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Masterthesis

Im Studienfach Geoökologie

Emerging pollutants in surface water

Developments in society and pollution of tomorrow

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List of abbreviations

BLAC	Bund- Länderarbeitskreis- Chemikaliensicherheit
DDT	dichlorodiphenyltrichloroethane
EAWAG	Swiss Federal Institute of Aquatic Science and Technology
ECs	Emerging Contaminants
EPs	Emerging Pollutants
IPCC	Intergovernmental Panel on Climate Change
NORMAN	Network of reference laboratories, research centers and related organizations for monitoring of emerging environmental substances
OECD	Organization for economic cooperation and development
PVC	Polyvinylchloride
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
SETAC	Society of Environmental Toxicology and Chemistry
SVHC	Substances of very high concern
WATCH	Water and Global Change
WFD	Water Framework Directive
WWQA	Assessment of World Water Quality to Meet the Global Water Quality Challenge
WWTP	Waste Water Treatment plants

„Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such.” (Water Framework Directive 2000/60/EC)

Abstract

Emerging pollutants are monitored in surface waters since the nineties. With progress in analytical chemistry it is possible to analyse these substances in low concentrations. Which pollutants can be expected if future developments in society are taken into account?

Such developments in society are described in a broad range of scenarios. Scenarios on climate change are well known and published by the IPPC. The UNESCO- WWAP Water Scenario Project refers to future trends in water consumption and water resources. Until now, implications of such developments for future pollutants have not been systematically discussed. The study presented here addresses the question whether predictions of changes in society can be used as an information source for pollutants of tomorrow. It is part of the SOLUTION[1] project.

In the first step, an overview about the existing emerging pollutants is presented. The second step assesses whether causal links can be seen between societal and also technological development on these future pollutants.

The results indicate several connections between developments in society and technology and the increase of emerging pollutants. Because of demographic change, the population in Europe will have a higher life-expectancy. Concomitantly there will be an increase of pharmaceutical consumption. A second development is the change of climate. The IPPC expects a rise in temperature as well as -the increase of extreme weather events. As a result, the behaviour of chemicals in water will change which will influence the ecosystems. Mobilization of chemicals from sediments might be facilitated by erosion, flood events or rising temperatures. Substitution of problematic substances like phthalates also per- and polyfluorinated hydrocarbons (PFCs) might be a further driver which leads to changes in the pattern of pollutants. Consumption Substances as Personal Care Products or Food additives will also have relevance in future depending on the lifestyle in future. In addition Nanomaterials are a sector with increasing importance for society – and a potential source for new emerging pollutants.

[1]SOLUTION: research project supported by the 7th Framework Programme of the European Union.

http://www.solutions-project.eu/ (acces on 14.07.2014)

Deutsche Zusammenfassung

Neuartige Schadstoffe, im englischen „emerging pollutants“, werden seit den Neunziger Jahren in Oberflächengewässern analysiert und überwacht. Durch den technischen Fortschritt in der analytischen Chemie ist es inzwischen sogar möglich diese Substanzen in kleinsten Konzentrationen nachzuweisen. Welche neuartigen Schadstoffe können durch zukünftige gesellschaftliche und technische Entwicklungen zunehmen?

Dieser Einfluss gesellschaftlicher und technischer Entwicklungen auf die Menge der Schadstofffreisetzungen wird in der vorliegenden Arbeit untersucht. Auch klimatische Szenarien, die von der IPCC veröffentlicht worden sind, werden dabei beachtet und analysiert. Auswirkungen von solchen Trends wurden bisher noch nicht systematisch betrachtet. Die Masterarbeit bearbeitet die Fragestellung, ob es möglich ist, Vorhersagen zu zukünftigen Schadstoffen durch die Veränderungen der Gesellschaft zu machen und ist thematisch in das SOLUTION Projekt eingebettet.

Im ersten Schritt werden die wichtigsten neuartigen Substanzen auf ihre Ökotoxizität definiert. Im zweiten Schritt werden kausale Zusammenhänge zwischen gesellschaftlichen und technischen Entwicklungen und neuartigen Schadstoffen analysiert.

Die Ergebnisse zeigen Parallelen zwischen den gesellschaftlichen, technischen Szenarien und der Zunahme von neuartigen Schadstoffen auf. Beispielsweise resultiert aus dem demographischen Wandel der Gesellschaft eine höhere Lebenserwartung, die zukünftig einen steigenden Medikamentenverbrauch und damit erhöhte Gewässerbelastungen verursacht. Auch der Klimawandel mit extremen Wetterereignissen, wie Trockenheiten oder Flutereignissen, wird laut IPCC zunehmen. Das Verhalten und die Verbreitung von neuartigen Schadstoffen wird dadurch zu einem wichtigen Thema werden. Mobilisierungen durch Erosionen, Fluten oder Wassertemperaturanstiege sind mögliche Konsequenzen. Desweiteren wird die Substitution von problematischen Substanzen wie Phthalate, Per- und Polyflurierte Verbindungen oder Flammschutzmittel die Schadstoffentwicklung einerseits positiv aber auch negativ beeinflussen. Neuartige Schadstoffe in Körperpflege-, Wasch- oder Reinigungsmittel als auch Zusatzstoffe in Nahrungsmitteln werden zukünftig ebenfalls zunehmen. Nanomaterialien, wie Titandioxid sind neben den oben genannten Schadstoffen auch ein zukünftiges relevantes Thema und eine potentielle Schadstoffquelle.

