Studies have shown chronic toxicological effects in many aquatic organisms (e.g. Daphnia, fishes, mussels) by one of the most used anti-inflammatory drugs – Diclofenac- found in aquatic environments (Schwaiger, et al., 2004; Triebskorn, et al., 2004; Lonappan, et al., 2016).
- **EDC** are chemicals that interact with the endocrine system and can cause adverse health effects such as breast cancer in humans and reproductive system alterations in male and female fishes (Bergman, et al., 2012). According to the World Health Organization (WHO), EDC can be found in pesticides, food additives, PPP and pharmaceuticals. Their potential impacts on human health and on several organisms are related to carcinogenic diseases, such as breast cancer in females and prostate cancer in males, modification of the reproductive system in males and females, altered immune system and growth malformations (Rosa, 2008).

Pesticides are extensively used in agriculture, forest and public areas in order to control weed and pests. They include insecticides, fungicides and herbicides among others (Hamza, et al., 2016). The introduction of pesticides to aquatic environments could potentially cause impacts in the environment such as fish mortality and macroinvertebrate species, endocrine system effects. However, pesticides with non-polar and less persistence properties are more used in order to reduce their impact in the environment (Tol, 2013). However, these properties make it hard to remove them with water treatment technologies.

2.1. CEC occurrence in aquatic ecosystems in the EU

The production and use of chemicals is considerable in the EU. Their economic and societal value to the EU makes the chemical industry one of the biggest industrial sectors on EU level. According to Cefic Chemdata International (2013), 85% of EU chemicals sales are solely produced by seven

member states. In 2012, more than 60% of EU chemicals sales were produced by Germany, France, the Netherlands and Italy. Germany had the highest level of chemical production with 28.9% of total chemicals sales, followed by France (14.8%), the Netherlands (9.6%) and Italy (9.3%). Note that the Netherlands chemicals sales were twelve times higher than Portugal which had 0.8% of the total chemicals sales in the EU market (Figure 2.2).

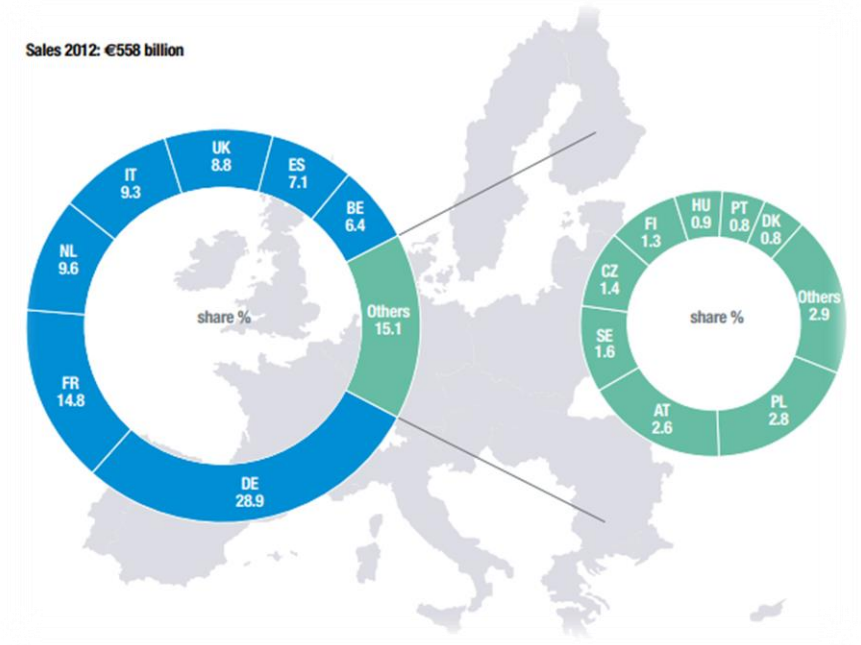

Figure 2.2 Chemical sales in EU Member States (Cefic, 2013)

The large production and use of chemicals in EU is a potential risk to the environment. CEC have been found in aquatic environments of numerous European countries. Loos *et al.* (2009) analysed more than 100 river water samples from 27 European countries and concluded that only 10% of the European rivers were considered in good chemical status. The most frequent chemicals found in the rivers and with higher concentrations were three industrial products (anenzotriazole, nonylphenoxy and tolyltriazole), one pharmaceutical (carbamazepine) and caffeine. Fisch *et al.* (2017) studied the occurrence of eleven ultraviolet filters and eight pharmaceuticals in five rivers discharging in the German Baltic Sea. In all water samples were detected four of the PPCP analysed (sulfamethoxazole, salicylic acid, 2-phenylbenzimidazole-5-sulfonic acid and octocrylene). However, PPCP concentrations found in the coast water samples were lower than in the rivers analysed (Fisch, et al., 2017). In France, a screening of French groundwater for regulated and emerging contaminants was done. Several chemicals such as pesticides, industrial products and pharmaceuticals were found in the groundwater, including the ones that are unregulated (Lopez, et al., 2015). In the Netherlands, a study was made of the grey water from residential area with separate sewer systems. The analysis of 18 CEC concluded that they were present in water at low concentrations (µg/L) after biological treatment (Leal, et al., 2010). In Portugal, a study of the occurrence of pharmaceuticals in Portuguese wastewater effluents and influents from five different regions revealed the presence of at least one of the 11 targeted

pharmaceuticals and indicated six rivers as a hotspots of contamination for this CEC group (Pereira, et al., 2016). Regarding pesticides, Palma *et al.* (2009) analysed 14 pesticides abundant in Alqueva reservoir, in the South of Portugal. The study concludes that atrazine, simazine, diuron and terbuthylazine were the most frequent pesticides found in the surface water samples. Atrazine and diuron were found in the surface water samples at concentrations above the EQS standards that are stated in the WFD. The highest concentrations of pesticides were detected during May, June and July which are the months with more agriculture activity (Palma, et al., 2009).

2.2. EU policies to control CEC in aquatic ecosystems

European Union legislation related to aquatic ecosystems protection aims to harmonize the interests and concerns of EU Member States by the development of Directives. With regards to CEC, European legislation do not regulate all the substances, especially because of lengthy process and compromises within the EU policies development (Houtman, 2010). Production, transport and use of CEC, including environmental emissions and protection of ecosystems from these substances are some of the themes regulated by EU legislation. Figure 2.3 is an adaption from van Wezel, et al. (2017a) and represents all EU legislation included in this thesis with regard to CEC sources, pathways and fate in aquatic ecosystems.

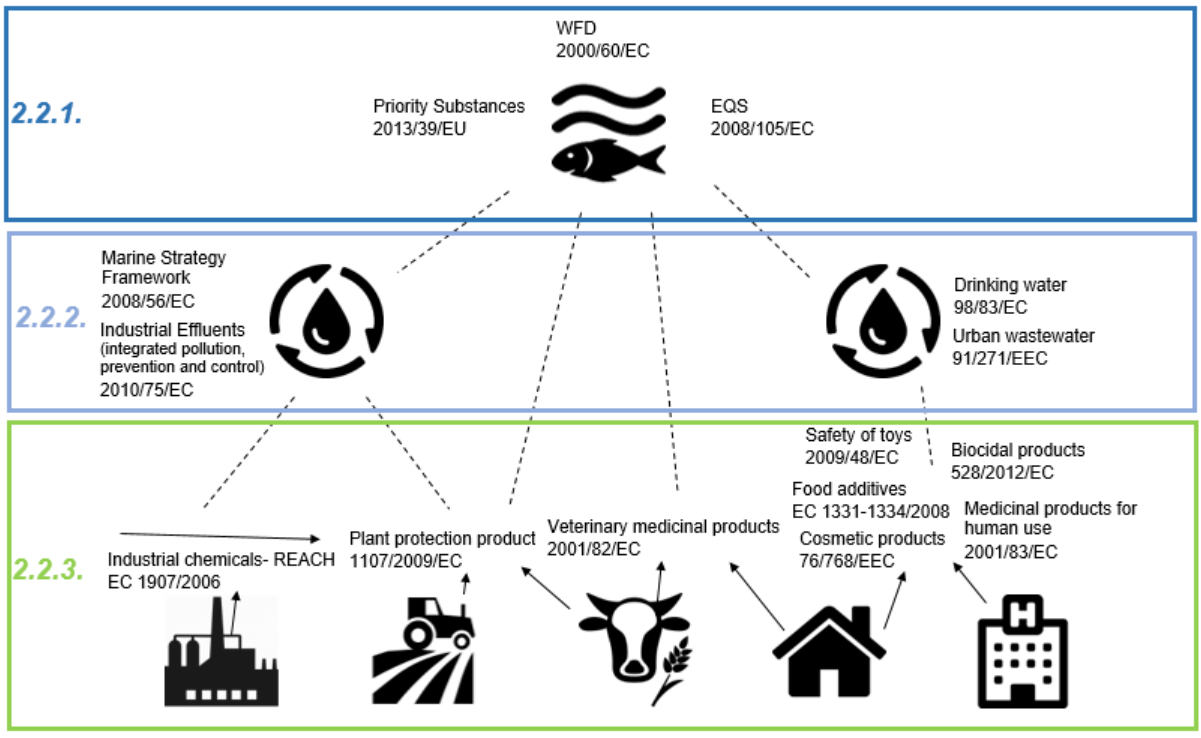

Figure 2.3 Chemical's legislation diagram (van Wezel, et al., 2017a).

Protecting the aquatic environments, such as surface water, groundwater and coastal waters from pollution, is one of the concerns in the European Union. The main policy for the protection of aquatic resources in EU, also with regards to CEC, is the WFD, which is described in sub-chapter 2.2.1. The WFD is complemented by other legislation, such as the directives of drinking water,

urban wastewater, industrial effluents and marine strategy framework, that are developed to control and protect the specific aquatic entry routes. These complementary directives are described in sub-chapter 2.2.2.

The increasing use of chemicals in Europe have made the development of policies that cover the different life stages of the chemicals essential. The EU has a wide range of legislation which control the production and authorization of chemicals on the market, such as REACH, and specific legislations for groups of chemicals, as the directives of biocide products, plant protection products, pharmaceutical products, veterinary products, cosmetics, food additives and toys. These directives are described in sub-chapter 2.2.3.

In this context, it should be noted that the current EU legislation does not cover all CEC and the existing knowledge is still insufficient, as were already mentioned in the previous chapter.

2.2.1. The Water Framework Directive

Directive 2000/60/EC

Directive 2000/60/EC is the main tool in EU water legislation (Pio, et al., 2000; Fürhacker, 2008; Tiedeken, et al., 2017). It establishes long-term protection of inland surface waters, transitional waters, coastal waters and groundwater (EU, 2000). The aim of the European water framework directive is to reduce and prevent pollution of aquatic ecosystems, promote sustainable water use, ensure the protection of aquatic ecosystems and contribute to mitigate the effects of floods and droughts.

The WFD encourage the integration of the various legal instruments and therefore is complemented by the following legislations (European Commission, 2014):

- Environmental Quality Standards Directive (2008)
- Marine Strategy Framework Directive (2008)
- Floods Directive (2007)
- Groundwater Directive (2006)
- Bathing Water Directive (2006)
- Drinking Water Directive (1998)
- Urban Wastewater Directive (1991)
- Nitrates Directive (1991)

The WFD establishes that all EU Member States have to ensure a good status of surface and groundwater bodies in their river basins, before 2015 (Tiedeken, et al., 2017). In order to achieve this goal, the WFD requires monitoring of the ecological and chemical status of surface waters and of the chemical and quantitative status of groundwaters (EEA, 2012). The ecological status is based on biological, hydromorphological and physico-chemical quality elements. The chemical

status is based on the concentrations of specific chemicals, identified in Annex X of WFD as priority substances (Fuerhacker 2009).

In order to ensure the protection of aquatic ecosystems, remove priority substances and achieve good water bodies status, the Commission provides a proposal with specific measures to the progressive reduction of priority substances emissions and their elimination, within 20 years (EU, 2000; Brack, et al., 2017). This proposal sets basic measures to identify the priority substances and establish procedures for the settings of EQS, to be adopted by the EU Members States (EU, 2000; Loos, et al., 2009).

The EQS requires a monitoring of priority substances in water, sediment or biota to ensure that they do not exceed the concentration limits established and to guarantee the protection of human health and the environment (Tiedeken, et al., 2017).

According to Article 16(2) of the WFD, priority substances are defined as substances "which present a significant risk to or via the aquatic environment". Among these substances are priority hazardous substances defined in Article 2(29) of the WFD as "substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern" (EU, 2000). Also, the Article 16 of the WFD establishes the need for a review of the priority substances as well as the possibility of adding new ones, every 4 years (Carere, et al., 2015).

The **Decision nº 2455/2001/EC** constitutes the first list of priority substances (represented in Appendix II) based on a procedure named COMMPS (Combined Monitoring-based and Modelling-based Priority Setting) (EU, 2001b). This list includes 33 substances where 14 are from EINECS (European INventory of Existing Commercial Substances) list, 10 are phytopharmaceuticals, 2 are biocides, 4 are toxic metals and the other 3 are polycyclic aromatic hydrocarbons and polybrominated diphenyl ethers (Pio, et al., 2000; Coquery, et al., 2005). In accordance with the REACH identification criteria for Substances of Very High Concern (SVHC), 13 of these substances are priority hazardous substances (Molander, et al., 2012).

The priority of substances suspected of having a significant risk "to or via the aquatic environment" should be assessed by (Carere, et al., 2015):

- Their intrinsic risk, specifically, the ecotoxicity of aquatic ecosystems and the human toxicity thru exposure;
- Monitoring data that identify, potential or real, situations of general environmental contamination such as production, quantity used and application of the substance evaluated;
- EU directives and regulations;

In addition to the list of priority substances and the procedures to set the EQS, the WFD identify a list of the main water pollutants (Annex VIII of the WFD) (EU, 2000). These pollutants were identified because of the significant discharge into water and, consequently, the potential risk to human health and the environment (EU, 2000). As required in WFD, the EU Member States have to establish EQSs for these pollutants (Molander, et al., 2012).

The WFD implementation is a challenge and corporation between Member States is vital to ensure a common approach used by Member States which is essential for an efficient implementation. The **Common Implementation Strategy (CIS)** for the WFD was agreed in 2001 by the Member States, European Commission and Norway in order to provide a technical guidance related to the WFD implementation to the Members (European Commission, 2015).

i. Directive 2008/105/EC

The Directive 2008/105/EC establishes a framework related to the Environmental Quality Standards (EQS) for specific substances in surface water (river, lake, transitional and coastal) in the field of water policy as required by the Directive 2000/60/EC (EU, 2008a).

Taking into account the provisions and environmental goals established on Directive 2000/60/EC, the aim of the Directive 2008/105/EC is to provide EQS to 33 priority substances. The EQS has to be achieved by EU Member States to ensure the good surface water chemical status (Viladomat, 2010; EU, 2008a). Also, the EU Member States should take the sediment compartment and biota into consideration at the national level (Carere, et al., 2015). However, the protection against indirect effects and secondary poisoning of hexachlorobenzene, hexachlorobutadiene and mercury at Community level is not ensured only with water surface EQS, therefore should be established a biota EQS to these substances (European Commission, 2010).

In accordance with the requirements mentioned in Part B of Annex I of the Directive 2008/105/EC, the EQS has two different applications to each priority substance in order to protect the aquatic environment short and long-term. Therefore, the applications of EQS are expressed by (Viladomat, 2010; Carere, et al., 2015):

- Annual average (AA) value of the substance concerned, ensuring a long-term protection of pollutants exposure;
- Maximum allowable concentration (MAC) of the substance concerned, to guarantee pollution limits for a short-term protection;

As requested by the Article 16(4) of WFD, the Directive 2008/105/EC reviews the Annex X of it with the aim of evaluate specific substances, potentially identified as priority substance or priority hazardous substance and (Molander, et al., 2012).

ii. Directive 2013/39/EU

The Directive 2013/39/EU amend the Directives 2000/60/EC and 2008/105/EC with regard to priority substances in the field of water policy (EU, 2013). Figure 2.4 represents the amends stablished in the Priority Substances Directive (2013/39/EU) regarding the protection of aquatic environments against CEC (Pinto, 2015; Ribeiro, et al., 2015a).

Figure 2.4 Main changes of the Priority Substances Directive (2013/39/EU) with regards to priority substances in the aquatic ecosystems.

The Directive identify 12 new priority substances and their inclusion in the list of priority substances, giving a total of 45 substances or groups of substances (represented in Appendix III). Also, this Directive reviews the EQS already established and their update according to the new scientific knowledge, establishes EQS for the new identified substances and defines of biota EQS to the new list of priority substances (represented in Appendix IV).

At Union level, the Commission defines a Watch list of substances, in accordance with Article 16(2) of WFD. The aim of this list is to support the future prioritization of chemicals with significant risk and ensure their monitoring data (EU, 2000; EU, 2013; Brack, et al., 2017). The Directive 2013/39/EU demands a maximum of 10 substances or groups of substances, including two pharmaceuticals (Diclofenac and 17α-ethinylestradiol (EE2)) and a natural hormone (17β-estradiol (E2)), in the Watch list (EU, 2013; Barbosa, et al., 2016). In 2015 the first EU watch list was established by the Decision 2015/495 (EU, 2015a) In addition to the three substances mentioned above, this list also includes pesticides, macrolide antibiotics, hormone, a UV filter and an antioxidant (represented in Appendix V) (Barbosa, et al., 2016).

In the same year, the first deadline to meet the environmental goals of WFD and the end of the first management cycle occurred. The management of WFD is evaluated on a six-year cycle that

started in 2015 as mentioned, and extend to 2021 and 2027. In 2027, there is also another evaluation of the objectives achieved (Voulvoulis, et al., 2017).

A resume of the WFD implementation deadlines and legislative changes with regards to CEC in aquatic environment is represented in Figure 2.5.

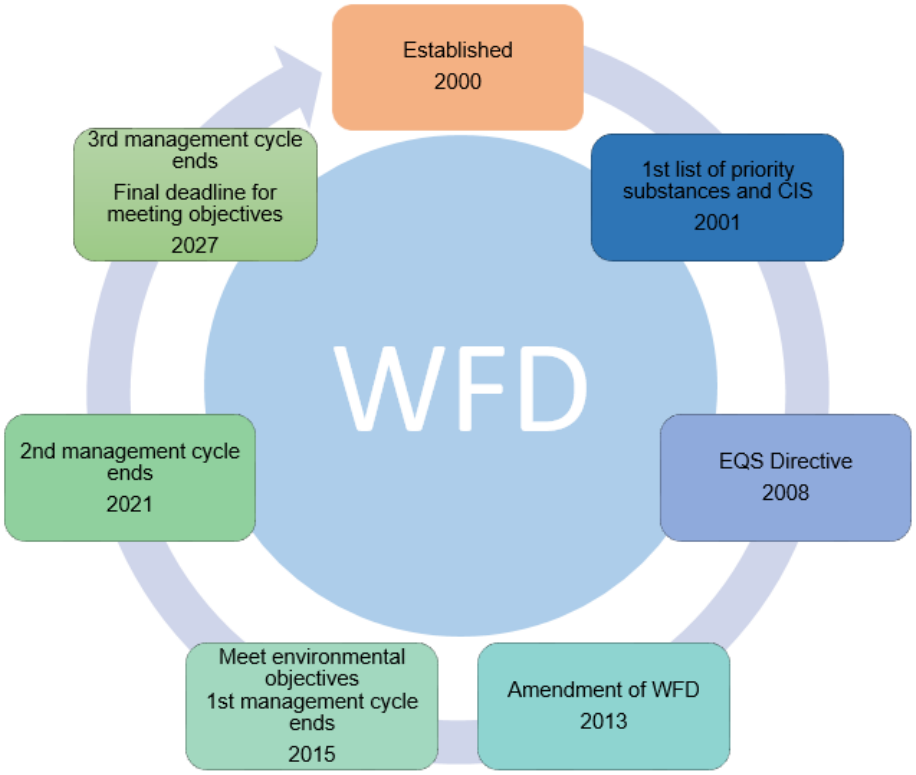

Figure 2.5 Implementation deadlines and legislative changes of WFD regarding CEC control.

2.2.2. EU Water Directives

Existing regulation in the EU focus on the protection of aquatic environments in order to safeguard human health and the environment. One of the aims of these directives is to regulate chemical substances and require their monitoring in the EU water bodies, with regards to established standards. The following directives provide requirements for the parameters that need to be monitor to control the ecological and chemical status of surface water.

Drinking Water Directive

The EU legislation that protects and ensure the quality standard of water for human consumption is the Directive 98/83/EC on the quality of water intended for human consumption. The directive requires the regularly monitor of 48 microbiological, chemical and indicator parameters in order to protect human health and avoid the contamination of drinking water (chemical parameters in Appendix I) (EU, 1998). In 2015, the annexe II and III of th Directive 98/83/EC were amended (EU, 2015b).

Urban Wastewater Directive

The discharges from urban and some industrial wastewater, if not treated properly can have adverse effects in the environment, particularly in aquatic ecosystems. The Directive 91/271/EEC establish requirements for wastewater treatment procedures and limit values for concentration for Biochemical Oxygen Demand (BOD5 at 20 °C), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), phosphorus and nitrogen to be applied in the Directive 91/271/EEC of European Parliament and of the Council of 21 May 1991 concerning urban waste water treatment (EU, 1991). The aim of this Directive is to protect the environment from the adverse effects of urban waste water and industry discharges. The monitoring required does not include CEC.