1 Motivation and Aim

„Plastics, Pesticides, Detergents and all the other emerging things will increase in production with each year. But we do not know what they will arrange with us and the environment. I know, that these substances can be very dangerous for human. Unfortunatly I also recognized that we are powerless.Because of a high **profitableness** ***no one wants to accept or hear this appell!"***

(Elisabeth Moritz, 1918-2011)

This opinion of a family member of me is awesome and inspires for critical thinking and motivates for more researching about that problem and development. Rather early it was clear to her, that the new products as plastic, detergents or pesticides could have negative effects to human and ecosystems. But the industry and human benefit of the advantages of these products and its substances since the beginning of the application. In these days, people use these products in nearly every area of life. Chemicals from these products are detected as new "emerging pollutant" (EPs) in ecosystems. However, such negative outcomes as environmental pollution and the resulting ecotoxicologial results as endocrine disrupting effects are misprized.

By now, more and more pollutants are discussed in public and cause also a sensation in newspaper and Television. Also scientists engaged ever greater with EPs and its impacts to environment and human. The increasing use of products which are or which contain emerging pollutants is and will be a challenge of risk management and -modelling for environmental chemists, toxicologists and ecotoxicologists. In addition, societal, environmental and technological changes in future will bring further challenges for risk manager and scientists. The water framework directive set the destination for a good ecological and chemical quality in surface waters to protect human health and environment within the European Community. Changes in society, which lead to an increased release of emerging pollutants, make it even more difficult to reach these objectives.

This master thesis has been written within the SOLUTION project. It searches for overarching common denominators and causal links between changes in society and climate, use of chemicals in materials and emissions of pollutants. In reality quite a lot of researchs of EPs cover different aspects on ecotoxicological and environmental chemistry aspects, but there are not many publications relating with all analysed EPs from NORMAN Network group[2].

Which pollutants can be expected if future developments in society, technology and also climatic changes are taken into account? Such developments are described in a broad range of scenarios. Predicted changes can have implications on the future contamination of the environment by emerging pollutants. To get a clear overview of all relevant substances and its future impacts to environment, this master thesis searches for causal links between the use of chemicals, materials and emissions of pollutants and also hypothesized if it is possible to predict future EPs and also the associated changes in society.

[2] List of emerging pollutants http://www.norman-network.net/?q=node/81 (acces on 17.07.2014)

2 Emerging pollutants: Introduction and background

The following chapter 2.1 gives a short historical introduction to ecotoxicicology. It describes important dangerous events and their consequences. Chapter 2.2 describes what EPs are and how they can be defined and classified. Chapter 2.3 gives an overview about the legislation referring to different groups of emerging pollutants. Chapter 2.4 outlines the scientific background and the main research activities regardind emerging pollutants.

2.1 Short history in ecotoxicology

In the last 60 years, there were several events which can be taken as historically events in ecotoxicology (Table 1). As it can be seen in Table 1, the first events in ecotoxicology date back to the 1950s, where Methylmercury in the food chain was found to cause cognition disorders and proceed also to the first recognition of a worldwide ecological movement in 1962 with the book Silent Spring. The main catastrophes as Tschernobyl or Sandoz are also mentionend which contributed and strengthened the ecological thinking.

Table 1 Historically events in ecotoxicology *(Triebskorn R.,Köhler H., Lecture documents Ecotoxicology, 2011)*

Time	Place	Event	Amendments
1956	Minamata	People get vision-, horns-, coordination disorders because of bioaccumulation of methylmercury in food chain	General warnings of chemicals in TV
Postwar period	World	Commitment of pesticides as DDT, dieldrin, aldrin	General warnings of chemicals in TV
1962	World	Rahel Carson- publication of Silent Spring	it is presumed to be the basis of the worldwide ecological movement
1965-1975	Vietnam War	Commitment of the herbicides Agent-Orange, obtain as genetically harmful	Worldwide demonstration, establish of first environmental organizations
1968	Munich	Friedhelm Korte- first concept of starting researchs in environmental chemistry	
70s	Black forest	Forest dieback because of acid rain	Convention on Long-Range Transboundary Air Pollution
1976	Seveso	Explosion of ICMESA during production of tetrachlorophenol many people suffered of chloric acne	1982: Seveso-I- Directive (82/501/EWG) 1980: First version of chemical act
1986	Tschernobyl	Nuclear catastrophe	Lead to worldwide discussion of critical values
1986	Sandoz	Conflagration in a chemical storage high fish mortality and contamination of drinking water with insecticides	Effect-orientated ecotoxicology Monitoring programme Introduction of plant protection act
1990	Lake Apopka, Florida	Theo Colborn discover endocrine disruption of pesticides in birds and alligator	Endocrine disruption is considered in laws

2.2 Emerging Pollutants (EPs)

-Definition and Classification

Emerging Pollutants (EPs) are a group of substances which are relatively “new” in science. Up to now around 700 EPs have been detected by the NORMAN Network group during the last 10 years. But some of them have been undetected for years and some are new in water analysis.

In literature the term emerging pollutants is often used as synonym for emerging substances or emerging contaminants (ECs). The following definitions show the variety of terms used in this field:

1. The Paper *of (Marinel La Farré, Pérez, Kantiani, & Barceló, 2008)* defined *„Emerging pollutants as compounds that are not currently covered by existing water quality regulations, have not been studied before, and are thought to be potential threats to environmental ecosystems and human health and safety”.*

2. The *OECD 2012 (Boxall, 2012)* wrote that an *„emerging contaminant is a contaminant from a chemical class that so far has not been studied extensively, where there is either a concern from stakeholders (scientists, regulators, NGOs etc.), that the contaminant class may be having an impact on environmental or human health; or where there is a concern that existing environmental assessment paradigms are not appropriate for the contaminant class‟.*

3. The *EU NORMAN network group* wrote that ECs are *"Substances that have been detected in the environment, but which are currently not included in routine monitoring programmes at EU level and whose fate, behaviour and (eco)toxicological effects are not well understood*. In the following, the term “emerging pollutants” is used, as defined by *La Farré et al 2008*.

The number of publications on emerging pollutants is growing rapidly every year. This reflects Figure 1.

Increasing relevance of these substances for research is illustrated in Figure 1.

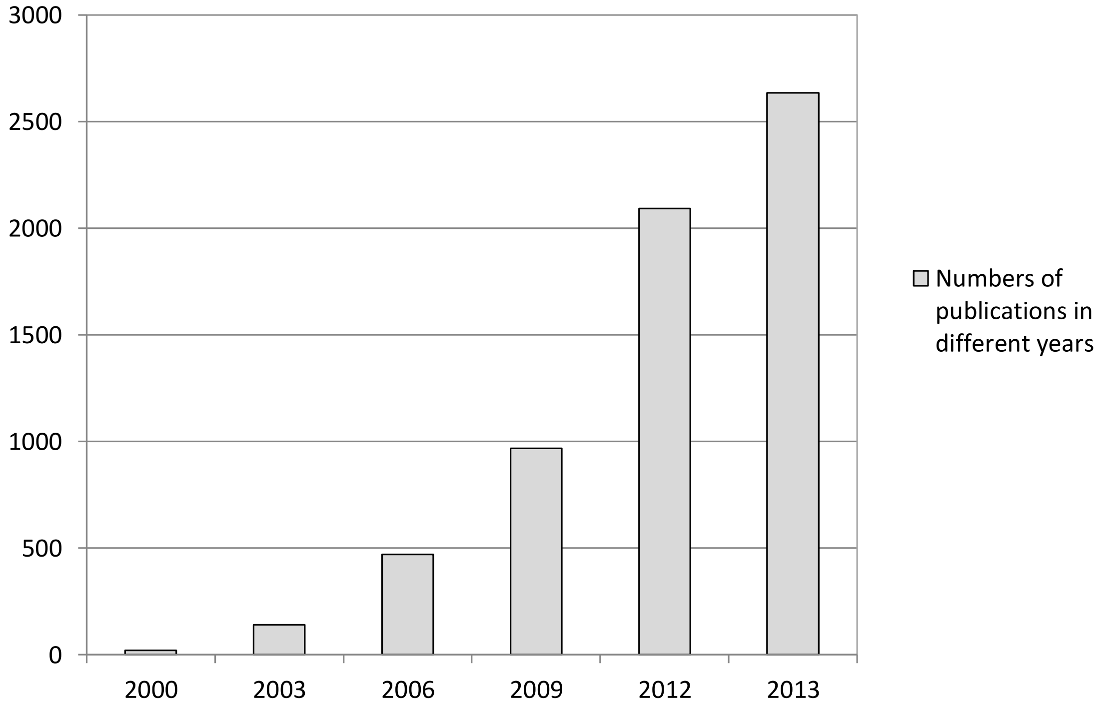

Figure 1 Numbers of publications with the words ‘emerging contaminants’ and ‘emerging pollutants’ in the title, abstract or text published since 2000 *(google scholar: access 06.03.2014)*

The first detection of a typical EP was in 1970. At that time measurements of hormonal substances in sources and springs were conducted *(Rurainski et al., 1977).* In the early nineties another EP was detected in groundwater and even in drinking water in Berlin. *Stan et al., 1994* analyzed Clofibric Acid used as a pharmaceutical *(Koschorreck, Lehmann, & Naulin, 2005), (Kern, 2004).* After these events the Bund- Länderarbeitskreis-Chemikaliensicherheit (BLAC) decided to conduct a monitoring and measurement programme in Germany at the 51. German Conference of Environment Ministers in 1998 to analyze pharmaceuticals. This report was published in 2003. Hence a lot of scientific groups keep working in that new field (chapter 2.4). One important research group is the NORMAN Network group.[3]

Because of technological progress and also awareness of EPs, the list of them will definitely grow in future. The detection sensitivity was improved towards (mg- ngL^{-1}) concentrations *(Zwiener and Frimmel 2004)*. *„The analytical techniques for detecting"* EPs *„are continually being improved and refined" (Marinel La Farré et al., 2008).* Therefore more pollutants could be analyzed in future *(Koschorreck et al., 2005)*.

Today, ECs which can become EPs are everywhere in daily life. The use of daily products containing EPs, as cosmetics, packaging, pharmaceuticals and many others show the high amount of EPs being in circulation. Humans and the ecosystem are confronted with these substances every day.

Figure 2 shows the lifecycle and pathways of EPs in environment compartments. They have a huge impact on ecosystems, waterbodies and also humans. The most important sources of EPs are shown in *Pal et al., 2010:* Hospitals, animal husbandries, household discharge, companies manufacturing drugs and wastewater and sewage treatment plants. Also inputs of *„disposal of municipal, industrial and agricultural wastes, excretion of pharmaceuticals and accedental spills"* plays a huge role*(Marinel La Farré et al., 2008).*

[3] NORMAN: http://www.norman-network.com/ (access on 06.03.2014); one of the largest projects about Emerging Pollutants