Industrial Effluents Directive

The Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control) is considered the main EU instrument to regulate harmful industrial emissions. The aim of this directive is to ensure a high level of protection of the public health and the environment, by applying the Best Available Techniques (BAT). Also, this directive requires the compliance of the established limit values for polluting substances (chemical parameters in Appendix I) and measures to prevent and control pollution from industrial activities (EU, 2010).

Marine Strategy Framework Directive

The Directive 2008/56/EU establishes a framework for community action in the field of marine environmental policy in order to protect the marine environment across Europe. The Good Environmental Status (GES) of the marine environment in EU must be achieved until 2020. The Directive provides detailed requirements for the monitoring and measures programmes and methodological standards for its implementation in the Member States.

2.2.3. Other relevant EU Directives

Current European Union directives for chemicals regulation are implemented to specific groups of chemical usage. The following directives, related to chemicals, are focused at production, labelling, transportation, authorization in the market and usage in order to protect the human health.

Cosmetic Products

Cosmetics are regularly used in our daily life (Takahashi & Sakamoto, 2017). The exposure to cosmetic products to human health is a concern for the regulators, producers and consumers (Nohynek, et al., 2010).

The Cosmetic Products Directive 76/768/EEC, amended by the regulation (EC) nº 1223/2009, establishes legal requirements to the EU cosmetic market and provides a list of substances that

are not allowed in these products (chemical parameters in Appendix I) in order to ensure consumer safety (EU, 1976).

Veterinary Medicinal products

Veterinary medicinal products are increasingly used in animal production (Guardo & Finizio, 2017). These products may have harmful effects on the environment or on the human health as the residues from pharmacologically active substances can reach water, soil or food after their application (Koschorreck, et al., 2002).

The Directive 2001/82/EC of the European parliament and of the council on the community code relating to veterinary medicinal products, sets requirements for the production, distribution and marketing authorization of these products to be placed on the market, particularly substances presented in Appendix I of this thesis.

Pharmaceutical products

Pharmaceutical products are widely produced to meet the needs of society. The Directive 2001/83/EC of the European parliament and of the council on the Community code relating to medicinal products for humans, establish requirements and procedures that cover the lifecycle of a medicinal product in order to ensure the safety of human health, promote innovative technologies and protect the internal market (EU, 2001a). This Directive is developed for substances present in Appendix I of this thesis.

Food additives

In order to ensure a good quality of food and protection of human health, the EU has developed regulations to control these requirements and encourage the use of new technologies to reduce the use of food additives (Le, et al., 2017; Moldes, et al., 2017). The Regulation (EC) nº 1334/2008 of the European parliament and of the council of 16 December 2008 on flavourings and certain food ingredients, provides authorization procedures, conditions to use and labelling, and a list of prohibited substances that cannot be added as such to food and a list of limit values concentration of substances which should not be exceeded (chemical parameters represented in Appendix I) (EU, 2008b).

Toys

The manufacture of toys can include materials that may contain hazardous substances and the subsequent exposure may be dangerous to human health (Oyeyiola, et al., 2017). To control the production of these products and substances related and guarantee the safety and free circulation of toys in the market, the European Commission developed the Directive 2009/48/EC of the European parliament and of the council on the safety of toys. This EU legislation provides safety requirements, allergenic fragrances that should not be contained in toys and substances with legal standards that must not be exceeded (chemical parameters represented in Appendix I) (EU, 2009a).

Plant protection products

Plant protection products are widely used in agriculture. However, the high production rates and extensive application of these products in the environment can pose a threat to ecosystems (Velki, et al., 2017). Regulation (EC) nº 1107/2009 regarding the placing of plant protection products on the market sets specific criteria for the approval of active substances (represented in Appendix I) which plant protection products could contain and requirements for their authorization, use and control in the market (EU, 2009b).

Also, Directive 2009/128/EC establishes a framework for Community action to achieve the sustainable use of plant protection products which promotes the use of innovative techniques for pest management without using chemicals, taking into account the impact of these substances on the environment, especially on the aquatic environment (EU, 2009c).

Biocides

Biocides are included in several pharmaceutical and personal care products as active substances (Chen, et al., 2012). The development of legislation to control the production and distribution of these substances became necessary (Bester, et al., 2008). According to Regulation (EU) nº 528/2012 of the European Parliament and of the council concerning the availability and use of biocides, it is established the active substances that can be used on biocide products (represented in Appendix I) as well as the requirements for their authorization in the (EU, 2012b)

REACH

The Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) is established in Directive EC 1907/2006 for industrial and household chemicals with the aim of ensuring the protection of public health and the environment and the safety of animals (EU, 2006). REACH has been one of the broadest EU legislation that control the production and circulation of chemicals on the market (Scruggs, et al., 2015). All chemical substances produced in or imported to EU, in amounts of 1 tonne or more per year, have to be registered according to REACH in the EU market (Yen, 2013). This Directive provides a list (chemical parameters represented in Appendix I) with Substances of Very High Concern (SVHC) that are subject to authorization and should not be produced or used on the EU market.

A resume of all EU legislation related to CEC and the aquatic ecosystems protection that were reviewed is represented chronologically in figure 2.6. After the WFD, the EU developed several directives related to chemical substances control and the protection of aquatic environments.

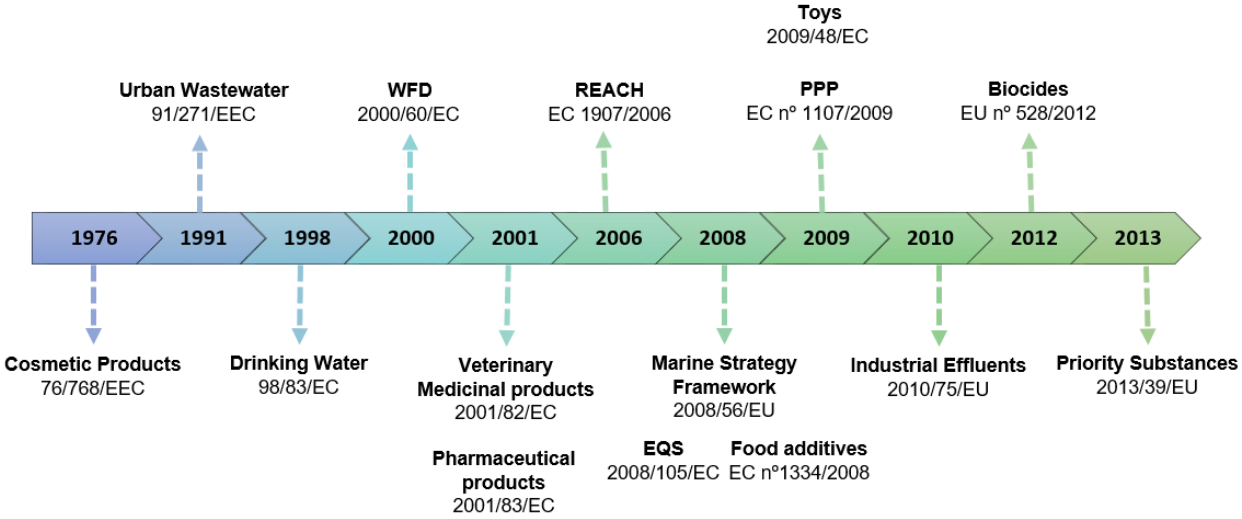

Figure 2.6 Timeline of the EU legislation reviewed.

3. METHODOLOGY

3.1. Elaboration and objectives

The figure 3.1 maps out the structure of the project, by allocating its different stages across time and identifying key moments of this dissertation.

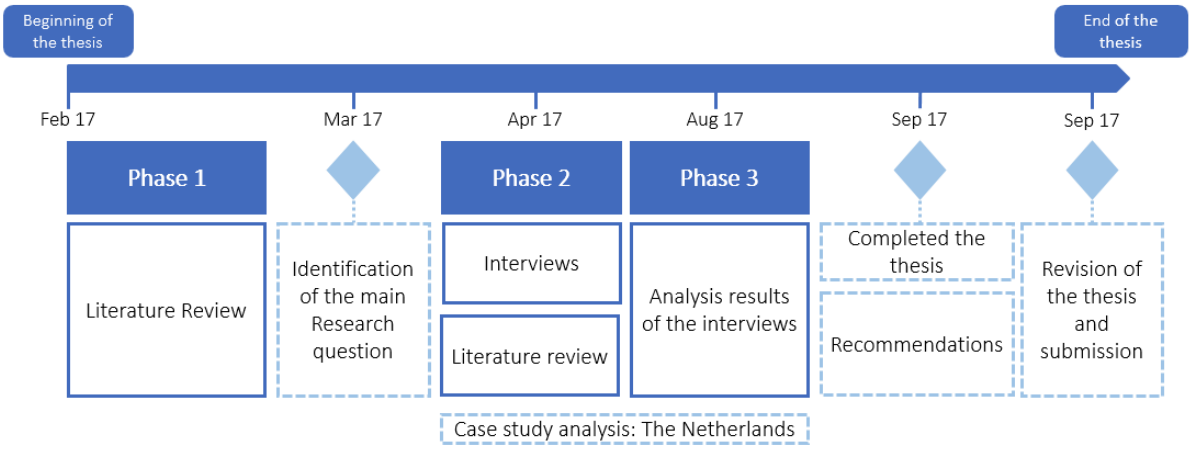

Figure 3.1- Dissertation timeline

With regard to the timeline represented above, it is verified that the present dissertation consists in three phases:

1. **Phase 1: Literature review-** Here the information collected and background study was analysed. The review was divided in two types of literature analysed: EU legal documents and scientific papers and reports;
2. **Phase 2: Interviews and literature review-** Here the interviews to relevant stakeholders were carry out as well as the review of the Dutch legal literature and scientific papers;
3. **Phase 3: Analysis results of the interviews**- Here the interviews results were analysed taking into account the review of the Dutch legal literature made before;

After the three phases described above, the interviews results were compared with the literature analysis results in order to answer to the research question and propose recommendations.

In order to answered to the main research question and its sub-questions, two methods were used: Literature review and Stakeholders interviews (Figure 3.2). This methodology process is focused on the relation between the knowledge acquired from the literature review and the analysis of the interviews of several stakeholders.

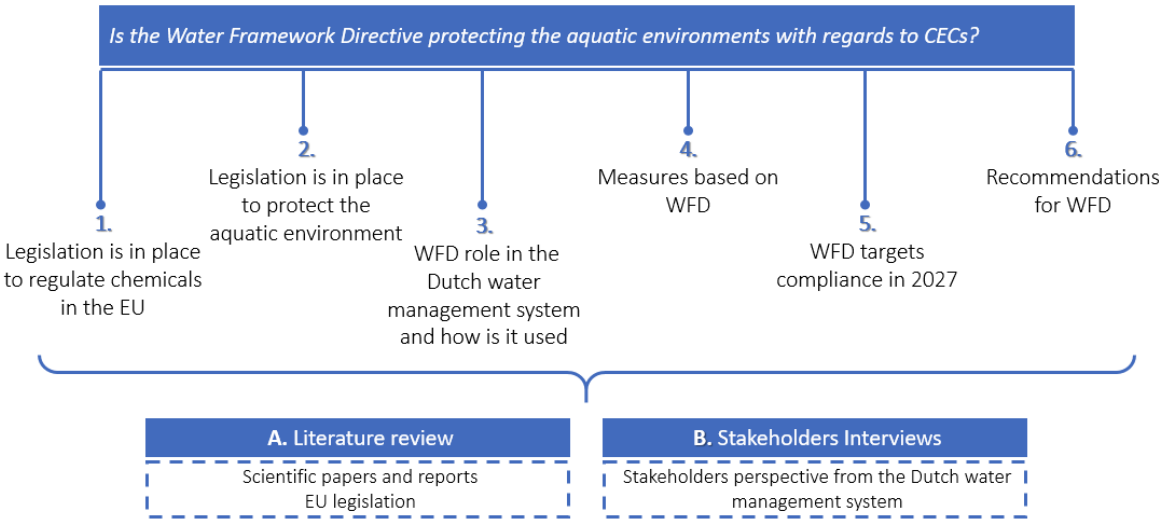

Figure 3.2 Methodology process of the dissertation.

3.2. Literature review

The literature review was one of the main tools used in this dissertation. An extensive literature review was carried out to understand the current issue of CEC in the aquatic environment and the corresponding EU policy. The literature review contained scientific literature, reports and the EU legal framework implemented.

I. EU legal framework

This review consists of a comprehensive analysis of EU policies and legislations, their strategies and implementation requirements in EU Member States. Firstly, the WFD was the main tool used for this analysis since it is the main directive for the protection of aquatic environments. The next step within the legal framework chapter was the analysis of the EU legislations that complement WFD and have specific requirements for CEC in water bodies. Finally, the review of the EU legal framework was completed with the analysis of other legislation which regulate the production, transportation and use of specific groups of chemicals.

II. Scientific literature and reports

In the last years, many studies concerning CEC, their occurrence in the environment and their potential impact on aquatic environment were published. A wide number of articles and reports related to the CEC issue as well as book chapters and websites were reviewed in order to identify their sources, fate, impact on human health and the environment and removal techniques

available. Additionally, scientific literature related to policy analysis and chemicals in the water cycle were excessively reviewed.

3.3. Stakeholder Interviews

Stakeholder interviews was the other tool used in this thesis. The interviews with specialists provide a better comprehension of EU policy and give the opportunity to collect information that could be missed. This method provides additional knowledge of the issue of CECs in the aquatic environments which is not available in writing. The perspective on the implementation of EU legislations and their challenges with CEC control from the stakeholders will complement the literature review.

The selection of the interviewed parties was made in order to have a representative sample of the Dutch water management system. All the participants are working directly or indirectly with the WFD. During four months, the interviews were carried out individually with 13 employees of water boards, drinking water companies, associations for water protection, institutional parties and a university (Figure 3.3). In order to get the different perspectives of the Dutch water management system, the stakeholders selection was based on a nonprobability sampling method from each government layer and other parties. The participants were contacted by e-mail with the interview questions (Appendix VI) included to ensure that all relevant information was not missed in the interview scheduled. It was contacted 18 stakeholders but only 11 were interviewed.

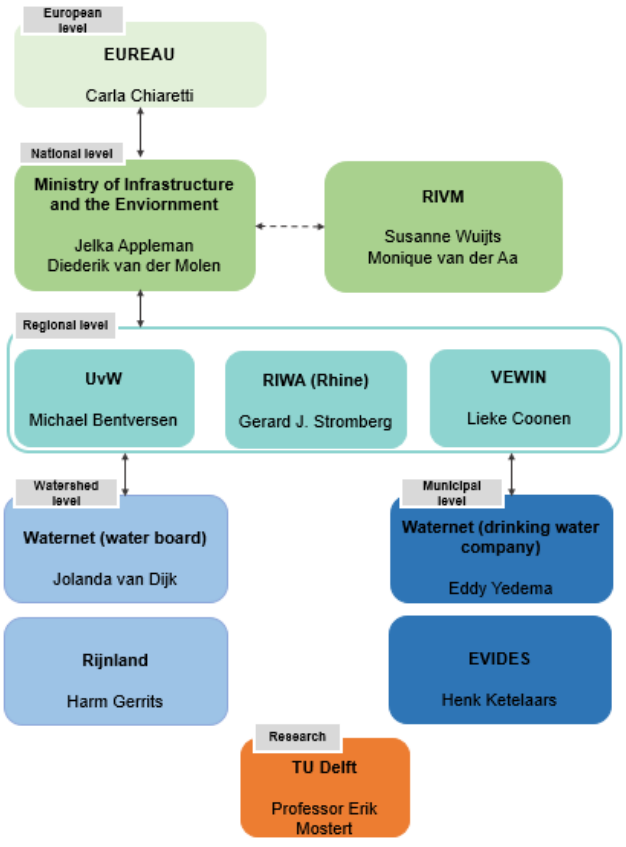

Figure 3.3 Stakeholders interviewed and their position in the Dutch system of water management

All the interviews were carried out as a semi-structured interviews focused on eight questions (Annex VI) about the WFD and other relevant EU policies related to CECs in the aquatic environment. The majority of the questions were open which gave the stakeholders the opportunity to discuss other relevant topics that are not included in the interview questions. Preferably, the interviews were conducted face-to-face however, some were conducted by telephone or Skype due to time and distance constraints. The 1-1,5 hours of interview were recorded for further analysis and during the interview notes were also taken to complement the recordings.

The organization of the recorded interviews was carried out in three steps. In the first step, the audios record was analysed and the main points were noted down for each question and each interview. The second step was to organize all the information selected in the previous step in seven tables where each corresponded to an interview question. The first question was analysed separately because it was only to confirm the understanding of the EU legal framework with regards to CECs. The key ideas of each interview were combined in the same question table. For this step, *post-its* (with different colours and shapes) were used to define the different stakeholders interviewed. The third and last step consisted of identifying statements within the same themes inside the same answer table and clustering the key ideas to a theme. Figure 3.4 illustrates the final result of the interview analysis.

Figure 3.4 Method used to the interviews analysis

Then, the analysis of the organized information from interviews results was carry out to each question regarding the following main topics considered:

- Current EU legislation related to CEC in the aquatic environment;
- Use of current EU legislation for the protection of the aquatic environment;
- How the WFD stimulates the protection of aquatic environments;
- Protective measures taken in the Netherlands;
- Protective measures taken in other EU Member States;
- Is the WFD seen as encouragement to protect the aquatic environment in Member States;
- Current improvements of WFD;
- Recommendations for WFD improvement;

4. CASE STUDY: THE NETHERLANDS

4.1. The Netherlands current situation

The Netherlands has a surface area of approximately 41 550 km^2 (PORDATA, 2015) and is located in the Northwest of Europe bordering Belgium and Germany. The country has a population of nearly 17 000 000 inhabitants (PORDATA, 2015) and is one of the most densely populated deltas in the world (NWP, 2009). At regional level, the country is divided into 12 provinces with the population more concentrated in the Western and Middle provinces (75%) and the North and South with less residents (Boomsma, et al., 2014).

The Netherlands is part of the largest delta in Northwest Europe. This delta consists of the three major European rivers the Rhine, the Meuse and the Scheldt (Mostert, 2006; NWP, 2009) and the Ems river. These river basins, including the coastal waters and aquifer systems were grouped and classified as the fourth River Basin Districts (RBD) of the Netherlands, within the scope of the WFD. All river basin districts are considered international since they are all shared with several countries (EU, 2012a). Figure 4.1 illustrates the location of the river basins districts of the Netherlands defined in the WFD.

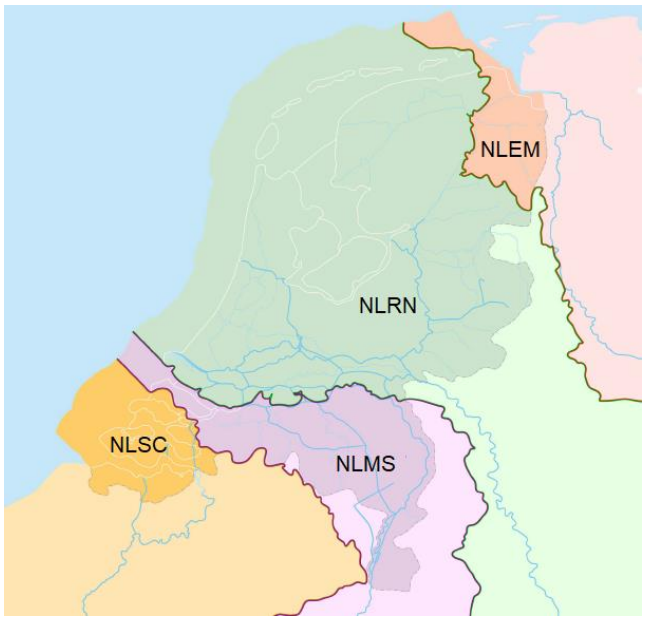

Figure 4.1- River Basin Districts of the Netherlands (NWP, 2015).

The river basin of the Rhine (NLRN) runs through eight countries before it arrives at the Netherlands. It is the biggest river of the four and 69% is located in the Netherlands. The river basin of the Meuse (NLMS) is the second largest river with 18% of it located in the Netherlands and it is shared with other four countries. The other two river basins, the Scheldt (NLSC) and the Ems (NLEM), are those who take less Dutch territory and are shared with only two and one countries, respectively (EU, 2012a).

The mean annual precipitation is around 800 mm in the Netherlands and more than half of the country is at sea level and the territory is generally flat. These factors contribute to the increasing risk of flooding by the sea or by rivers and is requiring a complex management of water resources (Mostert, 2006; NWP, 2009).

The Dutch drinking water supply was around 1068 million m^3/year in 2014. In order to guarantee this water, the water abstraction in the country was around 1124 million m^3/year with more than a half from groundwater resources (Geudens, 2015). The water resources are mainly used in the sectors: Domestic (private households), Agriculture, Industry and Services. The Domestic sector is the largest consumer of water followed by Industrial Activities, Services and the last one Agriculture (Geudens , 2012). These sectors have a major impact on aquatic environments and are responsible for mainly chemical pollution with the introduction of CEC in water (Bijlsma, 2011; Geudens , 2012). As the Netherlands is one big river delta, its water quality also heavily depends of the activities and management of the countries who share the river basins with it.

In the Netherlands, several groups of CEC are present in aquatic environments and some behave as ubiquitous persistent, bioaccumulative and toxic (PBT) substances. The ubiquitous substances can have a significant risk for aquatic environments and remain for decades in water bodies even though the measures taken to reduce and eliminate them. Some of these substances are identified as priority hazardous substances and are regulated under the WFD with monitoring requirements (EQSs). In 2015, 38% of the Dutch water bodies have met the EQS for the list of priority substances, 52% had concentrations of one or more non-ubiquitous substances higher than the EQS, and 10% did not comply with the standards defined for ubiquitous substances. Fluoranthene, nickel, cadmium, endosulfan and hexachlorobutadiene (non-ubiquitous substances) as well as mercury and tributyltin (ubiquitous substances) are the most common substances identified in these water bodies, for not meeting the standards of the WFD (Cox, 2016). Pyrazole which is an industrial compound was found in the Meuse and it has an unknown emitting source. Although, there is not a concrete data about the toxicological effects of this compound, it is now under the monitoring program of the Dutch drinking water production.

In order to meet the targets of the WFD in 2021 and, later, in 2027, the implementation strategies, measures and water plans have been improved and new substances, mostly PPP and medicines, were added to the Dutch monitoring programmes (NWP, 2015; Cox, 2016). Moreover, water quality in the Netherlands is improving in the last decades as seen in the Figures 4.2 and 4.3 that represent a comparison between 2009 and 2015 of chemical surface water status (Bijlsma, 2011; EU, 2012a).

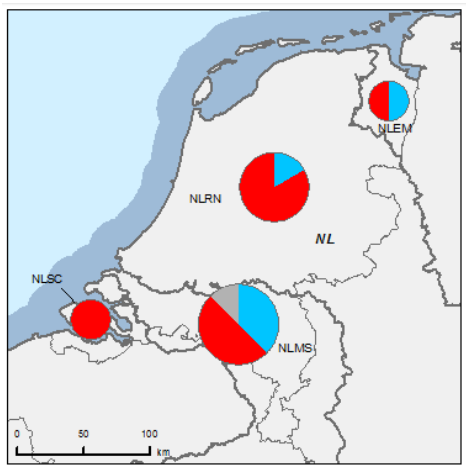

Figure 4.2- Chemical status of natural surface water in Netherlands 2009 *(EU, 2012a)*

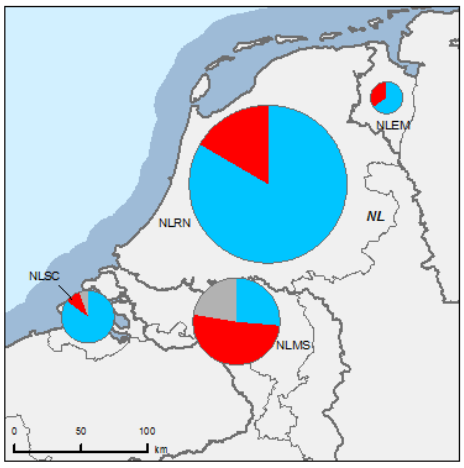

Figure 4.3- Chemical status of natural surface water in Netherlands 2015 *(EU, 2012a)*

4.2. The Dutch water management system

The specific conditions of the Netherlands' location, such as the high risk of flooding, have been a challenge for land use and water resources protection since the Middle Ages. Initially, villagers were responsible for draining water and build structures against flooding to protect their own land. Over the years, land lords and local communities became responsible for water management in their cities. In the 13th century, people common concerns in floods control started to work together and formed the regional water authorities. In the 18th century, the government formed a main institution for flood prevention and other issues related to water quality protection, called Rijkswaterstaat. The Dutch water management became a complex system where the government, public authorities and public administrative bodies are responsible for the safeguard of water resources (Mostert, 2006; Rijkswaterstaat, 2011).

Nowadays, water management in the Netherlands is carried out in the following institutional layers (Mostert, 2006; Beunen, et al., 2009; Rijkswaterstaat, 2011; OCDE, 2014):

- **European level:** Here is the EU legislation and regulations for water protection and the International River Basin Commission (Rhine, Scheldt, Meuse and Ems) which is liable for the protection and management of international river basin districts in EU;

- **National level:** The Ministry of Infrastructure and the Environment (I&M) is responsible for national measures, planning of national water policy and the translation of EU legislation in the Dutch system. At the same level, there is also the National Water Authority- Rijkswaterstaat (RWS)- which is the agency of the ministry and it is responsible for the design, management and maintenance of major waters, such as sea and rivers, it works with the ministry in policy development and also corporates with other parties;
- **Regional level:** The Netherlands has 12 provinces accountable for monitor and management of groundwater, developing water, environmental and land-use plans, translations of national water policy, management of groundwater, supervise water boards and municipalities, among others;
- **Watershed level**: 21 district water boards, such as Rijnland and Waternet (the part of water board) which were interviewed, they are liable for surface water quantity and quality management (ecological and chemical status), wastewater treatment, and flood defence strategies, among others;
- **Municipal level**: 408 Dutch municipalities are responsible for urban water management such as the sewer collection system, spatial planning and urban drainage;

Figure 4.4 represents a diagram of the different government layers which are responsible for the Dutch water management.

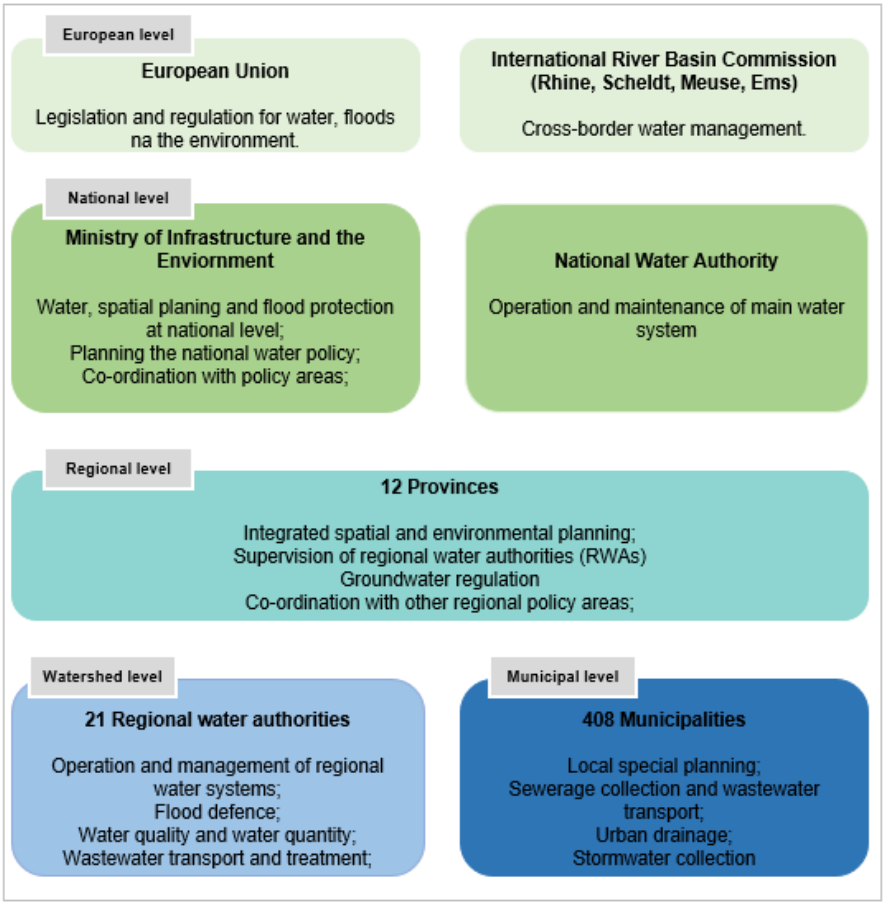

Figure 4.4- Government layers of water management institutions in the Netherlands (OCDE, 2014).

Apart from the government layers, water management is also carried out by other parties with an important role in this system (OCDE, 2014):

- **The Delta Commissioner** is responsible for Delta programme and works directly with the ministries, provinces, regional water authorities, municipalities and other stakeholders.
- **Drinking water companies**, examples are EVIDES and Waternet (the part of drinking water company) which were interviewed. The Netherlands has 15 private water supply companies which are responsible for drinking water production to municipalities and provinces.
- **Associations and institutes** with the aim of protecting the interests of water management institutions represented above (Figure 4.4) and represent them, such as RIWA (Rhine), VEWIN and UvW which were interviewed. RIWA is the Association of River Waterworks which works within Rhine and Meuse section. RIWA (Rhine) collects water quality data from their stakeholders and works together with Germany, France and Switzerland in the International Association of Water Works in the Rhine Basin. VEWIN (*Vereniging van drinkwaterbedrijven in Nederland*) is the Netherlands association of 10 water supply companies, which is practically the entire drinking water sector. This association promotes the common interests (politics and civil services) of drinking water companies. In order to meet its responsibilities, VEWIN also collaborates with numerous social organisations, namely local authorities, environmental organisations, chemical industry and research institutes. UvW (*Unie van Waterschappen*) is an organization that represents the regional water authorities in the Netherlands. This organization works around the needs and common interests of the Dutch regional water authorities at national and international level.
- **RIVM** (*Rijksinstituut voor Volksgezondheid en Milieu*) is the National Institute for Public Health and the Environment it is a knowledge institute for the protection of public health, consumer safety and the environment. The public health institute is responsible for collecting data from national and international sources, development of reports and advise the government in these areas
- **University researchers and specialist** in water management, drinking water and wastewater treatment and water policy work in corporation with the Dutch system in order to find the best solutions for water management.

4.3. Interviews analysis

As mentioned in the 3rd Chapter, the interviews were based on 8 main topics which correspond to the 8 questions made to the participants. The results representation is adapted to each topic analysed in order to contribute to a better understanding of the interviews analysis.

i. Current EU legislation related to CECs in the aquatic environment

The first question of the interview was to confirm if all relevant EU legislation was comprised in the diagram (Figure VI). All the participants agreed with the proposed diagram. In general, they affirmed that the directives selected were the most important regarding CECs in EU aquatic environments and the way they were represented in the diagram are correct. However, some of the stakeholders highlighted the need to include the Marine Framework Directive and the Priority Substances Directive (2013/39/EU) as relevant legislations that have to be seen in the diagram and for that reason they were added on the Figure 2.3.

ii. Use of current EU legislation for the protection of the aquatic environment

The second question was about the use and awareness of EU legislation related to CECs in the aquatic environment. The stakeholders were asked if they agreed with the statement that the Water Framework Directive (WFD), the Industrial Effluents, the Plant Protection Products and the Biocides regulations were the only EU legislation that took the aquatic environment directly into account, and which of these regulations they found were the most important with regards to safeguarding the aquatic environment.

As seen in table 4.1, all the stakeholders affirmed that the WFD is an instrument that takes the aquatic environment directly into account. As to be expected, the Industrial Effluents, the Plant Protection Products and the Biocides regulations were also mentioned in this question by some stakeholders. RIVM and VEWIN also identified the Veterinary Medicines and Human Medicine Directives due to the environmental assessments, including in aquatic environments that are required for these products. Professor Erik Mostert (TU Delft) also mentioned REACH and the Urban Wastewater Directive as directives which safeguards the environment.

Table 4.1- EU Directives represented on the diagram which are taking the aquatic Enviornment into account according to the stakeholders.

EU Directive	Stakeholders' responses										
	I&M	EUREAU	RIVM	Professor Erik Mostert (TU Delft)	RIWA	VEWIN	UvW	Waternet (drinking water)	Waternet (water board)	Evides	Rijnland
WFD	X	X	X	X	X	X	X	X	X	X	X
IPPC		X	X	X	X	X	X	X	X		
PPP		X	X	X	X	X	X	X	X		
Biocides		X	X	X	X	X	X	X	X		
Veterinary products			X			X					
Pharmaceuticals			X								
REACH				X							
Urban Wastewater				X							

The stakeholders were also questioned for which legislation they regularly refer to when arguing for the need for protecting the environment. All the interviewees stated that they adhere to the WFD for the protection of aquatic environments although their use of the directive is different due to their responsibilities. As an example, EVIDES and VEWIN focus on article 7(3) of WFD because it is the most relevant article for them and Rijnland and Waternet (water board) have to focus on the ecological objectives of WFD and the priority substances list.

Apart from the WFD, some stakeholders, as outlined in table 4.1, have identified other directives which they use to complement the WFD. For the UvW, the IPPC Directive is the second most important followed by the PPP and the Biocides Directive. RIVM stated that the WFD is the most important legislation to protect aquatic environments but the IPPC Directive is more suitable for protect aquatic environments from industrial effluents. VEWIN has classified the PPP and IPPC directives as essential. RIWA emphasized that they also frequently refer to the IPPC directive due to the industrial discharges along the Rhine.

iii. How the WFD stimulates the protection of aquatic environments

In the third question, the participants were asked to name examples of how the WFD stimulated the protection of aquatic environments. However, some of the stakeholders also identified aspects that are hampering rather than stimulating the protection of water bodies. The following stakeholders: VEWIN, UvW, Waternet (drinking water and water board), Professor Erik Mostert (TU Delft), RIVM and EVIDES gave examples of WFD stimulations in contrast to EUREAU, RIWA and Rijnland who identified issues that do not contribute to the protection of water bodies. Many stakeholders mentioned the same examples of stimulations and issues, this is represented in tables 4.2 and 4.3, respectively.

Table 4.2- WFD stimulations, the stakeholders who mentioned them and the number of responses to each specific stimulation.

Stimulation	Stakeholder	Number of responses
Targets	Waternet (water board); Professor Erik Mostert (TU Delft)	2
No deterioration of water quality	EVIDES; VEWIN; Professor Erik Mostert (TU Delft)	3
Required monitoring of priority substances	Professor Erik Mostert (TU Delft); RIVM; UvW; Waternet (drinking water); VEWIN	5
Fines for non-compliance	Professor Erik Mostert (TU Delft)	1

As shown to table 4.2, the WFD stimulation identified most frequently mentioned by the participants was the **required monitoring**. The WFD requires monitoring of priority substances and other relevant substances added by the Member States. Member States have to report if there are priority substances above the EQS or other relevant substance above the limit established by the country. Professor Erik Mostert (TU Delft), RIVM, UvW, Waternet (drinking water) and VEWIN affirmed that the monitoring programmes of priority substances and the reports with the monitoring data are stimulating the safeguarding of water bodies.

The second most mentioned stimulation was the **no deterioration of water bodies** required in Article 7(3) of WFD. The article states that the Member States should ensure no deterioration of water quality and that the use of simple water treatment techniques should be enough to safeguard drinking water production. VEWIN and EVIDES stated that the simple treatment required in Article 7(3) is a stimulation for drinking water production companies to ensure no deterioration of the aquatic environment. According to EVIDES, the simple treatment for drinking water production is filtration, disinfection and activated carbon which is also applied in the other drinking water companies. Professor Erik Mostert (TU Delft) also identified this aspect as a stimulation of WFD.

The **targets of WFD** were the third most mentioned. The WFD sets EQS for priority substances in water bodies that should be achieved by 2027 by Member States. Both Waternet (water board) and Professor Erik Mostert (TU Delft) have mentioned this stimulation. Waternet (water board) stated that their focus is mainly on the ecological status of water bodies, second to the priority substances list and the EQS targets that they have to achieve.

The **fines for non-compliance** were also identified as WFD stimulations. According to Professor Erik Mostert (TU Delft), the fines should be stimulating the Member States to protect the aquatic environment. The EU commission controls the WFD implementation in the Member States and if they do not comply the requirements laid down, they are fined for each day that they are not complying.

Apart from specific WFD stimulations, the same stakeholders stated relevant information within these subjects. The I&M stated that WFD indirectly stimulates the protection of aquatic environments. According to this stakeholder, the WFD gives them foundation to develop their own countries approach. The Dutch strategy for CECs was given as an example of a WFD based national policy and indirect stimulation. Finally, UvW affirmed that corporation between stakeholders and networking between the member states is being stimulated by the WFD requirements.

Table 4.3- Issues in WFD stimulations, the stakeholders who mentioned them and the number of responses to each issue.

Issue in WFD stimulations	Stakeholder	Number of responses
Obsolete substances and relevant substances not included in WFD	RIWA; Rijnland	2
Deficient connections between EU water policies	RIVM; EUREAU; UvW; VEWIN	4
Implementation is not efficient enough in some Member States	RIWA; Rijnland; Professor Erik Mostert (TU Delft)	3

As shown in table 4.3, the **deficient connections between EU water policies** was pointed as the biggest issue with the WFD, followed by the **implementation is not efficient enough in some Member States** and they may hamper the intended protection of the aquatic environment. RIVM, EUREAU, UvW and VEWIN affirmed that the connections between directives related to chemicals in aquatic environments could be better. UvW emphasized the need of link WFD goals with the other EU directives mentioned in the second question. EUREAU and VEWIN stated that WFD goals should take into account when other environmental directives are being developed or reviewed. RIWA, Rijnland and Professor Erik Mostert (TU Delft) affirmed that the WFD implementation is inefficient in each Member State. RIWA affirmed that WFD has the possibility to stimulate the protection of aquatic environments and even more in combination with other EU legislation the implementation, however, is lacking. RIWA gave the example of the situation with Germany, which is putting a lot of effort in rivers problematic to them and less in the Rhine. This is a problem for the Netherlands which is where Rhine's delta is situated and is responsible for the water quality affected by other Member States where the Rhine runs through, such as Germany.

According to the Netherlands perspective, some **obsolete substances and relevant substances not included in WFD** are an issue and they are hampering water quality protection. RIWA affirmed that there are substances on the priority substances list that are not relevant for the Netherlands and some of the strict limit values set in the list are for extinct substances. The water board of Rijnland measures several substances in their water bodies which are included in the Dutch monitoring program and they find a lot of chemicals which are not regulated in the WFD

yet. Polycyclic aromatic hydrocarbon (PAHs) and Perfluorooctane Sulfonate (PFOS) are some of the problematic chemicals for Rijnland.

EUREAU, UvW and RIVM affirmed that the connections between the WFD and other directives are not well implemented and the lack of integration of WFD objectives in other EU directives are also hampering the protecting of aquatic environments.

iv. Protective measures taken in the Netherlands

In the Netherlands, many measures and initiatives are being taken to control CECs in aquatic ecosystems. Table 4.4 lists the Dutch measures mentioned by the participants.

Table 4.4- Measures taken in the Netherlands mentioned by the stakeholders to protect the aquatic environments of the CECs

Measure	**Stakeholders' responses**									
	I&M	RIVM	RIWA	VEWIN	UvW	Waternet (Drinking water company)	Waternet (Water board)	EVIDES	Rijnland	Professor Erik Mostert (TU Delft)
Pharmafilter			X		X	X	X			X
Re-evaluation of industries discharges	X									
Reduction of pesticides emissions in urban areas					X	X				
Measures for agriculture sector to reduce PPP			X		X	X				
More risk based analysis and all substances found are reported	X									
Signalling value		X		X		X		X		
Improvement in treatment steps of drinking water production						X		X		
Improvement in WWTP-extra treatment steps									X	
National programmes and water plans	X			X	X	X				X
Fact sheets	X									

The **Pharmafilter** system is used to collect and treat hospitals' wastewater and it has been successfully tested in the *Reinier de Graaf* Hospital, Delft. The objective of this system is to remove the medicine residues and endocrine disruptors from faeces and urine of the patients which are collected by bedpans made of bioplastics. The disposable bedpans are placed into a

shredder (Tonto) and flushed through the sewer system (Figure 4.5). Solid waste is digested in a specific installation where biogas is later produced.

Figure 4.5 Shredder Tonto (Batelaan, et al., 2013).

Hospital wastewater is purified in the Pharmafilter installation which consists in a membrane bioreactor with three main compartments (anaerobic, anoxic and aerobic), ultrafiltration membranes, flux ozone installation and activated carbon used as an extra step (Figure 4.6). The installation can remove up to 80% of medicine residue and endocrine disruptors and up to 40% of the effluent water is reused.

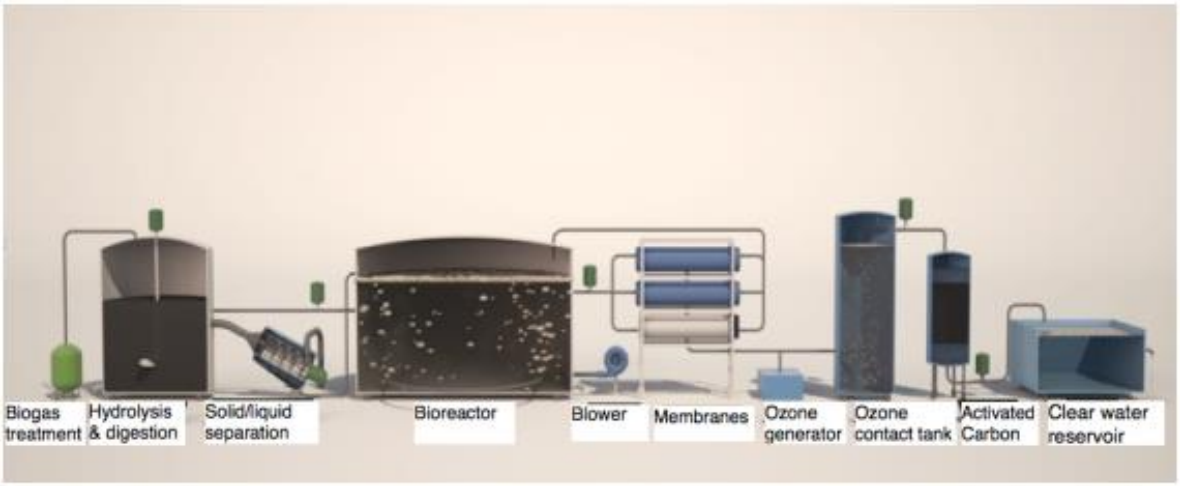

Figure 4.6 Pharmafilter system (Batelaan, et al., 2013).