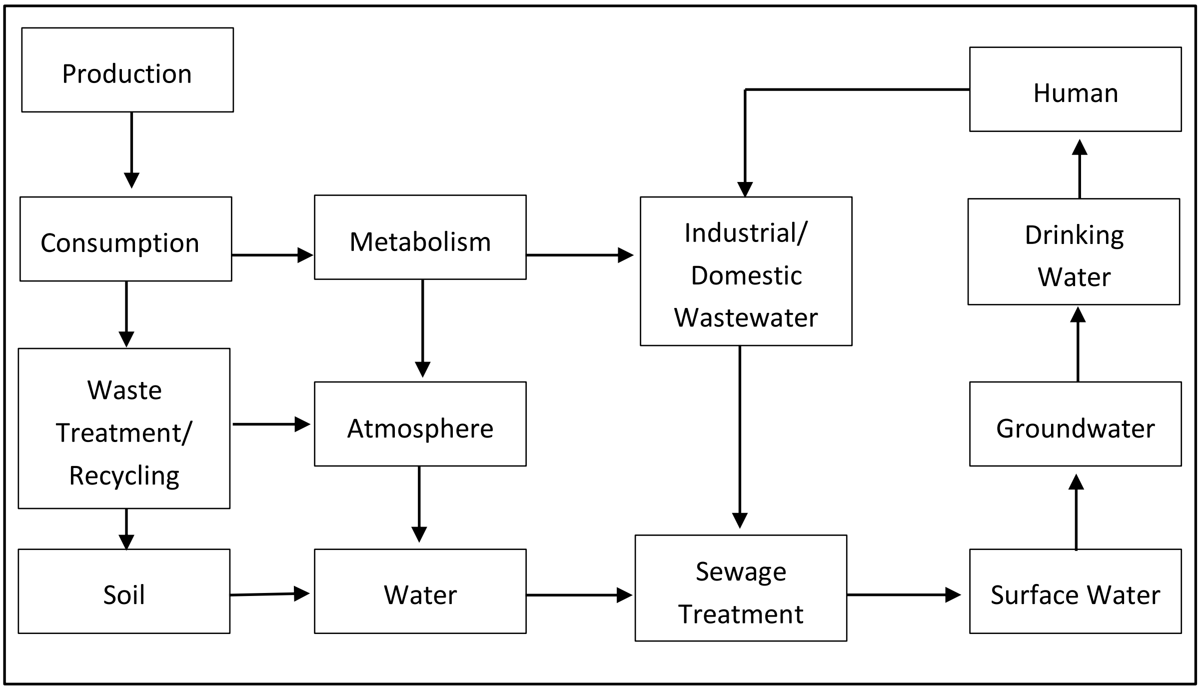

Figure 2 Lifecycle and pathways to environmental compartments of Emerging Pollutants in general (own design, simplified)

EPs cover a huge range of chemicals with different properties. The fate, concentration distribution and reactions of an individual chemical in the environment depend on several factors:

1) Sources, production volume, type of use, emission profile (local emissions, diffuse emissions, continuous/ discontinuous emissions)
2) Physical- chemical properties of the ecosystem (temperature, ph-value, salinity, amount of suspended load, sedimentation rate, nutrient cycle, redox conditions and the ratio of mixture)
3) Transformations processes (photolysis, hydrolysis, redox reactions and biotic degradation)
4) Physical- chemical properties of the chemical (e.g. molecular structure, vapor pressure, water- and fat solubility, distribution coefficient, absorbance, biodegradability, bioaccumulation and bioconcentration)

According to the NORMAN Network, six classes within around 700 substances of EPs can be distinguished. The most important classes subclasses are shown in the following Table 2.

Table 2 Most important substances/classes and its subclasses/subcategory for the master thesis

Classes	Subcategory
Pharmaceuticals	Analgesic Antibacterial Antidepressant Antidiabetic Antihypertensive Anti-inflammatory Beta-Blockers Lipid regulators Steroids and hormones X-ray contrast media
Industrial Chemicals	Perfluoroalkylated substances Fluorotelomer alcohols Plasticizers Flame retardants
Consumption Products	Detergents Food- additives Parabens (hydroxybenzoic acid esters) Insect repellents Sun-screen agents Carriers Fragrances
Pesticides	Insecticides Herbicides Fungicides
Biocides	Antimicrobial agents
Nanomaterials	Carbon Nano Tubes Titania

In this master thesis, focus is set on 6 classes and also some subclasses of EPs. The classes are highlighted fat in the Table 2. For these classes it has been found that their occurence in the environment can be influenced by developments of society.

2.3 Legal Framework

It is important to see that a large number of directives and regulations refer to water and EPs in water politics.

The Water Framework Directive is the most important one for gaining a good water quality in the European Union. It came into force in 2002 and has the goal to gradually improve the good water quality until 2015, 2021 and 2027. The framework sets objectives and gives the methods to achieve a good water quality and also good chemical and ecological conditions while analyzing surface waters as rivers between specific periods to obtain the pretended aims. There are also some new reforms in the latest amendment (2013/39/EU) of the water framework.

In the following Table 3 the most important pieces of European legislation for reaching a good water quality are listed.

Table 3 Important regulations in water politics

Important regulations in water politics
1. EU Water Framework Directive (2000/60/EC)
(1) (2008/105/EC)
(2) (2013/39/EC)
2. Marine Strategy Framework Directive (2008/57/EC)
3. Drinking Water Directive (98/83/EC)
4. Flood Risk Management Directive (2007/60/EC)
5. Urban Waste Water Directive (91/271/EC)
6. Surface water regulation in Germany „Oberflächenwasserverordnung“

Other pieces of legislation set regulate the placing of substances on the market. They should also be considered to reach a good water quality and protect environment and human health. The most important “substance-related” regulations and directives are listed in the following Table 4. They refer to different classes of substances which are emerging pollutants (see also chapter 4 for introductions to these classes of substances).