A **re-evaluation of all industrial emission** permits is being done in order to make sure that they are complying with the WFD and the drinking water production is not being affected by them. This evaluation is directly linked to Article 11 (5) of WFD about the programme of basic measures for river basin districts of Member States where monitoring of relevant permits should be examined if the data collected shows that the goals might not be achieved.

The **reduction of pesticides emissions in urban areas** is one of the national measures in the Netherlands. The use of pesticides hard services and green areas will be reduced for private and

public users in several regions of the Netherlands. For instance, according to the implementation programme 2015-2021 of Drentsche Aa, the following restrictions are settled for PPP usage in urban areas: Professional and private use of PPP on hard surfaces was banned in 2015; Professional use of PPP in other areas, such as parks and recreation areas, except for agriculture uses and unpaved terrain, will be banned in November of 2017, and private use will be reduced.

Measures for agriculture sector to reduce PPP are being taken for the protection of the Dutch aquatic environments and change the behavior of the farmers. Information about the best agriculture practices, the encouragement of environmental friendly chemicals use and awareness are some of the measures that have been taken.

With regard to the Dutch drinking water production, drinking water producers have to monitor a list of problematic substances and their standards settled by the Dutch government in the Decree on Quality Requirements and Monitoring Water (DQRMW) (BKMW, 2009). This list includes substances from WFD, Drinking Water Directive and relevant substances for the Netherlands. Additionally, drinking water producers have to monitor anthropogenic substances that are not in the Dutch legislation and report them to the ministry. However, numerous of anthropogenic substances have been reported and one of the Dutch strategies now is to apply **more risk based analysis** by drinking water producers and **all substances identified with the signalling value** are also included on the monitoring reports.

The Netherlands has many sophisticated laboratories for monitoring substances which enables the detection of thousands of chemicals in Dutch water bodies. Drinking water producers have to monitor substances which are not regulated in the Dutch policy and use the criterion of the **signalling value** as a standard. The signalling value for anthropogenic substances is a measure implemented in the Netherlands in order to take preventive actions for CECs in water bodies. If the value is exceeded, the toxicological effects on the environment from the substances has to be assessed. Currently, the value is 1 µg/L but now two other options are being discussed. The first one is use the current value of 1 µg/L for surface water and 0,1 µg/L for drinking water and groundwater sources. Or lower the value to 0,1µg/L for all surface water, drinking water and groundwater sources.

Drinking water companies are taking measures to improve their treatment steps in order to remove chemical substances. According to Evides, they are improving their existing activated carbon step, which can remove chemical substances by adsorption, and they are studying the selection of bacteria for chemicals removal, such as pyrazole. These improvements are done in a pilot plant with Wageningen University collaboration. EVIDES affirmed that other water companies are also improving their water treatment steps for CECs removal, such as Dunea with the use of UV and ozone in the treatment process and Waternet (drinking water company) is using ozone.

Also, **extra treatment steps** are being studied to improve CECs removal in **WWTP**. Rijnland affirmed that a pilot plan is part of a research within CECs removal from wastewater however, the results of the pilot are not yet disclosed.

In the Netherlands, **National programmes and water plans** for water protection are developed to meet the targets of WFD (EQSs) in the next revision (2021). These national programmes are implemented to manage the water related challenges in the Netherlands, including the occurrence of CECs in aquatic environments. The examples of national programmes and plans:

- At an EU level there is the *Stroomgebiedbeheerplan 2016-2021* (River Basin Management Plan) for each River Basin District (RBD), including programmes to international river basins management with other countries within the same river basins. River Basin Management Plans for the Rhine, Meuse, Scheldt and Eems were developed according to the WFD requirements. These plans establish measures for water quality protection, including ensuring a good quality chemical status;
- At national level there is the *Nationaal Waterplan 2016-2021* (National water plan) which is the official water plan of the Dutch government. As the national water policy plan, it is based on WFD requirements and targets and includes the protection of water bodies against CECs;
- The *Delta Programma* (Delta programme*)* provides strategies and plans carried out by several organizations and public authorities to protect the Netherlands against flooding and to ensure the supply of water the whole population. Also, the programme sets water quality objectives.
- At regional level the *Waterplan* (Water plan) for the provinces;
- *Waterbeheerplan* (Water management plan) for water boards;

Fact sheets were developed within the scope of the river basin management plans. These documents contain detailed information for each Dutch water body such as conditions, objectives, identification of challenges and specific measures in order to comply with WFD requirements with regards to ecological and chemical status of water bodies until 2021. According to the I&M, there are more than 700 fact sheets for surface water bodies and 23 for groundwater water bodies.

v. Protective measures taken in other EU Member States

Also measures for the protection of aquatic environments implemented in other Member States were asked from the stakeholders. Table 4.5 lists the specific measures mentioned.

Table 4.5- Measures taken in other EU countries mentioned by some of the stakeholders to protect the aquatic environments of the CECs

Measure	Stakeholders' responses					
	EUREAU	I&M	RIWA	Rijnland	VEWIN	UvW
WWTP extra treatment steps in Germany	X		X	X	X	X
WWTP extra treatment steps in Switzerland(1)	X	X	X	X	X	X
Water tax in Switzerland	X					
"Take-back" scheme	X					
TOPPs project	X					
ChemSec in Sweden	X					

(1)Switzerland not an EU Member States however, it is involved in EU's international river basins management plans.

As previously mentioned, conventional water treatment plants do not remove all the micropollutants present in wastewater. In order to remove these substances and reach the WFD targets, Germany and Switzerland implemented national measures to combat the chemical water pollution in WWTP. The improvements of their WWTP are focus on **extra treatment stages**, such as ozonation, Powdered Activated Carbon (PAC) dosage and Granular Activated Carbon (GAC) filtration.

Since 2016, Switzerland has an **annual tax** of 9 Swiss francs/person (7,88€) which will finance 75% of the investment of 100 WWTP improved with extra stages of ozonation or treatment with activate carbon (Swiss Federal Institute of Aquatic Science and Tec, 2016)

In regards to pharmaceuticals usage, the **"take-back" scheme** was mentioned as a measure for environmental information on human medicines. The "take-back" scheme of unused and/or expired medicines is an approach to reduce the discharges of pharmaceuticals in wastewater and it is implemented in several EU Member States, such as Sweden, Portugal and the Netherlands. This system contributes to raise consumers' awareness of the use of pharmaceuticals and their impact in the environment.

The **TOPPS** water protection project is a project that aims for the reduction of PPP in water by point sources, spray drift and runoff in agriculture fields. The project operates in 12 countries across Europe, including the Netherlands, and consists in educating the farmers with the Best Management Practices (BMPs) and training them to improve agriculture techniques.

ChemSec is a Swedish non-profit organization financed by the Swedish Government who works with NGOs, researchers, industries and companies, such as IKEA and H&M. ChemSec's role is to support the management of chemical legislations for these organizations and to help them reduce chemicals usage. ChemSec is an example of a national initiative with corporation between producers and users of chemicals and the government.

vi. Is the WFD seen as encouragement to protect the aquatic environment in Member States

All stakeholders stated that the WFD does encourage Member States to take actions for the protection of aquatic ecosystems. In this question the participants have specified how they believe this directive contributes to encouraging Member States, from their perspective in the Netherlands, and aspects that are not encouraging them. In general, stakeholders agree that *"it is better to have WFD than nothing"* (EUREAU), there is a *"high ambition level (in WFD)"* (RIWA) and *"(the WFD) encourage us to make plans and reach the targets"* (Rijnland). However, WFD is not directly encouraging the Member States (UvW; Waternet (water board)) and there is room for improvement-*"could be better"* as stated by VEWIN. All participants have appointed WFD's issues which are not fomenting this encouragement. The reasons why the WFD is seen as an encouragement to protect the aquatic environment and why it is not seen as an encouragement are represented in tables 4.6 and 4.7, respectively.

Table 4.6- WFD encouragements, the stakeholders who mentioned them and the number of responses to each specific encouragement.

WFD encouragement	Stakeholder	Number of responses
Required monitoring of priority substances	EUREAU	1
Development of action programmes and plans due to WFD	Waternet (water board); Rijnland	2
Awareness of CECs in the aquatic environment	EUREAU; UvW	2
Article 7(3) of the WFD	VEWIN; Waternet (drinking water)	2

Table 4.6 shows that the WFD is seen as encouraging the protection of the aquatic environments due to the monitoring programmes required by the WFD, the development of programmes and plans in Member States due to the WFD, the awareness of CECs in the aquatic environment has increased due to the directive and Article 7(3) of the WFD is also seen as an encouragement to

protection of water bodies. EUREAU stated that **required monitoring of priority substances** in WFD are giving information about water bodies status and this information encourages Member States to protect them. Waternet (water board) and Rijnland mentioned the **action programmes and plans due to WFD** that have been developed in the Netherlands in order to reach the targets of WFD as a reason why they see the WFD as an encouragement to protect the aquatic environment. EUREAU affirmed that initiatives and measures were taken in Member States because of increased **awareness of CECs in the aquatic environment** due to the WFD. It was also mentioned that countries outside of EU, namely India and part of South America, are developing new water policies based on the approach in the WFD. According to Waternet (drinking water) and VEWIN, WFD's **Article 7(3)** it is an encouragement for drinking water source protection because of the simple treatment requirement.

Table 4.7- Issues in WFD encouragements, the stakeholders who mentioned them and the number of responses to each issue.

Issue in WFD encouragement	Stakeholder	Number of responses
Technocratic approach	I&M	1
Suspension of Priority Substances list review	EUREAU; RIVM	2
Different implementation in different EU Member States	RIVM; Waternet (drinking water); Waternet (water board)	3
WFD is too strict	Rijnland; Waternet (water board)	2
WFD is not strict enough	Professor Erik Mostert (TU Delft); VEWIN; RIWA; Waternet (drinking water)	4
Complexity of CECs problematic	RIVM; UvW; VEWIN	3

Although the stakeholders all stated that the WFD does encourage the Member States to protect the aquatic environments, the majority also referred to aspects that are limiting the WFD in its ability protect the aquatic environment.

The issue stated most often was that the **WFD is not strict enough** and may not contribute enough to ensure actual protection of the aquatic environment. According to RIWA and Professor Erik Mostert (TU Delft), the EU commission could do more to achieve the targets, Waternet (drinking water) emphasized that WFD *"is very general"* which is not helping them, and VEWIN affirmed that the basic measures established in WFD are not enough and that they could be more concrete.

The **different implementation in different EU Member States** and the **complexity of CECs problematic** in the aquatic environment were the second most mentioned by the stakeholders.

Waternet (water board), RIVM and Waternet (drinking water) stated that the WFD encourage the Member States to protect water bodies but the difference in implementation between member states is an issue. RIVM, UvW and VEWIN indicated that the effects of CECs on human health and on the environment are very difficult to control and mitigate. The **suspension of Priority Substances list review** and the **WFD being too strict** were the third most mentioned by stakeholders. EUREAU and RIVM disclosed that the review of the priority substances list has been suspended. EU commission, working groups and interested parties are focussed on improve the priority substances list and their EQSs. The I&M affirmed that they are working on other approaches for the priority substances list and EQSs instead of an approach based only on a list of substances. However, EUREAU affirmed that the Watch list is being updated since the report of the first Watch list was published in July 2017. The Dutch water boards interviewed in this study emphasized that they found the requirements of the WFD very strict since their responsibility is the ecological status of their water bodies and to live up to the requirements of the WFD. They have also affirmed that the amount of documentation needed is high and the standards for CECs are changing too often.

The last issue mentioned was the technocratic approach required by EU commission for Member States on WFD implementation. According to the I&M, WFD encouraged the Member States to protect aquatic environment but there was a turning point that putted on hold. The I&M believes that the technocratic approach could lead to less focus on the water quality and more focus on technical details and bureaucratic matters.

vii. Current improvements of WFD

Many stakeholders mentioned the same ongoing improvements to the WFD. These answers are represented in Table 4.8 represents the number of responses for WFD improvements.

Table 4.8- WFD improvements, the stakeholders who mentioned them and the number of responses to each improvement.

WFD improvements	Stakeholder	Number of responses
Effect based tools	UvW; Rijnland; RIVM	3
Ecological Key Factors	Waternet (water board); UvW	2
CIS working groups	EUREAU; RIVM; Waternet (drinking water); Professor Erik Mostert (TU Delft)	4
Ubiquitous substances	Waternet (water board);I&M	2
End term of WFD	I&M	1

As shown in Figure 7, the **CIS working groups** were most often mentioned in this question. This was identified by EUREAU, RIVM, Waternet (drinking water) and the Professor Erik Mostert (TU

Delft). One of the groups is working on chemicals for monitoring and assessment in the WFD context. They are focusing on effect based tools (with bioassays), mixtures effects in aquatic life and reviewing the criterions for prioritization of compounds. The current research and consequent improvements of WFD are being done within working groups of CIS.

Effect-based tools were mentioned by RIVM, Rijnland and UvW. Effect-based tools are assessment techniques used to identify effects of a wide variety of chemicals in order to help the monitoring program of chemicals in water bodies.

The **Ecological Key Factors** (EKFs) was mentioned by UvW and Waternet (water board). EKFs are being developed by STOWA- *Stichting Toegepast Onderzoek Waterbeheer* (Foundation for Applied Water Research) for the Netherlands and it will be used by the water boards. This program is developed for water management in the Netherlands in response to the WFD targets in 2021 and 2027. The program consists in 10 EKFs which will describe the relation between cause, state and impact of the environmental pressure. One of the EKFs will be for toxicology which will allow the analysis of chemicals in the Dutch water bodies. The **ubiquitous substances**, was mentioned by Waternet (water board) and the I&M. According to Waternet (water board), the monitoring of **ubiquitous substances** regulated on the priority substances list of WFD (Annex III) are not needed anymore since their production and use is banned. The I&M affirmed that some ubiquitous substances were added in the last review of the priority substances list (Directive 2013/39/EU).

The **end term of the WFD** is being discussed by the EU commission, according to the I&M. Initially, all measures in place were supposed to remain after 2027 however, Member States wants additional measures after the target date. The I&M affirmed that the discussion about the end term of WFD is complex. If they extend the end term of the WFD could decrease the Member States ambition or could increase their stimulation to take actions.

Apart from the improvements of WFD identified in this question, some stakeholders referred the water quality improvement. EUREAU affirmed that water quality of EU aquatic ecosystems is actually improving, UvW is quite happy with the improvements of Dutch water quality and RIWA believes that the "*purification effort could be reduced"* since the water quality is improving.

Table 4.9- Issues in WFD improvements, the stakeholders who mentioned them and the number of responses to each issue.

Issue in WFD improvements	Stakeholder	Number of responses
Further development of the WFD is too slow	UvW; RIWA; VEWIN; Waternet (drinking water)	4
Economic interests	UvW; RIVM	2

The stakeholders interviewed identified two issues which may affect the expected improvements (Table 4.9). It was mentioned that the **further development of the WFD is too slow** and few improvements have been made. UvW, RIWA, VEWIN and Waternet (drinking water) responded that the WFD might not have enough improvements to meet the targets and they have been too slow. The **economic interests** involved not only with the WFD implementation but also in the development of improvements related with CECs could be a concern. UvW and RIVM referred the economic interests that might have been involved in the prioritization of substances for the priority substances list.

Regarding other relevant information stated in this question, EUREAU affirmed that the financial crisis and the loss of resources available in the environmental ministries may have affected the implementation of the WFD in some Member States and consequently reduced the improvements expected. Additionally, EUREAU indicated that only 52% of the water bodies within WFD is in good status. Since the improvements are too slow, RIWA mentioned that it should have more effort in the treatment techniques, consequently more economic effort, in order to achieve the targets in 2027.

viii. Recommendations for WFD improvement

To finish the interview, the participants were asked for their own recommendations to improve the WFD. This question was posed in order to understand what is missing in the policy and which challenges the Dutch water management systems has to deal with. The recommendations were grouped in the main topics presented in Figure 4.7.

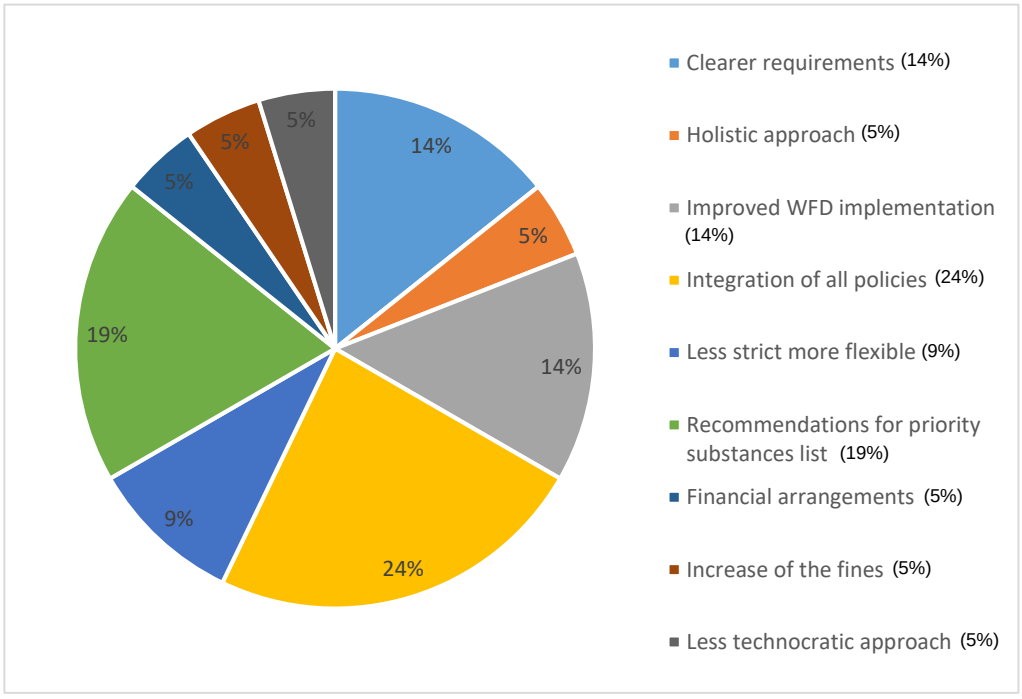

Figure 4.7 Personal recommendations of the stakeholders to the WFD.

As shown in Figure 4.7, it is clear that the **integration of EU water policies** is the most repeated recommendation from the stakeholders, with 25% of the responses related to this theme. Specifically, EUREAU and VEWIN affirmed the need of cross references between EU legislation, particularly between WFD and other EU legislation, EUREAU emphasized the need of taking WFD objectives into account when developing other policies, RIVM recommended harmonization of the WFD and national legislation and RIWA mentioned the need of cooperation between all the interested parties.

With regards to the **priority substances list**, RIWA stated that there are other strategies which could have a bigger impact on the protection of the aquatic environments instead of focus on a the EQSs from the priority substances list. RIWA recommended that Member States could focus on a list of principles, such as Article 7(3), VEWIN believes that it would be more effective if the standards were settled for groups of chemicals instead of individual substances. Rijnland and Waternet (drinking water) recommended effect based analysis to be included in the monitoring programmes. This was the second most recommended aspect. EUREAU believes that EU can regulate any chemical substance even if there is no exposer or less risk associated in order to protect all the resources in EU. Also, the substances could be forbidden if they were hazardous to human health and the environment because of the precautionary principle stated in WFD and in Article 191.2 of Treaty on the Functioning of the European Union (EU, 2000). EUREAU stakeholder believes that this approach could be a challenge in the future because of the growing chemical industry and economic interests involved.

Clearer requirements in the WFD for monitoring programmes and **improved WFD implementation** in the Member States were the second most recommended, with 15% each. RIWA, RIVM and Waternet (water board) affirmed that the WFD requirements for the monitoring programmes are not clear and they need to be specified. More guidelines for data collection in monitoring programmes were recommended. RIWA recommended the standardization of toxicological tests in order to make it clear and simple how to analyse the results for all parties. With regards to the WFD implementation, Waternet (drinking water) recommended improvements in WFD implementation since it is different in different Member States. VEWIN recommended more concrete requirements for the priority substances list and the monitoring programmes. RIWA believes that improvements on WFD implementation, including in the technical guidance, will contribute to enhance the efficiency of this Directive.

The fourth most mentioned recommendation, which had 10% of the responses, were **less restrictions and more flexibility** in the priority substances list and EQSs. UvW affirmed that nutrients and pesticides, including the usage of illegal pesticides, are the most important barriers for them to reach the WFD targets in time. The challenges faced by UvW are not really related to priority substances and a strict directive may not help them because the use of other legislations would be needed. Professor Erik Mostert suggested that strict regulations may not encourage Member States because if the WFD implementation fails they might be fine by EU commission.

The last recommendations were a holistic approach, fines for non-compliance, financial support and a less technocratic approach. RIVM suggested a **Holistic approach** to the WFD based on the environment, social and economic concerns and interests all at the same time. Professor Erik Mostert (TU Delft) affirmed that the EU commission could act more and that the increase of **fines for non-compliance** could be a possible measure. Also, VEWIN affirmed that **financial support** to the WFD implementation is needed as well as financial arrangements. The I&M proposed **a less technocratic approach** in order to have more focus on water quality.

An overview of the interviews results is made in tables 4.10 (from question one to three) and 4.11 (from question four to eight).

Table 4.10- Summary of interviews results from question one to question three.

Nº	Topic of the interviews question	Main results	
i.	**EU legislation related to CEC**	WFD, EQS Directive and PS Directive Marine Strategy Framework Directive Drinking Water Urban Wastewater Medicinal products for human use PPP Veterinary medicinal products	REACH Industrial Effluents Safety of Toys Cosmetic products Food additives Biocidal products
ii.	**WFD main use**	*European institute (EUREAU):* WFD implementation in the Member States; *Ministry (I&M):* WFD implementation in the Netherlands; *Water boards (Waternet; Rijnland):* Ecological status; EQS targets of priority substances;	*National associations and water institutes (VEWIN;UvW;RIWA):* WFD implementation in drinking water companies and water boards; Collecting relevant data from drinking water companies of the Rhine to VEWIN; *Drinking water companies (Waternet; EVIDES):* Article 7(3); EQS targets of priority substances;
iii.	**WFD stimulations**	Targets No deterioration of water quality Required monitoring of priority substances Fines for non-compliance	*Issues:* Obsolete substances and relevant substances not included in WFD Deficient connections between EU water policies Implementation is not efficient enough in some Member States

Table 4.11 Summary of interviews results from question four to question eight.

Nº	Topic of the interviews question	Main results	
iv.	**Measures of the Netherlands**	Pharmafilter Re-evaluation of industries discharges Reduction of pesticides emissions in urban areas Measure for agriculture sector to reduce PPP More risk based analysis and all substances found are reported	Signalling value Improvement in treatment steps of drinking water production Improvement in WWTP- extra treatment steps National programmes and water plans Fact sheets
v.	**Measures of other EU Member States**	WWTP extra treatment steps in Germany WWTP extra treatment steps in Switzerland(1)	Water tax in Switzerland “Take-back” scheme TOPPs project ChemSec in Sweden
vi.	**WFD encouragement**	Required monitoring of priority substances Development of action programmes and plans due to WFD Awareness of CECs in the aquatic environment Article 7(3) of the WFD	*Issues:* Technocratic approach Suspension of Priority Substances list review Different implementation in different EU Member States WFD is too strict WFD is not strict enough Complexity of CECs problematic
vii.	**Current improvements of WFD;**	Effect based tools Ecological Key Factors CIS working groups Ubiquitous substances End term of WFD	*Issues:* Further development of the WFD is too slow Economic interests
viii.	**Recommendations for WFD**	Integration of EU water policies Priority substances list Clearer requirements Improved WFD implementation Less restrictions and more flexibility	Holistic approach Fines for non-compliance Financial support Less technocratic approach

4.4. Discussion of results

All stakeholders affirmed that the WFD is the most important tool for the protection of aquatic environments regarding CECs. This fact was also mentioned in the literature review (Pio, et al., 2000; Fürhacker, 2008; Tiedeken, et al., 2017).

According to the review of legal documents made before the interviews, the stakeholders confirmed that the Industrial Effluents (EU, 2010), the Plant Protection Products (EU, 2009b) and the Biocides (EU, 2012b) regulations were also taking into account directly the aquatic environment. Additionally, Priority substances (EU, 2013), Veterinary medicines, Medicines for human health (EU, 2001a), REACH (EU, 2006) and Urban Wastewater Directives (EU, 1991)were identified by RIVM, VEWIN and Professor Erik Mostert (TU Delft). However, REACH takes into account the protection of the environment in general but do not include specific requirements for the aquatic environments. Also, Urban Wastewater Directive is not focused on chemicals. It is notice that these stakeholders are directly working and studying the EU water policy and they have a broader perspective of the current legislation regarding the protection of aquatic environments against CECs. In contrast, EVIDES and Rijnland stakeholders did not mentioned more than one directive because they have different responsibilities for the protection of aquatic environments and their work is more focused in specific articles of the WFD.

All Dutch governmental layers for water management are using WFD as a political instrument to regulate and control CECs in the aquatic environments according to their responsibilities (Table 4.10). EUREAU works with the WFD and helps the Member States to implement the directive. VEWIN and UvW work with the WFD and promote its implementation in drinking water companies and water boards, respectively, taking into account their political and civil services interests. RIWA (Rhine) collects the data from drinking water companies of the Rhine and provides them to VEWIN. Water boards have to focus in ecological status and the EQS of the priority substances list. Drinking water companies are working with the Article 7(3) about simple treatment in drinking water production. Both monitor the substances listed on the priority substances list of the WFD in order to meet the EQSs.

UvW, RIVM, VEWIN and RIWA are complementing the WFD usage with IPPC, PPP and Biocides Directives requirements, by different ways, since their responsibilities in the protection of aquatic environments in the Netherlands are broader and involve the integration of several environmental challenges.

Several aspects were given as examples of WFD stimulations for the protection of aquatic environment with regards to CEC (Table 4.10). They are stimulating the Member States, namely the Netherlands, to include more substances in the monitoring programmes and develop new strategies to detect CEC in surface water. The Dutch drinking water companies and water boards, affirmed that their monitoring programmes include the detection of priority substances and other relevant substances for them. However, some stakeholders mentioned the fact that some of the

priority substances are no longer a problem for the Netherlands and the other substances that are problematic are still not included in the WFD or in other directive which was also mentioned by Lopez *et al*. (2015). According to Houtman (2010), chemicals are still unregulated because of the "time-consuming process" needed for legislation. Also, the connection between the WFD and other directives related to chemicals in aquatic environments is not enough and the goals of WFD should be taken into account during the development of other environmental directives. They also mentioned that WFD implementation in the Netherlands could be more efficient as well as in other countries.

The Netherlands is mostly focused on pharmaceuticals and pesticides control measures since are their main problematic CEC, namely tributyltin (a ubiquitous substance) and pyrazole. In Dutch water management system perspective, they have made a lot of effort to take actions and more than the required they have been developing measures to protect the aquatic environment against CEC (Table 4.11). With regards to measures taken in other Member States, it was identified four measures from Germany, Switzerland and Sweden (Table 4.11). According to the stakeholders who have mentioned these measures stated that these countries are quite advanced in WWTP improvements and initiatives to control CEC, particularly pesticides and pharmaceuticals, in aquatic environments.

All the participants responded positively to WFD encouragement in Member States, specifically in the Netherlands (Table 4.11). Article 7(3) of WFD was once more referred by drinking water companies as the main encouragement for water protection against CEC. Water boards identified the water programmes that have been developed to support other initiatives and meet the targets of the WFD. EUREAU highlighted the awareness created by WFD in the Member States which encouraged them to take actions. The required monitoring of the priority substances listed was mentioned again as an example of WFD aspects that is protecting the aquatic environments. The analysis of the same answers by several stakeholders in two questions emphasise the fact that monitoring requirements for substances are an important WFD encouragement for Member States to safeguard the water quality of water bodies. Although the participants believe that the WFD encourages Member States to protect the aquatic environments, they have often referred to matters that are hampering the WFD encouragement rather than matters that are contributing to the protection of water bodies (Table 4.11). Drinking water companies defended that EQS for priority substances are regularly not strict enough to meet the drinking water requirements even if they see the monitoring requirements as WFD stimulation for the protection of the aquatic environments. Therefore, they defend that more restrictions in the WFD such as concrete measures for priority substances listed. In contrast, water boards defend fewer criterions required in WFD in the priority substances control. The responsibilities of water boards, including the ecological and chemical status, do not permit more requirements and their broadly approach for the protection of aquatic environments would not be efficient with more restrictions. Other stakeholders stated that WFD implementation is not efficient enough in some Member States which was also stated in the third question by other stakeholders and in the Beunen *et al*. (2009)

research paper where they explain the challenging task of WFD implementation. This means that the different WFD implementations are hampering rather than stimulating and encouraging the protection of aquatic environments.

It is notice that some issues identified in WFD encouragements were also mentioned as issues in WFD stimulations because they are not supporting enough not only the protection of aquatic environments but also Member States, namely the Netherlands, to take actions.

The participants identified five WFD improvements (Table 4.11). Regarding the problematic of CEC in aquatic environment, most of WFD improvements are being developed within the CIS working groups. The stakeholders mentioned their focus on monitoring procedures and prioritization of chemicals as groups proving that monitoring requirements are stimulating and encouraging Member States. According to the CIS Work programme of 2016-2018 it is confirmed the effort of EU commission in WFD improvements and what is expected to be done by the chemical's working group (European Commission, 2015). Some participants also mentioned that it has been seen improvements in the Netherlands that are not directly linked to the WFD, such as the Ecological Key Factors, but rather because of the WFD targets. However, the WFD improvements expected are too slow and does not encourage Member States to keep motivated.

With regards to Table 4.11, nine recommendations have been suggested for the WFD. This means that improvements in this directive is needed in order to enhance the control of CEC in water bodies. Regarding the issues in WFD stimulation and WFD encourages answered by the stakeholders, they mostly recommended the integration of relevant EU policies. This recommendation was also mentioned in the literature review that an integration and harmonization of EU water policies goals with WFD is needed (Fürhacker, 2008; Geissen, et al., 2015; Brack, et al., 2017). Within the same issues identified, the stakeholder made recommendations for the complexity of the priority substances list and suggested improvements on WFD implementation to guarantee the efficient use of the WFD by all Member States. Drinking water stakeholders mentioned the need of clear requirements in contrast with water boards participants who recommended less restrictions and more flexibility in WFD requirements because of their responsibilities.

Through the analysis of the Dutch perspective regarding the WFD protection of the aquatic environments against CEC, it is possible to make an overview of Portugal situation. Within the scope of WFD, Portugal have implemented monitoring programmes to each river basin district with the aim of evaluating the quality status of water bodies, problem assessment and development of measures. Regarding chemical pollution in surface waters, the monitoring of the priority substances and other relevant pollutants, which could be discharge in specific river basins, control of the diffuse pollution, especially from agriculture areas, and upgrade WWTP are some of the Portuguese measures established to protect surface water (APA, 2016a; APA, 2016b).

Nevertheless, it was expected to identify similar issues of the case study, such as the slow process to further WFD development, not enough connection between national policies and the lack of measures implemented in the last years (Quercus, 2016). According to the analysis of the case study, it is mainly recommended the use of the signalling value criterion for CEC identification and a structured water management system with a strong connection between government, water authorities, associations and companies.

5. CONCLUSION

5.1. Summary

The occurrence of CEC and their potential impact in the aquatic environments is a tremendous challenge for European Commission and water authorities of European Union. European water policy related with CEC and the protection of water quality has been increasingly developed and the WFD implementation was essential for this process.

Existing European Union directives for chemicals regulation are focusing at different life stages of chemicals, such as production, transportation and usages. Literature review has shown that Industrial Effluents, Biocides, PPP, Veterinary medicines and Medicines for human consumption Directives are the EU regulations of chemicals that are taking aquatic environment into account regarding CEC. Nevertheless, the directives analysed in this thesis are not yet regulating all chemical substances that have been detected in surface water and there is no sufficient connection between them.

The WFD is one of the most important European water legislation to protect the aquatic environment from the occurrence of CEC and it has been the main tool used for this purpose in the last years. The Directive has been creating awareness in Member States and encouraging them to monitor the priority substances and relevant pollutants in aquatic environments as well as develop the appropriate measures to further WFD objectives.

However, the most important issues found in WFD that are not contributing for the protection of aquatic environments are the following: not efficient implementation in some Member States, not enough integration of WFD goals in the EU legislation reviewed and the current prioritization and monitoring approach of the priority substances list.

In conclusion, the WFD has not been efficient enough in the protection of aquatic environments against CEC since nonregulated and regulated CEC are still found in the water bodies. Also, it is difficult to predict the efficiency of the WFD by the compliance of the EQS stablished for priority substances because the WFD is halfway to complete its implementation and evaluate the targets achievements of Member States. This way, it was assumed two possible scenarios for the WFD future in the last revision: negative scenario and positive scenario.

The negative scenario leads to the believe that WFD might not be efficient enough in the end for the protection of aquatic environments and Member States might not comply the environmental objectives in 2027, as was initially expected. The Dutch improvements in water policy and measures developed were not all based on WFD and much effort has been devoted to enhance the chemical water quality of the Dutch water bodies using national policies. The WFD challenges that remain to be resolved, the targets yet to be achieved and the slow improvements needed, might contribute for the decreasing of ambition level in Member States and became less

encourage to meet the targets until 2027. The positive scenario leads to believe that WFD might actually be efficient to protect the aquatic environment in the end and the targets could be achieved in 2027. Firstly, several WFD improvements are being made within the subject of CEC prioritization approach and their monitoring plan. The WFD improvements might increase the ambition level of Member States to make changes in water quality, encourage them to keep to protect their water bodies and, consequently, water quality improvements could be seen after 2027. Second, the WFD efficiency might not be based on the EQS for the priority substances list. The EQS do not include all relevant CEC for all Member States and many of them are establishing additional measures to control unregulated substances in the EU with success. The Netherlands is an example since it is monitoring several other substances that are relevant for their country.

At last, it is proposed the following recommendations for WFD improvements which could be implemented by the Member States:

- Strong connection between EU legislation which regulates chemicals and EU legislation for water protection. Particularly, the integration of WFD main goals in the development of national policies in order to take the aquatic environment protection into account;
- Consistent assessment of CEC in aquatic environments to fill data gaps. This way, it is recommended the standardization of monitoring techniques and the use of the effect based tools on the identification of CEC in the aquatic environments;
- Collaboration between all interested parties which include the sharing of knowledge regarding CEC, measures and innovative monitoring techniques;
- Integrated strategy in WFD implementation in the Member States which takes into account the environment, social and economic concerns with a less boreoarctic approach;

5.2. Development of future studies

European Union and Member States should do more effort to meet WFD targets and protect the aquatic environments from CEC. Within the thesis objectives, the following subjects are suggested to be studied:

- Development of a deeply study about current measures being taken in the EU to control CEC in aquatic environments;
- Use other Member States as case study to analyse WFD implementation in order to compare to each other and the Netherlands case;
- Continue the current dissertation objectives and analyse WFD improvements and efficiency in 2027;

REFERENCES

Adeel, M., Song, X., Wang, Y., Francis, D., Yang, Y., 2017. Environmental impact of estrogens on human, animal and plant life: A critical review. *Environment International,* Volume 99, p. 107–119.

APA, 2016a. *Avaliação Ambiental Estratégica- Plano de Gestão de Região Hidrográfica das Ribeiras do Algarve (RH8) e Plano de Gestão dos Riscos de Inundações (RH8),* s.l.: Agência Portuguesa do Ambiente.

APA, 2016b. *Avaliação Ambiental Estratégica- Plano de Gestão de Região Hidrográfica do Tejo e Ribeiras do Oeste (RH5) | Plano de Gestão dos Riscos de Inundações (RH5),* s.l.: Agência Portuguesa do Ambiente.

Araújo, R. S., Alves, M. G., Condesso de Melo, M. T., Chrispim, Z. M. P., Mendes, M. P., Silva Júnior, G. C., 2015. Water resource management: A comparative evaluation of Brazil, Rio de Janeiro, the European Union, and Portugal. *Science of the Total Environment,* Volume 511, p. 815-828.

Aris, A. Z., Shamsuddin, A. S. & Praveena, S. M., 2014. Occurrence of 17α-ethynylestradiol (EE2) in the environment and effect on exposed biota: a review. *Environment International,* Volume 69, p. 104–119.

Barbosa, M. O., Moreira, N. F. F., Ribeiro, A. R., Pereira, M. F. R. , Silva, A. M. T, 2016. Occurence and removal of organic micropollutants: An overview of the watch list of EU decision 2015/495. *Water Research,* Volume 94, p. 257-279.

Barnes, K., Moreira, N. F. F., Ribeiro, A. R., Pereira, M. F. R. , Silva, A. M. T., 2008. A national reconnaissance of pharmaceuticals and other organic wastewater contaminants in the United States- I) Groundwater. *Science of The Total Environment,* 402(2-3), p. 192-200.

Batelaan, M., Moreira, N. F. F., Ribeiro, A. R., Pereira, M. F. R., Silva, A. M. T., 2013. *Evaluation report Pharmafilter- Full scale demonstration in the Reinier de Graaf Gasthuis (Hospital) Delft,* Amersfoort: STOWA.

Bedoux, G., Roig, B., Thomas, O., Dupont, V., Le Bot, B., 2012. Occurrence and toxicity of antimicrobial triclosan and by-products in the environment. *Environmental Science and Pollution Research,* 19(4), p. 1044–1065.

Bergman, Å., Heindel, J. J., Jobling, S., Kidd, K. A., Zoeller, R. T., 2012. *State of the science of endocrine disrupting chemicals. An assessment of the state of the science of endocrine disruptors*

prepared by a group of experts for the United Nations Environment Programme and World Health Organization., s.l.: United Nations Environment Programme and the World Health Organization.

Bester, K., Scholes, L., Wahlberg, C. & McArdell, C. S., 2008. Sources and Mass Flows of Xenobiotics in Urban Water Cycles—an Overview on Current Knowledge and Data Gaps. *Water, Air, & Soil Pollution: Focus,* 8(5), p. 407–423.

Beunen, R., van der Knaap, W. & Biesbroek, G., 2009. Implementation and integration of EU Environmental Directives. Experiences from the Netherlands. *Enviornmental policy and Governance,* Volume 19, p. 57-69.

Bijlsma, L., 2011. *Water Management in the Netherlands,* The Netherlands: Rijkswaterstaat-Ministry of Infrastructure and Environment.

BKMW, 2009. *Overheid.nl.* [Online] Available at: http://wetten.overheid.nl/BWBR0027061/2017-01-01# [Accessed 27 Agosto 2017].

Boomsma, D. I., Wijmenga, C., Slagboom, E. P., Swertz, M. A., Karssen, L. C., Abdellaoui, A., Ye, K., Guryev, V., Vermaat, M., Dijk, F. van, Francioli, L. C., Hottenga, J. J., Laros, J. F. J.,, 2014. The Genome of the Netherlands: design, and project goals. *European Journal of Human Genetics,* Volume 22, p. 221-227.

Brack, W., Dulio, V., Âgerstrand, M., Allan, I., Altenburger, R., Brinkmann, M., Bunke, D., Burgess, R. M., Cousins, I., Escher, B. I., Hernández, F. J., Hewitt, L. M., Hilscherová, K., Hollender, J., Hollert, H., Kase, R., Klauer, B., Lindim, C., Herráez, D. L., Miège, C., Munthe, J., O'Toole, S., Posthuma, L., Rudel, H., Schafer, R. B., Sengl, M., Smedes, F., van de Meent, D., van den Brink, P. J., van Gils, J., van Wezel, A. P., Vethaak, A. D., Vermeirssen, E., von der Ohe, P. C., Vrana, B., 2017. Towards the review of the European Union Water Framework Directive: Recommendations formore efficient assessment andmanagement of chemical contamination in European surface water resources. *Science of the Total Environment,* Volume 576, p. 720-737.

Carere, M., Polesello, S., Kase, R. & Gawlik, B. M., 2015. The emerging contaminants in the context of the EU Water Framework Directive. *Springer International Publishing Switzerland,* p. 197-216.

Carvalho, R. N., Arukwe, A., Ait-Aissa, S., Bado-Nilles, A., Balzamo, S., Baun, A., Belkin, S., Blaha, L., Brion, F., Conti, D., Creusot, N., Essig, Y., Ferrero, V. E. V., Flander-Putrle, V., 2014. Mixtures of chemical pollutants at European legislation safety concentrations: how safe are they?. *Toxicological Sciences,* Volume 141, p. 218-233.

Cefic, 2013. *The European chemical industry- Facts & Figures 2013,* Brussels: The European Chemical Industry Council.

Chen, Z. F., Ying, G. G., Lai, H. J., Chen, F., Su, H. C., Liu, Y. S., Peng, F. P., Zhao, J. L., 2012. Determination of biocides in different environmental matrices by use of ultra-high-performance liquid chromatography–tandem mass spectrometry. *Analytical and Bioanalytical Chemistry,* 404(10), p. 3175–3188.

Conerly, O. & Ohanian, E. V., 2010. Pharmaceuticals in the Environment: Regulatory Challenges Ahead. *Human and Ecological Risk Assessment: An International Journal,* 16(6), p. 1234–1241.

Coquery, M., Morin, A., Bécue, A. & Lepot, B., 2005. Priority substances of the European Water Framework Directive: Analytical challenges in monitoring water quality. *Trends in Analytical Chemistry,* Volume 24, p. 117-127.