Table 4 Regulations and directives related to substances

Directives for substances

1. Pharmaceuticals
   (1) 2004/27/EC of the European Parliament and of the Council of 31 March 2004 amending Directive No. 2001/83/EC on the Community code relating to medicinal products for human use
   (2) 2004/28/EC of the European Parliament and of the Council of 31 March 2004 amending Directive No. 2001/82/EC on the Community code relating to veterinary medicinal products
2. Industrial Chemicals
   (1) 2010/75/EU- Industrial Emission Directive
   (2) REACH
3. Pesticides and Biocides
   (1) 2009/128/EC for a sustainable use of pesticides
   (2) 528/2012 Regulation (EU) 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
   (3) 1107/2009/EC 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 97/117/EEC and 91/414/EEC

For more information about the prime guidelines in the interested reader may refer to *(Exner, Seemann, Barjenbruch, Hinkelmann, 2011).*

2.4 Scientific Background and worldwide research activities on emerging pollutants

As already shown in chapter 2.2, research on EPs is increasing every year (Figure 1). This field gets more and more priority in Europe and also all over the world. The initial findings, possible risks and outcomes (chapter 4) are becoming more important and relevant for scientists and also humanity. Nowadays there are several large research projects on EPs. They are shown in Table 5. They have been analyzed in this master thesis.

Research groups have different key aspects and set the focus on several topics as establishing a large data bank while working on a uniform European monitoring programme (NORMAN and RISK IDENT). Other projects model water flows or water resources (WATCH) for future scenarios in developing countries and also for arid regions as the Mediterranean Sea (WWQA). The focus of RISKWA or SOLUTIONS is on the development of scenarios and assessments for the management of river basins.

Table 5 Worldwide projects engaged with EPs

Project Name/ duration time	Domain	Key aspects
NORMAN **2005**	Europe	a) Enhance the exchange of information and collection of data on emerging environmental substances b) Encourage the validation and harmonization of common measurement methods and monitoring tools so that the demands of risk assessors can be better met c) Ensure that knowledge of emerging pollutants is maintained and developed by stimulating coordinated, interdisciplinary projects on problem-oriented research and knowledge transfer to address identified needs d) Organizes expert group meetings, workshops, databases and methods validation exercises
RISKWA **n/s**	Germany	a) Include many other projects as TRANSRISK, SAUBER+, RISK Ident, SchussenAktivPlus b) Promote characterization- and management of risks, new technologies for emissions/ immissions management, communication and education arrangements, identification of pollutants
SOLUTIONS **2013-2018**	Europe	a) common denominators and causal links between changes in society and climate, use of chemicals in materials and emissions of pollutants b) aim to predict future emerging pollutants – based on scenarios for developments in society
SCARCE **2009-2014**	Europe	a) Assessing and predicting the effects on water quantity and quality in Iberian rivers caused by global change b) define the long-term patterns and actual mechanisms that operate in the hydrology, water quality, habitat dynamics, and ecosystem structure and function of Mediterranean watersheds
SCENES **2006-2010**	Europe	a) Development of scenarios of water resources in Europe until 2050
WATCH **2007-2010**	Europe	a) bring together the hydrological, water resources and climate communities b) to analyse, quantify and predict the components of the current and future global water cycles and related water resources states c) evaluate their uncertainties and clarify the overall vulnerability of global water resources related to the main societal and economic sectors
WWQA **2013-2015**	World	a) Scenarios for development countries b) Analyze contaminants in developing countries

3 Approach

This master thesis aims to test the hypothesis, that scenarios on developments in society can give indications for future emerging pollutants. For this purpose – and in order to get a well-structured report – in the first step an overview of the most important EPs was established in the first step. A more detailed analysis was made for classes of EPs with a high emission potential: Pharmaceuticals, industrial chemicals as flame retardants, plasticizers, poly- and perfluorinated substances, consumption substances as personal care products and food additives, pesticides, biocides and nanomaterials. A short overview of the most important characteristics of these groups of EPs is given in chapter 4. Information from different publications, information on the ingredients of substances in products and also the NORMAN database of EPs supported the analysis. In addition the main projects engaged with EPs in Europe and worldwide were identified and analysed (chapter 2.4).

Substances, substance groups, or product groups were identified which have the potential of becoming, or containing, EPs in surface water due to changes in society, technology or climate (chapter 4).

In the second step, existing reports (Chapter 9, Table 10) on developments of society and technologies were identified and analysed. Potential implications of trends for future pollutants were described. The second step assessed whether causal links exist between societal development and the previously identified pollution hotspots. For each of the studies which have been analysed, key characteristics as institution, aspects which are covered, time period, main developments which are predicted, drivers for change, number and type of scenarios, and (causal) links to pollutants were documented in a report profile (Chapter 9, Table 11). In parallel the trends identified in pollution and risks were discussed with experts e.g. from the SOLUTIONS think tank. The experts come from different disciplines as ecotoxicology, environmental chemistry or professionals for sewage plants. They addressed future trends with a different view and developed management options for risk management.

After the evaluation and analysis of step one and two, scenarios for developments in society and related drivers to future EPs were evaluated and described (chapter 5). Finally, conclusions and outlook regarding future pollutants were given (chapter 6 and 7).

4 Important Groups of Emerging Pollutants

In this chapter, an overview about five of the most important groups of EPs is given:

1) Pharmaceuticals

2) Industrial chemicals

3) Consumption products

4) Pesticides and Biocides

5) Nanomaterials

The presence of these chemicals can change with developments in society which have been analysed in this thesis (see chapter 5). For each group, the following characteristics are described:

a) First detection; b) Production; c)Use; d)Emission routes to ecosystems e)Ecotoxicology

4.1 Pharmaceuticals

*„Pharmaceuticals are a class of emerging environmental contaminants that are extensive and increasingly being used in human and veterinary medicine" (Christen & Fent, 2009)***.** As mentioned before, Clofibric Acid, used as a lipid lowering drug, was first analyzed in the Nineties. Hormonal substances were also measured in water in the Seventies. In addition, *„the occurrence of pharmaceuticals was reported in the USA in the range of 0, 8- 2 µg/L in wastewater" (Garrison et al., 1976)*. In ensuing years, substances as ibuprofen and naproxen were found in rivers *(Richardson and Brown 1985) (Rogers et al., 1986)*. In 2004 it was reported that three species of vulture were affected by diclofenac and had a high death rate after being confronted with these substances in India and Pakistan *(Oaks et al., 2004)*. Monitoring showed that the consumption and the distribution of pharmaceuticals could have negative effects for the environment. Today many human and also veterinary drugs are in circulation. The BLAC found out that human pharmaceuticals are mostly detected in surface water with a concentration of about 1 µg/ l. Veterinary drugs are analyzed in a not significant concentration in e.g. soils and groundwater probably because of lower consumption and stricter statutory regulations (chapter 2.3). *Triebskorn et al., 2011* predict that pharmaceuticals are the main group of the verified micropollutants in water. It is challenging to measure pharmaceuticals in aquatic systems because of their physico-chemical properties and their low concentrations (NORMAN). There are many research

groups investigating the ecotoxicological impacts of pharmaceuticals *((Triebskorn et al.), (Kümmerer et al.,), (Richardson & Ternes, 2007) (Schwaiger et al., 2004)).* Many scientific papers were published, but acute toxic effects on human health are still not be proved *(Götz et al., 2011). However, they* could be deflected from animal experiences. After metabolism, pharmaceuticals can be excreted unchanged or transformed. They enter the aquatic systems. Another fact is that metabolized extreted,unchanged pharmaceuticals and their transformation products often entering aquatic systems through leaching or run-off. Often stable, persistent molecules are entering waste water and dump leak water. This can result from non- point sources such as house sewage and from point sources as hospitals, pharmaceutical industry and nursing homes. In sewage plants, some of these substances are not well degradable and entering surface water, reaching also groundwater after run-off *(Marinel La Farré et al., 2008)* and also the drinking water in small concentrations. The consumption of pharmaceuticals is increasing every year. In Germany there are 7428 preparations and 2.200 substances of pharmaceuticals for humans in circulation *(Rote Liste® Service GmbH, 2012)*. *Fent et al., 2006* identified that in Europe about 3000 different human and veterinary medicine substances are in use. The most commonly used substances are anti-inflammatory drugs/analgesics, antibiotics, lipid regulators, beta blockers, steroids and related hormones *(Daughton et al., 1999).* For the placing on the market, it is important to know that veterinary pharmaceuticals are regulated stricter as human pharmaceuticals. There are two important laws in Europe for placing pharmaceuticals at the market: Directive (2004/27/EC) and Directive (2004/28/EC) (chapter 2.3).

4.2 Industrial Chemicals

Industrial Chemicals are a large group of substances. According to their chemical structure they belong to many classes and also subclasses. Industrial Chemicals are man-made substances which have not a naturally origin. They are often used to produce speciality chemicals such as flame retardants, plasticizers, substances for human care products and food additives *(IKSR, CIPR, & ICBR, 2002)*. In the next chapter 4.2.1 three important groups of industrial chemicals and their characteristics are explained.

4.2.1 Flame retardants

„Worldwide, more than 200000 t of brominated flame retardants are produced each year" (Richardson, 2008). Flame retardants are used in a broad way to avoid combustion in materials as plastic materials, textiles and timber. The main uses appeared for electric equipment, vehicles of every description, building constructions and as mentioned before in textiles and furniture. Within the flame retardants, Brominated Flame retardants are cost-efficient which is one of the main reasons why these substances are produced in a high rate *(UBA, 2008)*. However brominated flame retardants have also negative properties. Because of their chemical structure many of these compounds are persistent, some are also bioaccumulative. The most frequently detected and also most produced flame retardants are: Hexabromocyclododecane (HBCD), Tetrabromobisphenol A (TBBPA) and Decabromodiphenylether (DecaBDE). The main emissions from these flame retardants result from the production of plastic materials over point sources. There are also diffuse sources coming from migration from articles and elution of the flame retardant out of the products while they are produced, used or depolluted. The persistent and bioaccumulative substances can be found in sediments, dust, in wild animals and humans *(UBA, 2008)*. They can be also analyzed in surface water. In a review paper from *Richardson et al., 2012* the increasing measurements of brominated flame retardants in environmental waters are documented.

Some flame retardants are regulated under European legislation. REACH is playing the most important role for the registration, restriction and authorization of chemicals in the EU. HBCDD is listed in the Authorisation List of REACH (REACH Annex XIV) with a sunset date in 2015. This means, that after 2015 it is forbidden to produce or use this substance in Europe (without a use-specific authorization). The flame retardant DecaHBD is included in the REACH Candidate list. This means, it has been identified as substance of very high concern (SVHC).