Cox, O., 2016. *River basin management plans 2016-2021 of the Netherlands- Summary,* The Hague, the Natherlands: Ministry of Infrastructure and the Environment.

Daghrir, R. & Drogui, P., 2013. Tetracycline antibiotics in the environment: a review. *Environmental Chemistry Letters,* 11(3), p. 209–227.

De la Cruz, N., Giménez, J., Esplugas, S., Grandjean, D., Alencastro, L.F., Pulgarín, C., 2012. Degradation of 32 emergent contaminants by UV and neutral photo-fenton in domestic wastewater effluent previously treated by activated sludge. *Water Research,* Volume 46, p. 1947 e1957.

EEA, 2011. *Hazardous substances in Europe's fresh and marine waters: An overview,* Copenhagen: European Environmental Agency.

EEA, 2012. European waters — assessment of status and pressures. *European Environmental Agency Report 8,* p. 8-96.

EEA, 2013. *Towards a green economy in Europe: EU environmental policy targets and objectives 2010–2050,* Copenhagen: European Environment Agency .

EU, 1976. Directive of the European Parliament and of the Council 76/768/EEC on the approximation of the laws of the Member States relating to cosmetic products. *Official Journal of the European Communities ,* p. 169-200.

EU, 1991. Directive 91/271/EEC of European Parliament and of the Council of 21 May 1991 concerning urban waste water treatment. *Official Journal of the European Communities,* p. 40-52.

EU, 1998. Directive 98/83/EC of European Parliament and of the Council of 3 November 1998 on the quality of water intended for human consumption. *Official Journal of the European Communities,* p. 32-54.

EU, 1998. Directive of the European Parliament and of the Council 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. *Official Journal of the European Communities,* p. 32-53.

EU, 2000. Directive of the European Parliament and of the Council 2000/60/EC Establishing a framework for Community action in the field of water policy. *Official Journal of the European Communities,* p. 1-93.

EU, 2001a. Directive of the European Parliament and of the Council 2001/83/EC on the Community code relating to medicinal products for human use. *Official Journal of the European Communities,* p. 67-127.

EU, 2001b. Decision of European Parliament and of the Council nº 2455/2001/EC Establishing the list of priority substances in the field of water policy and amending Directive. *Official Journal of the European Communities,* p. 1-5.

EU, 2006. Regulation (EC) nº 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC*, Official Journal of the European Communities*.

EU, 2008a. Directive of the European Parliament and of the Council 2008/105/EC Establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). *Official Journal of the European Union,* p. 1-97.

EU, 2008b. Regulation (EC) nº 1334/2008 of the European Parliament and of the Council on flavourings and certain food ingredients with flavouring properties for use in and on foods and amending Council Regulation (EEC) No 1601/91, Regulations (EC) No 2232/96. *Official Journal of the European Union,* p. 34-50.

EU, 2009a. Directive of the European Parliament and of the Council 2009/48/EC of 18 June 2009 on the safety of toys. *Official Journal of the European Union,* p. 1-37.

EU, 2009b. Regulation (EC) nº 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC. *Official Journal of the European Union,* p. 1-50.

EU, 2009c. Directive of the European Parliament and of the Council 2009/128/EC of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides. *Official Journal of the European Union,* p. 1-26.

EU, 2010. Directive of the European Parliament and of the Council 2010/75/EU of 24 November 2010 on industrial emissions (integrated pollution prevention and control). *Official Journal of theEuropean Union,* p. 17-117.

EU, 2012a. *Accompanying the document: Report from the European Commission to the European Parliament and the Council on the Implementation of the Water Framework Directive (2000/60/EC)- River Basin Management Plans (The Netherlands),* Brussels: European Commission.

EU, 2012b. Regulation (EC) nº 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products. *Official Journal of the European Union,* p. 1-122.

EU, 2013. Directive of the European Parliament and of the Council 2013/39/EU Amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy. *Official Journal of the European Union,* p. 1-17.

EU, 2015a. Commission Implementing Decision (EU) 2015/495 Establishing a watch list of substances for Union-wide monitoring in the field of water policy pursuant to Directive 2008/105/EC of the European Parliament and of the Council. *Official Journal of the European Union,* p. 1-3.

EU, 2015b. Commission Directive (EU) 2015/1787 of 5 October 2015 amending Annexes II and III to Council Directive 98/83/EC on the quality of water intended for human consumption. *Official Journal of the European Union,* p. 1-12.

.European Commission, 2008a. Water Notes on the Implementation of the Water Framework Directive. *Water Note 8- Pollution: Reducing dangerous chemicals in Europe's waters*, December, p. 1-2.

European Commission, 2008b. Water Notes on the Implementation of the Water Framework Directive. *Water Note 9- Integrating water policy: Linking all EU water legislation within a single framework*, December, p. 1-4.

European Commission, 2010. *Guidance Document Nº 25: Guidance on chemical monitoring of sediment and biota under the Water Framework Directive,* Luxembourg: Office for Official Publications of the European Communities.

European Commission, 2014. EU publications. *The EU Water Framework Directive*, 10 November, p. 4.

European Commission, 2015. *Common Implementation Strategy for the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC)- Work programme 2016-2018,* Luxembourg: European Union Commission.

Fisch, K., Waniek, J. J., Schulz-Bull, D.E. 2017. Occurence of pharmaceuticals and UV-filters in riverine run-offs and waters of the German Baltic Sea.*Marine Pollution Bulletin.*Volume 124 (1), p. 388-399

Fischer, A., Bronders, J., Desmet, N., Christoffels, E., Wezel, A. Van, Peter, J., Hoek, Van D.,., 2017. Decision support for water quality management of contaminants of emerging concern. *Journal of Environmental Management,* Volume 193, p. 360-372.

Fürhacker, M., 2008. The Water Framework Directive – can we reach the target?. *Water Science and Technology 57,* p. 9-17.

García, S. O., Pinto, G., Encina, P. G. & Mata, R. I., 2013. Consumption and occurrence of pharmaceutical and personal care products in the aquatic environ- ment in Spain.. *Science of the Total Environment,* Volume 444, p. 451–465.

Geissen, V., Mol, H., Klumpp, E., Umlauf, G., Nadal, M., van der Ploeg, M., van de Zee, S. E.A.T.M., Ritsema, C. J.,., 2015. Emerging pollutants in the environment: A challenge for water resource management. *International Soil and Water Conservation Research,* Volume 3, p. 57-65.

Germany, P., 2010. *Biocides – risks and alternatives: Challenges and perspectives regarding the handling of biocides in the EU,* Hamburg: Pestizid Aktions-Netzwerk (PAN) e.V..

Geudens , P., 2012. *Dutch drinking water statistics- The water cycle from source to tap,* Rijswijk, The Netherlands: Association of Dutch Water Companies (Vewin).

Geudens, P., 2015. *Dutch drinking water statistics,* The Hague, the Netherlands: Association of Dutch water companies (Vewin).

Graymore, M., Stagnitti, F. & Allinson, G., 2001. Impacts of atrazine in aquatic ecosystems. *Environment International,* 26(7-8), p. 483-495.

Grinten, E., Breure, A., Lambooij, M. & Lette, M., 2015. *Towards balancing the benefits of pharmaceutical care and minimizing its environmental harm Identification of potential levers in the medicinal product chain. RIVM Report 2015-0145,* Bilthoven, The Netherlands: National Institute for Public Health and the Environment.

Guardo, A. D. & Finizio, A., 2017. Sustainable use of veterinary pharmaceuticals on the territory (Sust-PHarm): Linking available database of manure management and environmental fate models. *Science of The Total Environment,* Volume 575, p. 1014–1026.

Hamza, R. A., Iorhemen, O. T. & Tay, J. H., 2016. Occurrence, impacts and removal of emerging substances of. *Environmental Technology & Innovation,* Volume 5, p. 161-175.

Houtman, C. J., 2010. Emerging contaminants in surface waters and their relevance for the production of drinking water in Europe. *Journal of Integrative Environmental Sciences ISSN:,* 7(4), p. 271-295.

Kolpin, D., Furlong, E.T., Meyer, M.T., Thurman, E.M., Zaugg, S.D., Barber, L.B., 2002. Simultaneous determination of antiseptics and acidic drugs in sewage and river water. *Environment Science Technology,* Volume 36, p. 1202-1211.

Koschorreck, J., Koch, C. & Rönnefahrt, I., 2002. Environmental risk assessment of veterinary medicinal products in the EU—a regulatory perspective. *Toxicology Letters,* 131(1-2), p. 117–124.

Leal, L., Vieno, N., Temmink, H., Zeeman, G., Buisman, C.J.N., 2010. Occurrence of Xenobiotics in Gray Water and Removal in Three Biological Treatment Systems. *Enviornmental Science and Technology,* 44(17), p. 6835–6842.

Le, T. H. H. L., Nguyen, T. Q. H., Tran, C. S., Vu, T. T., Nguyen, T. L., Cao, V. H., Ta, T. T., Pham, T. N. M., Nguyen, T. A. H., 2017. Screening determination of food additives using capillary electrophoresis coupled with contactless conductivity detection: A case study in Vietnam. *Food Control,* Volume 77, p. 281–289.

Lonappan, L., Brar, S. K., Das, R. K., Verma, M., Surampalli, R. Y., 2016. Diclofenac and its transformation products: Environmental occurrence and toxicity - A review. *Environment International,* Volume 96, p. 127–138.

Loos, R., Gawlik, B. M., Locoro, G., Rimaviciute, E., Contini, S., Bidoglio, G., 2009. EU-wide survey of polar organic persistent pollutants in European river waters. *Environmental Pollution,* Volume 157, p. 561-568.

Lopez, B., Ollivier, P., Togola, A., Baran, N., Ghestem, J. P., 2015. Screening of French groundwater for regulated and emerging contaminants. *Science of the Total Environment,* Volume 518-519, p. 562-573.

Luo, Y., Guo, W., Ngo, H. H., Nghiem, L. D., Hai, F. I., Zhang, J., Liang, S., Wang, X. C., 2014. A review on the occurrence of micropollutants in the aquatic environment and their fate and removal during wastewater treatment. *Science of the Total Environment,* Volume 473-474, p. 619-641.

Meador, J. P., Yeh, A., Young, G. & Gallagher b,, E. P., 2016. Contaminants of emerging concern in a large temperate estuary. *Environmental Pollution,* Volume 213, p. 254-267.

Molander, L., Breitholtz, M.; Andersson, Patrik L.; Rybacka, A.; Rudén, C., 2012. Are chemicals in articles an obstacle for reaching environmental goals? - Missing links in EU chemical management. *Science of the Total Environment,* Volume 435-436, p. 280-289.

Moldes, A.-. B., Vecino, X. & Cruz, J. M., 2017. Nutraceuticals and Food Additives. In: M. Á. S. G. D. C. R. S. C. D. Ashok Pandey, ed. *Current Developments in Biotechnology and Bioengineering .* Amsterdam: Elsevier, p. 143–164.

Mostert, E., 2006. Integrated Water Resources Management in The Netherlands: How Concepts Function. *Journal of Contemporary Water Research & Education,* Volume 135, p. 19-27.

Muis, J., 2015. *Plant protection products, pharmaceuticals and household products in the aquatic environment: Emission roadmaps and decentralized measures,* the Netherlands: TAPES project.

Muñoz, Ivan, Gómez, M., Molina-Díaz, A., Huijbregts, M., Fernández-Alba, A., García-Calvo, E. , 2008. Ranking potential impacts of priority and emerging pollutants in urban wastewater through life cycle impact assessment. *Chemosphere,* Volume 74, p. 37-44.

Naidu, R., Espana, V., Liu, Y. & Jit, J., 2016a. Emerging contaminants in the environment: Risk-based analysis for better management. *Chemosphere,* Volume 154, p. 350-357.

Naidu, R., Jit, J., Kennedy, B. & Arias, V., 2016b. Emerging contaminant uncertainties and policy: The chicken or the egg conundrum. *Chemosphere,* Volume 154, p. 385-390.

Nohynek, G. J., Antignac, E., Re, T. & Toutain, H., 2010. Safety assessment of personal care products/cosmetics and their ingredients. *Toxicology and Applied Pharmacology,* 243(2), p. 239–259.

NORMAN, 2016. *Network of reference laboratories, research centres and related organisations for monitoring of emerging environmental substances.* [Online] Available at: http://www.normandata.eu/?q=node/19 [Accessed 30 March 2017].

NWP, 2009. *National Water Plan 2009-2015,* The Netherlands: Rijksoverheid.

NWP, 2015. *Nationa Water Plan 2016-2021,* The Hague, the Netherlands: Ministry of Infrastructure and the Environment and Ministry of Economic Affairs.

OCDE, 2014. *Water Governance in the Netherlands: Fit for the future?,* The Netherlands: OCDE Studies on Water.

Oliveira, R., McDonough, S., Ladewig, J. C. L., Soares, A. M. V. M., Nogueira, A. J. A., Domingues, I., 2013. Effects of oxytetracycline and amoxicillin on development and biomarkers

activities of zebrafish (Danio rerio). *Environmental toxicology and pharmacology,* Volume 36, p. 903–912.

Ong, C. N., 2016. Water reuse, emerging contaminants and public health: state-of-the-art analysis. *International Journal of Water Resources Development,* 32(4), p. 1-12.

Oyeyiola, A., Akinyemi, M.I, Chiedu, I.E, Adetunde, O.T, Olayinka, K.O, 2017. Statistical analyses and risk assessment of some potentially toxic metals (PTMs) in children's toys. *Journal of Taibah University for Science,* p. 1-25.

Palma, P., Kuster, M., Alvarenga, P., Palma, V.L., Fernandes, R.M., Soares, A.M.V.M., López de Alda, M.J., Barceló, D., Barbosa, I.R., 2009. Risk assessment of representative and priority pesticides, in surface water of the Alqueva reservoir (South of Portugal) using on-line solid phase extraction-liquid chromatography-tandem mass spectrometry. *Environment International,* 35(3), p. 545-551.

Pereira, A., Silva, L.J.G., Lino, C.M., Meisel, L.M., Pena, A. , 2016. Assessing environmental risk of pharmaceuticals in Portugal: An approach for the selection of the Portuguese monitoring stations in line with Directive 2013/39/EU. *Chemosphere,* Volume 144, p. 2507-2515.

Pinto, M. I. A., 2015. Pesticides in water , sediments and biota of semi-closed coastal lagoons : sources , pathways and impact on aquatic organisms. *Faculdade de Ciências e Tecnologias da Universidade Nova de Lisboa,* Issue MSc. in Environmental Analytical Chemistry.

Pio, S., West, C. A. & Henriques, A. G., 2000. *Protecção das águas de superfície contra a poluição por substâncias perigosas no âmbito da Directiva-Quadro da água.* Lisboa, Associação Portuguesa dos Recursos Hídricos, p. 1-16.

PORDATA, 2015. *PORDATA.* [Online] Available at: http://www.pordata.pt/Europa/Superf%C3%ADcie-2489 [Accessed 20 June 2017].

PORDATA, 2015. *PORDATA- População residente.* [Online] Available at: http://www.pordata.pt/Europa/Popula%C3%A7%C3%A3o+residente-1951 [Accessed 20 June 2017].

Quercus, 2016. *Relatório de avaliação da implementação da Directiva Quadro da Água,* Lisboa: Quescus- Associação Nacional de Conservação da Natureza.

Ribeiro, A. R., Nunes, O. C., Pereira, M. F. R. & Silva, A. M. T., 2015a. An overview on the advanced oxidation processes applied for the treatment of water pollutants defined in the recently launched Directive 2013/39/EU. *Environment International,* Volume 75, p. 33-51.

Ribeiro, A. R., Pedrosa, M., Moreira, N. F. F., Pereira, M. F. R., Silva, A. M. T, 2015b. Environmental friendly method for urban wastewater monitoring of micropollutants defined in the Directive 2013/39/EU and Decision 2015/495/EU. *Journal of Chromotography A,* Volume 1418, p. 140-149.

Richardson, S. D., 2010. Environmental mass spectrometry: Emerging contaminants and current issues. *Analytical Chemistry,* Volume 82, p. 4742-4774.

Richardson, S. D. & Ternes, T. A., 2011. Water Analysis: Emerging Contaminants and Current Issues. *Analytical Chemistry,* Volume 83, p. 4614-4648.

Rijkswaterstaat, 2011. *Water Management in the Netherlands,* The Netherlands: Ministry of Infrastructure and Environment.

Rosa, R. M. R., 2008. *Contribuição para o estudo de compostos desreguladores endócrinos (EDC) em estações de tratamento de águas residuais (ETAR): estudo da remoção de EDC numa etar com tratamento terciário,* Lisboa: Dissertação para obtenção do grau de Mestre em Engenharia do Ambiente - Perfil Engenharia Sanitária, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa.

Sauvé, S. & Desrosiers, M., 2014. A review of what is an emerging contaminant. *Chemistry Central Journal,* 8(15), p. 1-7.

Schwaiger, J., Ferling, H., Mallow, U., Wintermayr, H., Negele, R. D., 2004. Toxic effects of the non-steroidal anti-inflammatory drug diclofenac: Part I: histopathological alterations and bioaccumulation in rainbow trout. *Aquatic Toxicology,* 68(2), p. 141-150.

Schwarzenbach, R. P., Escher, B. I., Fenner, K., Hofstetter, T. B., Johnson, C. A., Gunten, U.; Bernhard W., 2006. The challenge of micropollutants in aquatic systems. *Science,* Volume 313, p. 1072-1077.

Scruggs, C. E., Ortolano, L., Wilson, M. P. & Schwarzman, M. R., 2015. Effect of company size on potential for REACH compliance and selection of safer chemicals. *Environmental Science and Policy,* Volume 45, p. 79-91.

Segev, O., Kushmaro, A. & Brenner, A., 2009. Environmental Impact of Flame Retardants (Persistence and Biodegradability). *International Journal of Environmental Research and Public Health,* Volume 6, p. 478-491.

Stuart, M., Lapworth, D., Crane, E. & Hart, A., 2012. Review of risk from potential emerging contaminants in UK groundwater. *Science of the Total Environment,* Volume 416, p. 1-21.

Swiss Federal Institute of Aquatic Science and Technology, 2016. 100 Water Treatment Plants must be Upgraded – Eawag Info day 2015. [Online] Available at:

https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-58567.html. Acceded in August 28th 2017.

Takahashi, M. & Sakamoto, K., 2017. Chapter 9 – Regulations on Cosmetics. In: *Cosmetic Science and Technology.* Amsterdam, Netherlands: Elsevier, p. 137–146.

Tiedeken, E. J., Tahar, A., McHugh, B. & Rowan, N. J., 2017. Monitoring, sources, receptors, and control measures for three European Union watch list substances of emerging concern in receiving waters – A 20 year systematic review. *Science of the Total Environment 574,* p. 1140–1163.

Tol, J. v., 2013. *Organic micro pollutants: Assessment on optimum treatment strategies in the water cycle,* Delft: Faculty of Civil Engineering and Geosciences of Delft University of Technology.

Triebskorn, R., Casper, H., Heyd, A., Eikemper, R., Köhler, H. R., Schwaiger, J., 2004. Toxic effects of the non-steroidal anti-inflammatory drug diclofenac: Part II. Cytological effects in liver, kidney, gills and intestine of rainbow trout (Oncorhynchus mykiss). *Aquatic Toxicology,* 68(2), p. 151-166.

van Wezel, A. P., ter Laak, T. L., Fischer, A., Bäuerlein, P. S., Munthe, J., Posthuma, L., 2017a. Mitigation options for chemicals of emerging concern in surface waters; operationalising solutions-focused risk assessment. *Environmental Science: Water Research & Technology.*

Velki, M., Paolo, C. D., Nelles, J., Seiler, T. B., Hollerta, H., 2017. Diuron and diazinon alter the behavior of zebrafish embryos and larvae in the absence of acute toxicity. *Chemosphere,* Volume 180, p. 65–76.

Viladomat, M. R., 2010. *Effects of priority and emerging pollutants on river biofilms,* Universitat de Girona: Institut d'Ecologia Aquàtica.

Voulvoulis, N., Arpon, K. & Giakoumis, T., 2017. The EU Water Framework Directive: From great expectations to problems with implementation. *Science of The Total Environment,* Volume 575, p. 358-366.

WHO, 2003. *1,2-Dichloroethane in Drinking-water- Background document for development of WHO Guidelines for Drinking-water Quality,* s.l.: World Health Organization (WHO).

Yang, G. C. C., 2017. Global challenges and solutions of emerging contaminants: An editorial overview and beyon. *Chemosphere,* Volume 168, p. 1222-1229.

Yen, J. H., 2013. *Chemical Regulation in the European Union (EU): Registration, Evaluation and Authorization of Chemicals,* s.l.: Congressional Research Service.

Yin, Y. Y., 2014. *Investigation of Emerging Contaminants in Environmental Waters,* Macquarie University: Department of Chemistry and Biomolecular Sciences.

APPENDICES

Appendix I- Chemical substances covered by EU legislation

In order to comprehend which are the chemical substances regulated in current EU legislation, was carried out an intensive research review of EU policies and was drafted a summary table with the important information.