4.2.2 Plasticizer

„In the second half of the 20th century, plastics became one of the most universally-used and multi- purpose materials in the global economy" (PlasticsEurope, 2013). Plasticizers are a group of substances which increase as additives the plasticity of materials. They *„incorporate into a material to increase its flexibility, workability, or distensibility" (Cadogan & Howick, 2012).* With increasing production of Polyvinylchlorid (PVC), the application of plasticizers

was growing more rapidly in the fifties. Since then, plasticizers are used in many fields of applications. Nowadays plasticizers as Phthalates are mostly used for the production of plasticized flexible PVC by mixing resin, phthalate and other additives together. For more information about the most important plasticizers see *(Cadogan & Howick, 2012).* Plasticized PVC is widely used for example in wires, interlayers, packaging, floor covers, composition leather, baby products, shoes, sport articles and also medical equipment. In Western Europe the production of phthalates is around one million tons a year *(UBA, 2007).* The European Council for Plasticizers and Intermediates (ECPI) calculated that the mostly used phthalates are DINP (Di-isononyl-phthalat), DIDP (Di-isodecyl- phthalat) und DPHP (Di-2-propyl-heptyl-phthalat). Phthalates can be placed into two groups- low molecular weight phthalates (LMW) (which have 3-6 carbon atoms in backbones) and high molecular weight (HMW which have 7 or more carbon atoms in backbones). DEHP (Bis(2-ethylhexyl) phthalate), DBP (Dibutyl phthalate), DIBP (Diisobutyl phthalate) and BBP (Benzylbutyl) belong to the LMW Phthalates while DIDP (Diisodecyl phthalate), DINP (Diisononyl phthalate *),* and DPHP (Di(2-Propyl Heptyl) belong to the HWM Phthalates *((LfU, 2012)* and *(ECPI, webpage.)*. Phthalates can be easily released out of the product because they are not chemical bound. According to that, they can evaporate, being washed out or abraded out of products. Once entering the ecosystems they are semi-volatile Organic Compounds *(UBA, 2007)* and can negatively influence animals and also human life *(Bornehag, C.-G et al., 2004) (Fukuwatari et al., 2002)*. They were also found in surface water ((NORMAN list) *(Horn et al., 2004)).*

Because of their toxicicity for reproduction in animal experiments, the LMW phthalates are regulated tightly by REACH (Table 6), the European Chemicals Legislation (Table 4). The HMW are also a group of substances which could have been negative effects for environment but actually there are no references for negative impacts to the environment *(LfU, 2012)*. Because of possible restrictions, the industry has to search for alternatives for this large sector. It is expected that in 2018 the demand for phthalates will increase to 7,6 million t per year *(Ceresana Research, Marktstudie Weichmacher 11/2013).*

According to the report of the Bayrisches Landesamt für Umwelt, there are some substitutes for phthalates *(LfU, 2012)*. In addition the Fraunhofer UMSICHT found also some substitutes *(Fraunhofer UMSICHT, 2014)* which are more biodegradable *(Erythropel, Maric, & Cooper, 2012).*

Table 6 Phthalate regulated under REACH *(ECHA, webpage acces on 01.07.2014)*

Substance	CAS	Candidate list of SVHC for authorisation. Date of inclusion	Authorization list Annex XIV
Benzyl butyl phthalate (BBP)	85-68-7	-	2015
Bis(2-ethylhexyl) phthalate (DEHP)	117-81-7	-	2015
Dibutyl phthalate (DBP)	84-74-2	-	2015
Diisobutyl phthalate (DIBP)	84-69-5	-	2015
Dihexyl phthalate (DHP)	84-75-3	2013	-
Dipentyl phthalate (DPP)	131-18-0	2013	-
N-pentyl-isopentylphthalate	776297-69-9	2012	-
Diisopentylphthalate (DIPP)	605-50-5	2012	-
Bis(2-methoxyethyl) phthalate	117-82-8	2011	-

4.2.3 Per- and polyfluorinated Chemicals

Per- and polyfluorinated chemicals (PFCs), sometimes also called Fluorinated Surfactants, are in use in many areas and are one of the rising themes of environmental chemistry since 2006 *(NORMAN)*. In literature, different appellations as Perfluorinated compounds or Fluorinated Surfactants circulate, to describe these substances. They have been used in industrial and consumer products since the 1950s. The fluorine compounds are used in products which are stain repellents (probably the best known groups containing PFCs are Gore-Tex and Teflon). In addition they are produced for paints, adhesives, waxes, metals, electronics and caulks, grease proof coatings, outdoor textiles and also for food packaging (e.g. French fry boxes, hamburger wrappers) *(Richardson, 2008), (NORMAN)*. Perfluorinated compounds are *„organic substances in which all the hydrogens of the hydrocarbon backbones are substituted with fluorine atoms" (Stahl, Mattern, & Brunn, 2011).* These substances are persistent, toxic and can be also bioaccumulative in the environment *(Marinel La Farré et al., 2008)*. Therefore they can be found in wildlife even in the Arctic, dust, surface water and even in human blood *(Stahl et al., 2011), (Hölzer et al., 2008), (Giesy et al., 2001).* It is also proved that some PFCs are harmful to reproduction in animal experiments *(Greenpeace e.V., 2012).* In addition they can promote the growth of tumors *(UBA 2009).* Because of these facts, there is an increasingly interest in science and regulatory for PFCs. They can enter ecosystems through direct or indirect sources *(Prevedouros, Cousins, Buck, & Korzenioski, 2006)*. The Umweltbundesamt *(Umweltbundesamt, 2009)* developed a summary of these sources. Direct sources relate to production and processing of PFCs in textiles industry, electroplating and paper industry. Indirect sources result from washing of textiles containing PFCs, evaporating of volatile perfluorated chemicals from furniture, using impregnant and effluent sludge which contains PFCs.