The appendix I present a table with chemical substances regulated in the directives: REACH, Cosmetics Products, Veterinary Medicinal Products, Medicinal Products for human use, Flavourings and Food additives, Safety of Toys, Biocides Products, Protection Plants Products, Drinking water and Industrial Emissions. Also, includes some information about chemicals and the important requirements for their control, implemented in these legislation.

Table I.1 Substances, including CECs, covered by EU legislation and respective information.

Chemical's EU legislation	Substances covered by legislation and some additional information	
REACH **(EC 1907/2006)** **Industrial products**	List of substances subject to authorisation . 1,2-dichloroethane (EDC) . 2,2'-dichloro-4,4'-methylenedianiline (MOCA) . 2,4-dinitrotoluene (2,4-DNT) . 4,4'- Diaminodiphenylmethane (MDA) . 5-tert-butyl-2,4,6-trinitro-m-xylene (Musk xylene) . Acids generated from chromium trioxide and their oligomers . Chromic acid . Dichromic acid . Oligomers of chromic acid and dichromic acid . Ammonium dichromate . Arsenic acid . Benzyl butyl phthalate (BBP) . Bis(2-ethylhexyl) phthalate (DEHP) . Bis(2-methoxyethyl) ether . Chromium trioxide . Diarsenic pentaoxide . Diarsenic trioxide . Dibutyl phthalate (DBP) . Dichromium tris(chromate) . Diisobutyl phthalate (DIBP) . Formaldehyde, oligomeric reaction products with aniline . Hexabromocyclododecane (HBCDD) . Hexabromocyclododecane . hexabromocyclodecane . alpha-hexabromocyclododecane . beta-hexabromocyclododecane . gamma-hexabromocyclododecane . Lead chromate	*Article 56* General provisions 1.A manufacturer, importer or downstream user shall not place a substance on the market for a use or use it himself if that substance is included in Annex XIV *Article 58* Inclusion of substances in Annex XIV 3.Prior to a decision to include substances in Annex XIV, the Agency shall, taking into account the opinion of the Member State Committee, recommend priority substances to be included specifying for each substance the items set out in paragraph 1. Priority shall normally be given to substances with: a) PBT or vPvB properties; b) wide dispersive use; c) high volumes. The number of substances included in Annex XIV and the dates specified under paragraph 1 shall also take account of the Agency's capacity to handle applications in the time provided for. The Agency shall make its first recommendation of priority substances to be included in Annex XIV

Table I.2 Substances, including CECs, covered by EU legislation and respective information (Cont.)

REACH **(EC 1907/2006)** **Industrial products**	. Lead chromate molybdate sulfate red . Lead sulfochromate yellow . Pentazinc chromate octahydroxide . Potassium chromate . Potassium dichromate . Potassium hydroxyoctaoxodizincatedichromate . Sodium chromate . Sodium dichromate . Strontium chromate . Trichloroethylene . Tris(2-chloroethyl) phosphate	by 1 June 2009. The Agency shall make further recommendations at least every second year with a view to including further substances in Annex XIV. The chemical safety report need not include consideration of the risks to human health from the following end uses: a) in food contact materials within the scope of Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food; (b) in cosmetic products within the scope of Directive 76/768/EEC.
	Substances allowed in the cosmetic market *Article 5*	Substances prohibited in cosmetic market *Article 4*
Cosmetics Directive (76/768/EEC)	For a period of three years from notification of this Directive, Member States shall accept the marketing of cosmetic products containing: a) the substances listed in Part 1 of Annex IV(1) within the limits and under the conditions laid down; b) the colouring agents listed in Part 2 of Annex IV(2) within the limits and under the conditions laid down, if these products are intended for application in the vicinity of the eyes, on the lips, in the oral cavity, or to the external genital organs; c) the colouring agents listed in Part 3 of Annex IV(3), if these products either are not intended to come into contact with the mucous membranes or are only intended to come into brief contact with the skin.	Without prejudice to their general obligations deriving from Article 2, Member States shall prohibit the marketing of cosmetic products containing: a) substances listed in Annex II(4); b) substances listed in the first part of Annex III(5), beyond the limits and outside the conditions laid down; c) colouring agents other than those listed in the second part of Annex III(6), if these products are intended for application in the vicinity of the eyes, on the lips, in the oral cavity or to the external genital organs; d) colouring agents listed in the second part of Annex III, beyond the limits and outside the conditions laid down, if these products are intended for application in the vicinity of the eyes, on the lips, in the oral cavity or to the external genital organs.

Table I.3 Substances, including CECs, covered by EU legislation and respective information (Cont.).

Veterinary Pharmaceutical Products Directive (2001/82/EC)	Substances included in *European Pharmacopoeia*[7] or National Pharmacopoeia.	
Pharmaceutical Products Directive (2001/83/EC)	Substances included in *European Pharmacopoeia* or National Pharmacopoeia	
Food Additives (EC 1331-1334/2008)	Annex III- Presence of certain substances Part A: Substances which shall not be added as such to food . Agaric acid . Aloin . Capsaicin . 1,2- Benzopyrone, coumarin . Hypericine . Beta-asarone . 1-Allyl-4-methoxybenzene, estragole . Hydrocyanic acid . Menthofuran . 4-Allyl-1,2-dimethoxybenzene, methyleugenol . Pulegone . Quassin . 1-Allyl-3,4-methylene dioxy benzene safrole . Teucrine A . Thujone (alpha and beta) Part B: Maximum levels of certain substances, naturally present in flavourings and food ingredients with flavouring properties, in certain compound food as consumed to which flavourings and/or food ingredients with flavouring properties have been added . Beta-asarone . 1-Allyl-4-methoxybenzene . Estragol . Hydrocyanic acid . Menthofuran . 4-Allyl-1,2-dimethoxy-benzene . Methyleugenol . Pulegone	*Article 6* Presence of certain Substances 1.Substances listed in Part A of Annex III shall not be added; 2.Maximum levels of certain substances, naturally present in flavourings and/or food ingredients with flavouring properties, in the compound foods listed in Part B of Annex III shall not be exceeded as a result of the use of flavourings and/or food ingredients with flavouring properties in and on those foods. The maximum levels of the substances set out in Annex III shall apply to foods as marketed, unless otherwise stated. Maximum levels of certain substances, naturally present in flavourings and food ingredients with flavouring properties, in certain compound food as consumed to which flavourings and/or food ingredients with flavouring properties have been added;

Table I. 4 Substances, including CECs, covered by EU legislation and respective information (Cont.).

Food Additives (EC 1331-1334/2008)	. Quassin . 1-Allyl-3,4-methylene dioxy benzene safrole . Teucrine A . Thujone (alpha and beta) . Coumarin	
Plant Protection Products (1107/2009/EC)	List of co-formulants which are not accepted for inclusion in plant protection products as referred to in Article 27 is the Regulation (EU) nº 540/2011 of 25 May 2011 implementing Regulation (EC) No 1107/2009 of the European Parliament and of the Council as regards the list of approved active substances	Section 3 Unacceptable co-formulants *Article 27* Co-formulants 2. Co-formulants which are not accepted for inclusion in a plant protection product pursuant to paragraph 1 shall be included in Annex III in accordance with the regulatory procedure with scrutiny referred to in Article 79(4).
Toys Directive (2009/48/EC)	Annex II- Particular safety requirements III. Chemical properties 11. Toys shall not contain the following allergenic fragrances: . Alanroot oil . Allylisothiocyanate . Benzyl cyanide . 4 tert-Butylphenol . Chenopodium oil . Cyclamen alcohol . Diethyl maleate . Dihydrocoumarin . 2,4-Dihydroxy-3-methylbenzaldehyde . 3,7-Dimethyl-2-octen-1-ol (6,7-Dihydrogeraniol) . 4,6-Dimethyl-8-tert-butycoumarin . Dimethyl citraconate . 7,11-Dimethyl-4.6,10-dodecatrien-3-one . 6,10-Dimethyl-3.5,9-undecatrien-2-one . Diphenylamine . Ethyl acrylate . Fig leaf, fresh and preparations . trans-2-Heptenal . trans-2-hexenal diethyl acetal . trans-2-hexenal dimethyl acetal . Hydroabietyl alcohol . 4-Ethoxy-phenol . 6-Isopropyl-2-decahydronaphthalenol . 7-Methoxycoumarin . 4-Methoxyphenol	. 2-Pentylidene-cyclohexanone . 3.6,10-Trimethyl-3.5,9-undecatrien-2-one . Verbena oil . Musk ambrette . 4-Phenyl-3-buten-2-one . Amyl cinnamal . Amylcinnamyl alcohol . Benzyl alcohol . Benzyl salicylate . Cinnamal alcohol . Cinnamal . Citral . Coumarin . Eugenol . Geraniol . Hydroxy-citronellal . Hydroxy-methylpentycyclohexenecarboxaldehyde . Isoeugenol . Oakmoss extracts . Treemoss extracts 13. Components in toys that shall not be exceeded . Aluminium . Antimony . Arsenic

Table I.5 Substances, including CECs, covered by EU legislation and respective information (Cont.).

Toys Directive (2009/48/EC)	. 4-(p-Methoxyphenyl)-3-butene-2-one . 1-(p-Methoxyphenyl)-1-penten-3-one . Methyl trans-2-butenoate . 6-Methylcoumarin . 7-Methylcoumarin . 5-Methyl-2,3-hexanedione . Costus root oil . 7-Ethoxy-4-methylcoumarin . Hexahydrocoumarin . Peru balsam, crude	. Barium . Boron . Cadmium . Chromium (III) and (VI) . Cobalt . Copper . Lead . Manganese . Mercury . Nickel . Selenium . Strontium . Tin . Organic tin . Zinc
Biocides Products (528/2012/EC)	Annex I- List of active substances referred to in article 25(a) . Lactic acid . Sodium acetate . Sodium benzoate . (+)- Tartaric acid . Acetic acid . Propionic acid . Ascorbic acid . Linseed oil . Lavender oil . Oct-1-en-3-ol . Webbing clothes moths pheromone . Carbon dioxide . Nitrogen . (Z,E)-Tetradec-9,12-dienyl acetate . Baculovirus . Bentonite . Citronellal . Iron sulphate	Chapter V Simplified authorisation procedure *Article 25* Eligibility for the simplified authorisation procedure For eligible biocidal products, an application for authorisation may be made under a simplified authorisation procedure. A biocidal product shall be eligible if all the following conditions are met: a) all the active substances contained in the biocidal product appear in Annex I and satisfy any restriction specified in that Annex;
Drinking water directive (98/83/EC)	Annex I - parameters and parametric values Part B- Chemical parameters . Acrylamide . Antimony . Arsenic . Benzene . Benzo(a)pyrene . Boron . Bromate . Cadmium . Chromium . Copper . Cyanide . 1,2-dichloroethane	. Pesticides — Total . Epichlorohydrin . Fluoride . Lead . Mercury . Nickel . Nitrate . Nitrite . Pesticides . Polycyclic aromatic hydrocarbons . Selenium . Tetrachloroethene and Trichloroethene . Trihalomethanes — Total . Vinyl chloride

Table I.6 Substances, including CECs, covered by EU legislation and respective information (Cont.).

Industrial Effluents (2010/75/EU)	Annex II- List of polluting substances Water . Organohalogen compounds and substances which may form such compounds in the aquatic environment . Organophosphorus compounds . Organotin compounds . Substances and mixtures which have been proved to possess carcinogenic or mutagenic properties or properties which may affect reproduction in or via the aquatic environment . Cyanides . Metals and their compounds . Persistent hydrocarbons and	. Arsenic and its compounds . Biocides and plant protection products . Materials in suspension . Substances which contribute to eutrophication (in particular, nitrates and phosphates) . Substances which have an unfavourable influence on the oxygen balance (and can be measured using parameters such as BOD, COD, etc.) . Substances listed in Annex X to Directive 2000/60/EC . persistent and bioaccumulable organic toxic substances

(1)Annex IV of Directive 76/768/ECC– List of substances provisionally allowed

(2)Annex IV of Directive 76/768/ECC–list of colouring agents provisionally allowed which may be contained in cosmetic products intended to come into contact with the mucous membranes in accordance with article 5

(3)Annex IV of Directive 76/768/ECC- list of colouring agents provisionally allowed for cosmetic products which do not come into contact with the mucous membranes

(4)Annex II of Directive 76/768/ECC- List of substances which cosmetic products must not contain

(5)Annex III part 1 of Directive 76/768/ECC- List of substances which cosmetic products must not contain except subject to the restrictions and conditions laid down

(6)Annex III part 2 of Directive 76/768/ECC- List of colouring agents which can be contained in cosmetics products intended to come into contact with the mucous membranes

(7) The European Pharmacopoeia (Ph. Eur.) is Europe's legal and scientific benchmark for pharmacopoeia standards which contribute to delivering high quality medicines in Europe and beyond (EDQM-European Directorate for the Quality of Medicines)

Appendix II- First list of priority substances in the field of water policy (Decision nº 2455/2001/EC)

Table II.1- First list of priority substances.

	CAS number (*)	EU number (*)	Name of priority substance	Identified as priority hazardous substance
(1)	15972-60-8	240-110-8	Alachlor	
(2)	120-12-7	204-371-1	Anthracene	(X) (***)
(3)	1912-24-9	217-617-8	Atrazine	(X) (***)
(4)	71-43-2	200-753-7	Benzene	
(5)	not applicable	not applicable	Brominated diphenylethers (**)	X (****)
(6)	7440-43-9	231-152-8	Cadmium and its compounds	X
(7)	85535-84-8	287-476-5	C_{10-13}-chloroalkanes (**)	X
(8)	470-90-6	207-432-0	Chlorfenvinphos	
(9)	2921-88-2	220-864-4	Chlorpyrifos	(X) (***)
(10)	107-06-2	203-458-1	1,2-Dichloroethane	
(11)	75-09-2	200-838-9	Dichloromethane	
(12)	117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	(X) (***)
(13)	330-54-1	206-354-4	Diuron	(X) (***)
(14)	115-29-7	204-079-4	Endosulfan	(X) (***)
	959-98-8	not applicable	(alpha-endosulfan)	
(15)	206-44-0	205-912-4	Fluoranthene (*****)	
(16)	118-74-1	204-273-9	Hexachlorobenzene	X
(17)	87-68-3	201-765-5	Hexachlorobutadiene	X
(18)	608-73-1	210-158-9	Hexachlorocyclohexane	X
	58-89-9	200-401-2	(gamma-isomer, Lindane)	
(19)	34123-59-6	251-835-4	Isoproturon	(X) (***)
(20)	7439-92-1	231-100-4	Lead and its compounds	(X) (***)
(21)	7439-97-6	231-106-7	Mercury and itrs compounds	X
(22)	91-20-3	202-049-5	Naphthalene	(X) (***)
(23)	7440-02-0	231-111-4	Nickel and its compounds	

Table II.2- First list of priority substances (Cont.).

	CAS number (1)	EU number (2)	Name of priority substance	Identified as priority hazardous substance
(24)	25154-52-3	246-672-0	Nonylphenols	X
	104-40-5	203-199-4	(4-(para)-nonylphenol)	
(25)	1806-26-4	217-302-5	Octylphenols	(X) (***)
	140-66-9	not applicable	(para-tert-octylphenol)	
(26)	608-93-5	210-172-5	Pentachlorobenzene	X
(27)	87-86-5	201-778-6	Pentachlorophenol	(X) (***)
(28)	not applicable	not applicable	Polyaromatic hydrocarbons	X
	50-32-8	200-028-5	(Benzo(a)pyrene),	
	205-99-2	205-911-9	(Benzo(b)fluoranthene),	
	191-24-2	205-883-8	(Benzo(g,h,i)perylene),	
	207-08-9	205-916-6	(Benzo(k)fluoranthene),	
	193-39-5	205-893-2	(Indeno(1,2,3-cd)pyrene)	
(29)	122-34-9	204-535-2	Simazine	(X) (***)
(30)	688-73-3	211-704-4	Tributyltin compounds	X
	36643-28-4	not applicable	(Tributyltin-cation)	
(31)	12002-48-1	234-413-4	Trichlorobenzenes	(X) (***)
	120-82-1	204-428-0	(1,2,4-Trichlorobenzene)	
(32)	67-66-3	200-663-8	Trichloromethane (Chloroform)	
(33)	1582-09-8	216-428-8	Trifluralin	(X) (***)

(*) Where groups of substances have been selected, typical individual representatives are listed as indicative parameters (in brackets and without number). The establishment of controls will be targeted to these individual substances, without prejudicing the inclusion of other individual representatives, where appropriate.
(**) These groups of substances normally include a considerable number of individual compounds. At present, appropriate indicative parameters cannot be given.
(***) This priority substance is subject to a review for identification as possible "priority hazardous substance". The Commission will make a proposal to the European Parliament and Council for its final classification not later than 12 months after adoption of this list. The timetable laid down in Article 16 of Directive 2000/60/EC for the Commission's proposals of controls is not affected by this review.
(****) Only Pentabromobiphenylether (CAS-number 32534-81-9).
(*****) Fluoranthene is on the list as an indicator of other, more dangerous Polyaromatic Hydrocarbons.
(1) CAS: Chemical Abstract Services.
(2) EU-nummer: European Inventory of Existing Commercial Chemical Substances (EINECS) or European List of Notified Chemical Substances (ELINCS).'

Appendix III- Current list of priority substances in the field of water policy (Directive 2013/39/EU)

Table III.1- Current list of priority substances.

Number	CAS number (1)	EU number (2)	Name of priority substance (3)	Identified as priority hazardous substance
(1)	15972-60-8	240-110-8	Alachlor	
(2)	120-12-7	204-371-1	Anthracene	X
(3)	1912-24-9	217-617-8	Atrazine	
(4)	71-43-2	200-753-7	Benzene	
(5)	not applicable	not applicable	Brominated diphenylethers	X (4)
(6)	7440-43-9	231-152-8	Cadmium and its compounds	X
(7)	85535-84-8	287-476-5	Chloroalkanes, C_{10-13}	X
(8)	470-90-6	207-432-0	Chlorfenvinphos	
(9)	2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)	
(10)	107-06-2	203-458-1	1,2-dichloroethane	
(11)	75-09-2	200-838-9	Dichloromethane	
(12)	117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	X
(13)	330-54-1	206-354-4	Diuron	
(14)	115-29-7	204-079-4	Endosulfan	X
(15)	206-44-0	205-912-4	Fluoranthene	
(16)	118-74-1	204-273-9	Hexachlorobenzene	X
(17)	87-68-3	201-765-5	Hexachlorobutadiene	X
(18)	608-73-1	210-168-9	Hexachlorocyclohexane	X
(19)	34123-59-6	251-835-4	Isoproturon	
(20)	7439-92-1	231-100-4	Lead and its compounds	
(21)	7439-97-6	231-106-7	Mercury and its compounds	X
(22)	91-20-3	202-049-5	Naphthalene	
(23)	7440-02-0	231-111-4	Nickel and its compounds	
(24)	not applicable	not applicable	Nonylphenols	X (5)
(25)	not applicable	not applicable	Octylphenols (6)	
(26)	608-93-5	210-172-0	Pentachlorobenzene	X
(27)	87-86-5	201-778-6	Pentachlorophenol	
(28)	not applicable	not applicable	Polyaromatic hydrocarbons (PAH) (7)	X
(29)	122-34-9	204-535-2	Simazine	
(30)	not applicable	not applicable	Tributyltin compounds	X (8)

Table III.2- Current list of priority substances (Cont.).

Number	CAS number (1)	EU number (2)	Name of priority substance (3)	Identified as priority hazardous substance
(31)	12002-48-1	234-413-4	Trichlorobenzenes	
(32)	67-66-3	200-663-8	Trichloromethane (chloroform)	
(33)	1582-09-8	216-428-8	Trifluralin	X
(34)	115-32-2	204-082-0	Dicofol	X
(35)	1763-23-1	217-179-8	Perfluorooctane sulfonic acid and its derivatives (PFOS)	X
(36)	124495-18-7	not applicable	Quinoxyfen	X
(37)	not applicable	not applicable	Dioxins and dioxin-like compounds	X (9)
(38)	74070-46-5	277-704-1	Aclonifen	
(39)	42576-02-3	255-894-7	Bifenox	
(40)	28159-98-0	248-872-3	Cybutryne	
(41)	52315-07-8	257-842-9	Cypermethrin (10)	
(42)	62-73-7	200-547-7	Dichlorvos	
(43)	not applicable	not applicable	Hexabromocyclododecanes (HBCDD)	X (11)
(44)	76-44-8/ 1024-57-3	200-962-3/ 213-831-0	Heptachlor and heptachlor epoxide	X
(45)	886-50-0	212-950-5	Terbutryn	

(1) CAS: Chemical Abstracts Service.

(2) EU-number: European Inventory of Existing Commercial Substances (EINECS) or European List of Notified Chemical Substances (ELINCS).

(3) Where groups of substances have been selected, unless explicitly noted, typical individual representatives are defined in the context of the setting of environmental quality standards.

(4) Only Tetra, Penta, Hexa and Heptabromodiphenylether (CAS -numbers 40088-47-9, 32534-81-9, 36483-60-0, 68928-80-3, respectively).

(5) Nonylphenol (CAS 25154-52-3, EU 246-672-0) including isomers 4-nonylphenol (CAS 104-40-5, EU 203-199-4) and 4-nonylphenol (branched) (CAS 84852-15-3, EU 284-325-5).

(6) Octylphenol (CAS 1806-26-4, EU 217-302-5) including isomer 4-(1,1',3,3'-tetramethylbutyl)-phenol (CAS 140-66-9, EU 205-426-2).

(7) Including benzo(a)pyrene (CAS 50-32-8, EU 200-028-5), benzo(b)fluoranthene (CAS 205-99-2, EU 205-911-9), benzo(g,h,i)perylene (CAS 191-24-2, EU 205-883-8), benzo(k)fluoranthene (CAS 207-08-9, EU 205-916-6), indeno(1,2,3-cd)pyrene (CAS 193-39-5, EU 205-893-2) and excluding anthracene, fluoranthene and naphthalene, which are listed separately.

(8) Including tributyltin-cation (CAS 36643-28-4).

(9) This refers to the following compounds:
7 polychlorinated dibenzo-p-dioxins (PCDDs): 2,3,7,8-T4CDD (CAS 1746-01-6), 1,2,3,7,8-P5CDD (CAS 40321-76-4), 1,2,3,4,7,8-H6CDD (CAS 39227-28-6), 1,2,3,6,7,8-H6CDD (CAS 57653-85-7), 1,2,3,7,8,9-H6CDD (CAS 19408-74-3), 1,2,3,4,6,7,8-H7CDD (CAS 35822-46-9), 1,2,3,4,6,7,8,9-O8CDD (CAS 3268-87-9)
10 polychlorinated dibenzofurans (PCDFs): 2,3,7,8-T4CDF (CAS 51207-31-9), 1,2,3,7,8-P5CDF (CAS 57117-41-6), 2,3,4,7,8-P5CDF (CAS 57117-31-4), 1,2,3,4,7,8-H6CDF (CAS 70648-26-9), 1,2,3,6,7,8-H6CDF (CAS 57117-44-9), 1,2,3,7,8,9-H6CDF (CAS 72918-21-9), 2,3,4,6,7,8-H6CDF (CAS 60851-34-5), 1,2,3,4,6,7,8-H7CDF (CAS 67562-39-4), 1,2,3,4,7,8,9-H7CDF (CAS 55673-89-7), 1,2,3,4,6,7,8,9-O8CDF (CAS 39001-02-0)
12 dioxin-like polychlorinated biphenyls (PCB-DL): 3,3',4,4'-T4CB (PCB 77, CAS 32598-13-3), 3,3',4',5-T4CB (PCB 81, CAS 70362-50-4), 2,3,3',4,4'-P5CB (PCB 105, CAS 32598-14-4), 2,3,4,4',5-P5CB (PCB 114, CAS 74472-37-0), 2,3',4,4',5-P5CB (PCB 118, CAS 31508-00-6), 2,3',4,4',5'-P5CB (PCB 123, CAS 65510-44-3), 3,3',4,4',5-P5CB (PCB 126, CAS 57465-28-8), 2,3,3',4,4',5-H6CB (PCB 156, CAS 38380-08-4), 2,3,3',4,4',5'-H6CB (PCB 157, CAS 69782-90-7), 2,3',4,4',5,5'-H6CB (PCB 167, CAS 52663-72-6), 3,3',4,4',5,5'-H6CB (PCB 169, CAS 32774-16-6), 2,3,3',4,4',5,5'-H7CB (PCB 189, CAS 39635-31-9).

(10) CAS 52315-07-8 refers to an isomer mixture of cypermethrin, alpha-cypermethrin (CAS 67375-30-8), beta-cypermethrin (CAS 65731-84-2), theta-cypermethrin (CAS 71697-59-1) and zeta-cypermethrin (52315-07-8).

(11) This refers to 1,3,5,7,9,11-Hexabromocyclododecane (CAS 25637-99-4), 1,2,5,6,9,10- Hexabromocyclododecane (CAS 3194-55-6), α-Hexabromocyclododecane (CAS 134237-50-6), β-Hexabromocyclododecane (CAS 134237-51-7) and γ- Hexabromocyclododecane (CAS 134237-52-8).".

Appendix IV- Environmental quality standards for priority substances and certain other pollutants (Directive 2013/39/EU)

Table IV.1- Environmental quality standard for priority substances and other pollutants.

AA: Annual Average.

MAC: Maximum Allowable Concentration.

Unit: [µg/l] for columns (4) to (7) and [µg/kg wet weight] for column (8).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
No	Name of substance	CAS number (1)	AA-EQS (2) Inland surface waters (3)	AA-EQS (2) Other surface waters	MAC-EQS (4) Inland surface waters (3)	MAC-EQS (4) Other surface waters	EQS Biota (12)
(1)	Alachlor	15972-60-8	0,3	0,3	0,7	0,7	
(2)	Anthracene	120-12-7	0,1	0,1	0,1	0,1	
(3)	Atrazine	1912-24-9	0,6	0,6	2,0	2,0	
(4)	Benzene	71-43-2	10	8	50	50	
(5)	Brominated diphenyl-ethers (5)	32534-81-9			0,14	0,014	0,0085
(6)	Cadmium and its compounds (depending on water hardness classes) (6)	7440-43-9	≤ 0,08 (Class 1) 0,08 (Class 2) 0,09 (Class 3) 0,15 (Class 4) 0,25 (Class 5)	0,2	≤ 0,45 (Class 1) 0,45 (Class 2) 0,6 (Class 3) 0,9 (Class 4) 1,5 (Class 5)	≤ 0,45 (Class 1) 0,45 (Class 2) 0,6 (Class 3) 0,9 (Class 4) 1,5 (Class 5)	
(6a)	Carbon-tetrachloride (7)	56-23-5	12	12	not applicable	not applicable	
(7)	C10-13 Chloroalkanes (8)	85535-84-8	0,4	0,4	1,4	1,4	
(8)	Chlorfenvinphos	470-90-6	0,1	0,1	0,3	0,3	
(9)	Chlorpyrifos (Chlorpyrifos-ethyl)	2921-88-2	0,03	0,03	0,1	0,1	
(9a)	Cyclodiene pesticides: Aldrin (7) Dieldrin (7) Endrin (7) Isodrin (7)	309-00-2 60-57-1 72-20-8 465-73-6	Σ = 0,01	Σ = 0,005	not applicable	not applicable	

Table IV.2- Environmental quality standard for priority substances and other pollutants (Cont.).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
No	Name of substance	CAS number (2)	AA-EQS (3) Inland surface waters (3)	AA-EQS (3) Other surface waters	MAC-EQS (4) Inland surface waters (3)	MAC-EQS (4) Other surface waters	EQS Biota (12)
(9b)	DDT total (7), (8)	not applicable	0,025	0,025	not applicable	not applicable	
	para-para-DDT (7)	50-29-3	0,01	0,01	not applicable	not applicable	
(10)	1,2-Dichloroe-thane	107-06-2	10	10	not applicable	not applicable	
(11)	Dichlorome-thane	75-09-2	20	20	not applicable	not applicable	
(12)	Di(2-ethylhexyl)-phthalate (DEHP)	117-81-7	1,3	1,3	not applicable	not applicable	
(13)	Diuron	330-54-1	0,2	0,2	1,8	1,8	
(14)	Endosulfan	115-29-7	0,005	0,0005	0,01	0,004	
(15)	Fluoranthene	206-44-0	0,0063	0,0063	0,12	0,12	30
(16)	Hexachloro-benzene	118-74-1			0,05	0,05	10
(17)	Hexachloro-butadiene	87-68-3			0,6	0,6	55
(18)	Hexachloro-cyclohexane	608-73-1	0,02	0,002	0,04	0,02	
(19)	Isoproturon	34123-59-6	0,3	0,3	1,0	1,0	
(20)	Lead and its compounds	7439-92-1	1,2 (13)	1,3	14	14	
(21)	Mercury and its compounds	7439-97-6			0,07	0,07	20
(22)	Naphthalene	91-20-3	2	2	130	130	
(23)	Nickel and its compounds	7440-02-0	4 (13)	8,6	34	34	
(24)	Nonylphenols (4-Nonylphenol)	84852-15-3	0,3	0,3	2,0	2,0	
(25)	Octylphenols ((4-(1,1',3,3'-tetramethyl-butyl)-phenol))	140-66-9	0,1	0,01	not applicable	not applicable	
(26)	Pentachloro-benzene	608-93-5	0,007	0,0007	not applicable	not applicable	

Table IV.3- Environmental quality standard for priority substances and other pollutants (Cont.).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
No	Name of substance	CAS number (1)	AA-EQS (2) Inland surface waters (3)	AA-EQS (2) Other surface waters	MAC-EQS (4) Inland surface waters (3)	MAC-EQS (4) Other surface waters	EQS Biota (12)
(27)	Pentachloro-phenol	87-86-5	0,4	0,4	1	1	
(28)	Polyaromatic hydrocarbons (PAH) (11)	not applicable	not applicable	not applicable	not applicable	not applicable	
	Benzo(a)pyrene	50-32-8	$1,7 \times 10^{-4}$	$1,7 \times 10^{-4}$	0,27	0,027	5
	Benzo(b)fluor-anthene	205-99-2	see footnote 11	see footnote 11	0,017	0,017	see footnote 11
	Benzo(k)fluor-anthene	207-08-9	see footnote 11	see footnote 11	0,017	0,017	see footnote 11
	Benzo(g,h,i)-perylene	191-24-2	see footnote 11	see footnote 11	$8,2 \times 10^{-3}$	$8,2 \times 10^{-4}$	see footnote 11
	Indeno(1,2,3-cd)-pyrene	193-39-5	see footnote 11	see footnote 11	not applicable	not applicable	see footnote 11
(29)	Simazine	122-34-9	1	1	4	4	
(29a)	Tetrachloro-ethylene (7)	127-18-4	10	10	not applicable	not applicable	
(29b)	Trichloro-ethylene (7)	79-01-6	10	10	not applicable	not applicable	
(30)	Tributyltin compounds (Tributyltin-cation)	36643-28-4	0,0002	0,0002	0,0015	0,0015	
(31)	Trichloro-benzenes	12002-48-1	0,4	0,4	not applicable	not applicable	
(32)	Trichloro-methane	67-66-3	2,5	2,5	not applicable	not applicable	
(33)	Trifluralin	1582-09-8	0,03	0,03	not applicable	not applicable	
(34)	Dicofol	115-32-2	$1,3 \times 10^{-3}$	$3,2 \times 10^{-3}$	not appli-cable (10)	not appli-cable (10)	33
(35)	Perfluorooctane sulfonic acid and its derivatives (PFOS)	1763-23-1	$6,5 \times 10^{-4}$	$1,3 \times 10^{-4}$	36	7,2	9,1
(36)	Quinoxyfen	124495-18-7	0,15	0,015	2,7	0,54	

Table IV.4 Environmental quality standard for priority substances and other pollutants (Cont.).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
No	Name of substance	CAS number (1)	AA-EQS (2) Inland surface waters (3)	AA-EQS (2) Other surface waters	MAC-EQS (4) Inland surface waters (3)	MAC-EQS (4) Other surface waters	EQS Biota (12)
(37)	Dioxins and dioxin-like compounds	See footnote 10 in Annex X to Directive 2000/60/EC			not applicable	not applicable	Sum of PCDD+PCDF+ PCB-DL 0,0065 µg.kg^{-1} TEQ (14)
(38)	Aclonifen	74070-46-5	0,12	0,012	0,12	0,012	
(39)	Bifenox	42576-02-3	0,012	0,0012	0,04	0,004	
(40)	Cybutryne	28159-98-0	0,0025	0,0025	0,016	0,016	
(41)	Cypermethrin	52315-07-8	8×10^{-5}	8×10^{-6}	6×10^{-4}	6×10^{-5}	
(42)	Dichlorvos	62-73-7	6×10^{-4}	6×10^{-5}	7×10^{-4}	7×10^{-5}	
(43)	Hexabromo-cyclododecane (HBCDD)	See footnote 12 in Annex X to Directive 2000/60/EC	0,0016	0,0008	0,5	0,05	167
(44)	Heptachlor and heptachlor epoxide	76-44-8/1024-57-3	2×10^{-7}	1×10^{-8}	3×10^{-4}	3×10^{-5}	$6,7 \times 10^{-3}$
(45)	Terbutryn	886-50-0	0,065	0,0065	0,34	0,034	

(1) CAS: Chemical Abstracts Service.
(2) This parameter is the EQS expressed as an annual average value (AA-EQS). Unless otherwise specified, it applies to the total concentration of all isomers.
(3) Inland surface waters encompass rivers and lakes and related artificial or heavily modified water bodies.
(4) This parameter is the EQS expressed as a maximum allowable concentration (MAC-EQS). Where the MAC-EQS are marked as "not applicable", the AA-EQS values are considered protective against short-term pollution peaks in continuous discharges since they are significantly lower than the values derived on the basis of acute toxicity.
(5) For the group of priority substances covered by brominated diphenylethers (No 5), the EQS refers to the sum of the concentrations of congener numbers 28, 47, 99, 100, 153 and 154.
(6) For Cadmium and its compounds (No 6) the EQS values vary depending on the hardness of the water as specified in five class categories (Class 1: < 40 mg $CaCO_3$/l, Class 2: 40 to < 50 mg $CaCO_3$/l, Class 3: 50 to < 100 mg $CaCO_3$/l, Class 4: 100 to < 200 mg $CaCO_3$/l and Class 5: ≥ 200 mg $CaCO_3$/l).
(7) This substance is not a priority substance but one of the other pollutants for which the EQS are identical to those laid down in the legislation that applied prior to 13 January 2009.
(8) No indicative parameter is provided for this group of substances. The indicative parameter(s) must be defined through the analytical method.
(9) DDT total comprises the sum of the isomers 1,1,1-trichloro-2,2 bis (p-chlorophenyl) ethane (CAS number 50-29-3; EU number 200-024-3); 1,1,1-trichloro-2 (o-chlorophenyl)-2-(p-chlorophenyl) ethane (CAS number 789-02-6; EU Number 212-332-5); 1,1-dichloro-2,2 bis (p-chlorophenyl) ethylene (CAS number 72-55-9; EU Number 200-784-6); and 1,1-dichloro-2,2 bis (p-chloro-phenyl) ethane (CAS number 72-54-8; EU Number 200-783-0).
(10) There is insufficient information available to set a MAC-EQS for these substances.
(11) For the group of priority substances of polyaromatic hydrocarbons (PAH) (No 28), the biota EQS and corresponding AA-EQS in water refer to the concentration of benzo(a)pyrene, on the toxicity of which they are based. Benzo(a)pyrene can be considered as a marker for the other PAHs, hence only benzo(a)pyrene needs to be monitored for comparison with the biota EQS or the corresponding AA-EQS in water.
(12) Unless otherwise indicated, the biota EQS relate to fish. An alternative biota taxon, or another matrix, may be monitored instead, as long as the EQS applied provides an equivalent level of protection. For substances numbered 15 (Fluoranthene) and 28 (PAHs), the biota EQS refers to crustaceans and molluscs. For the purpose of assessing chemical status, monitoring of Fluoranthene and PAHs in fish is not appropriate. For substance number 37 (Dioxins and dioxin-like compounds), the biota EQS relates to fish, crustaceans and molluscs, in line with section 5.3 of the Annex to Commission Regulation (EU) No 1259/2011 of 2 December 2011 amending Regulation (EC) No 1881/2006 as regards maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs (OJ L 320, 3.12.2011, p. 18).
(13) These EQS refer to bioavailable concentrations of the substances.
(14) PCDD: polychlorinated dibenzo-p-dioxins; PCDF: polychlorinated dibenzofurans; PCB-DL: dioxin-like polychlorinated biphenyls; TEQ: toxic equivalents according to the World Health Organisation 2005 Toxic Equivalence Factors.'

Appendix V- Watch list of substances for Union-wide monitoring in the field of water policy (Decision nº 2015/495)

Table V- Watch list of substances for Union-wide monitoring.

Name of substance/group of substances	CAS number (1)	EU number (2)	Indicative analytical method (3) (4) (5)	Maximum acceptable method detection limit (ng/l)
17-Alpha-ethinylestradiol (EE2)	57-63-6	200-342-2	Large-volume SPE — LC-MS-MS	0,035
17-Beta-estradiol (E2), Estrone (E1)	50-28-2, 53-16-7	200-023-8	SPE — LC-MS-MS	0,4
Diclofenac	15307-86-5	239-348-5	SPE — LC-MS-MS	10
2,6-Ditert-butyl-4-methylphenol	128-37-0	204-881-4	SPE — GC-MS	3 160
2-Ethylhexyl 4-methoxycinnamate	5466-77-3	226-775-7	SPE — LC-MS-MS or GC-MS	6 000
Macrolide antibiotics (6)			SPE — LC-MS-MS	90
Methiocarb	2032-65-7	217-991-2	SPE — LC-MS-MS or GC-MS	10
Neonicotinoids (7)			SPE — LC-MS-MS	9
Oxadiazon	19666-30-9	243-215-7	LLE/SPE — GC-MS	88
Tri-allate	2303-17-5	218-962-7	LLE/SPE — GC-MS or LC-MS-MS	670

(1) Chemical Abstracts Service.
(2) European Union number — not available for all substances.
(3) To ensure comparability of results from different Member States, all substances shall be monitored in whole water samples.
(4) Extraction methods:
LLE — liquid liquid extraction,
SPE — solid-phase extraction.
Analytical methods:
GC-MS — Gas chromatography-mass spectrometry,
LC-MS-MS — Liquid chromatography (tandem) triple quadrupole mass spectrometry.
(5) For monitoring 2-Ethylhexyl 4-methoxycinnamate in suspended particulate matter (SPM) or in sediment (size < 63 µm), the following analytical method is indicated: SLE (solid liquid extraction) — GC-MS, with a maximum detection limit of 0,2 mg/kg.
(6) Erythromycin (CAS number 114-07-8, EU number 204-040-1), Clarithromycin (CAS number 81103-11-9), Azithromycin (CAS number 83905-01-5, EU number 617-500-5).
(7) Imidacloprid (CAS number 105827-78-9/138261-41-3, EU number 428-040-8), Thiacloprid (CAS number 111988-49-9), Thiamethoxam (CAS number 153719-23-4, EU number 428-650-4), Clothianidin (CAS number 210880-92-5, EU number 433-460-1), Acetamiprid (CAS number 135410-20-7/160430-64-8).

Appendix VI- Interview questions for water framework policy analysis

1. The diagram below outlines the legislation in place to regulate chemicals in the EU. Have we missed anything?
    - New initiatives or other EU legislation that are currently being considered or put into place which is relevant with regards to chemicals of emerging concern?

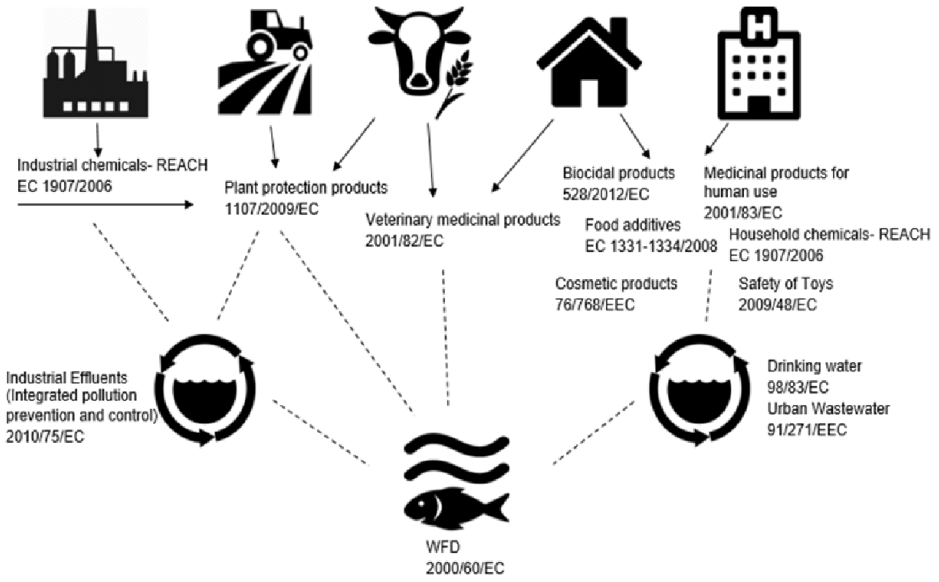

Figure VI- Diagram of current EU legislation regulating chemicals. Adaptation of the diagram developed by van Wezel et al. (2017).

2. As far as we know at this moment only the Water Framework Directive (WFD), the Industrial Effluents, the Plant Protection Products and the Biocides regulations take the aquatic environment directly into account, is this correct?
    - Which of these are the most important for you with regards to safeguarding the aquatic environment?

3. How does the WFD stimulate protection of the aquatic environment with regards to chemicals of emerging concern?

4. Do you know successful measures that have been taken in The Netherlands based on the WFD to protect the aquatic environment with regards to chemicals of emerging concern?

5. Do you know measures which have been implemented in other EU member states with success?

6. Do you think the WFD in its current form actually encourage Member States to protect the aquatic environment with regards to chemicals of emerging concern? Why/why not?

7. Do you know of any improvements to the WFD that are currently being considered or put into place with regards to chemicals of emerging concern?

8. What changes would you recommend to make WFD more adequate to protect the aquatic environment with regards to chemicals of emerging concern?