According to the Umweltbundesamt, the OECD registered around 850 PFCs with different chain-lengths. Because of being more persistent long- chain PFCs with C_{8-14} are more hazardous than short- chain ones. In this thesis, an introduction is given to Concentrating on two well-known substances: PFOS and PFOA. *(Richardson & Ternes, 2005)* found out that *„ PFOS (Perfluorooctane sulfonate) and PFOA (Perfluorooctanois acid) were the first fluorinated surfactants to receive considerable attention, research is expanding beyond these two contaminants to other long-chain perfluorinated acids and alcohols".* For example PFOA is used for the development of Polytetrafluoroethylene- based membranes as Gore-Tex and Teflon. It is added during the manufacture of these polymers. Especially for long- chain persistent PFCs there are restrictions under different directives as REACH and the Stockholm Convention (Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOS-F)) *(Stockholm Convention, 2014)*. PFOA, and also some other long chain C_{11-14} PFCAs as substances from Table 7 are regulated under REACH. They are also on the candidate list for SvHc *(ECHA, webpage.).* At present, short- chain PFCs are used from industry as an alternative. However, they have problematic properties too. These substances are already analyzed in the environment ((chapter 5.4.1) *(Benskin et al., 2012)*).

Table 7 Substances on the REACH Candidate List (long-chain=blue marked ones)

Substance	**CAS**
Pentadecafluorooctanoic acid	335-67-1
Ammonium pentadecafluorooctanoate	3825-26-1
Henicosafluoroundeanoic acid	2058-94-80
Heptacosafluorotetradecanoic acid	376-06-70
Tricosafluorododecanoic acid	307-55-10
Pentacosafluorotridecanoic adic	72629-94-8
Tetrafluoroborate	13814-96-5

4.3 Consumption Substances

Consumption Substances are another widely used group which gain more and more interest for ecotoxicolgists. They are covering a lot of products which are in use in a wide range. In the meantime Personal Care Products and Detergents are known for their negative impacts to environment more or less. Intense research activity is going on in this field, to discover causal links of ecotoxicological effects of these substances.

4.3.1 Personal Care Products/ Detergents

Personal Care Products (PCPs) and Detergents are in use every day and also everywhere in the world. Nowadays cosmetics as soaps, lotions, toothpastes, shampoos, sun crèmes and detergents for textiles or dishes are part of daily life. To achieve specific functional properties, these products often contain ingredient as parabens, synthetic musk, fragrances, antimicrobials, UV- filters and also insect repellents. Scientists identified that these substances can have negative impacts on the ecosystems and even for human. *Rimkus and Wolf 1993* found out that some of these substances can accumulate in organisms because of their lipophilic character. One example for a toxic substance used for detergents is the fragrance nitromusk xylol *(Brunn& Rimkus 1997)*. In addition parabens used as preservative could be endocrine disruptive *(Kartenkamp 2012)*. Ethylhexyl methoxycinnamate used as UV-B filter is also endocrine disruptive and can be found in surface waters *(Schlumpf et al., 2001), (NORMAN)*. Because of these facts, PCPs can be found in the list of emerging pollutants of NORMAN. Another important point is that the production volume of PCPs is much higher than the pharmaceuticals production *(Ternes & Knacker, 2003).* Therefore a higher distribution of these substances in ecosystems is expected. PCPs can easily enter the water system via waste water *(Peck A.M. 2006),* and it is necessary to control these substances.

4.3.2 Food additives

Another group of Consumption Substances are food additives. In the NORMAN list Sucralose, Triacetin and Triethylcitrat are named as emerging pollutants found in surface waters. Because of their possibly negative impacts to human health and environment, food additives are gaining in importance. The most commonly used substances are sweet additives as Cyclamate, Saccharin, Sucralose, Acesulfame and Aspartame *(Richardson & Ternes, 2011), (Lange, Scheurer, & Brauch, 2012)*. They are used as sweeteners in drinks, food, and in drugs *(Scheurer, Brauch, & Lange, 2009) and (Weihrauch et al. 2004)*. *Scheurer et al., 2009* and *Lange et al., 2012* give an overview about these substances and their structure. In the following a short introduction to the sweetener sucralose is given.

Sucralose is a good example to describe problematic properties of food additives and to give some facts about their impacts. Because of its structure, sucralose is a very persistent, polar and a highly water soluble substance. *„It is made by chlorinating sucrose, where three hydroxyl groups are replaced by chlorine atoms" (Richardson & Ternes, 2011).* Sweeteners are found in surface waters. Many scientists measured these substances in waste water and also in surface water *(Scheurer et al., 2009) (Richardson & Ternes, 2011).*

Lennart K.J. from the NORMAN Network described that the problem of these substances is not acute toxicity, *„but about a slowly degraded substance potentially building up higher concentrations and, for example, entering drinking water systems or having an undesirable influence on sensitive organisms" (Dulio,NORMAN Network 2009).*

4.4 Pesticides and Biocides

Pesticides and Biocides often belong to similar chemical groups. They have different areas of application.

Pesticides are common in conventional agriculture and also in urban areas to protect either the economic plants against unwanted organism as insects, weed or rodents or to protect urban parks. In Germany, 691 pesticides were allowed in 2011 *(UBA, webpage.)* They are used in agriculture but also in urban parks, lawns and even on sealed areas *(I. K. Wittmer et al., 2010), (Bucheli T.D. et al., 1998)*.

„Biocides are used for all compounds that are used for non-plant protection purposes" (I. K. Wittmer et al., 2010). In addition biocides are used in cosmetics, in cleaning products, for material protection in textiles, plastics and for wood protection, in agents on facades and roofs *(Burkhardt, 2006).*

As the other substances mentioned before, pesticides and biocides enter ecosystems, including surface water and ground water. Leaching, Run-off, incorrect drainage or removal and using of spray liquids are possibilities for contamination. There can be also huge inputs from urban areas to surface water*(I. Wittmer & Burkhard, 2009).* For this reason pesticides and biocides and also their transformation products are detected in ground- and surface water *(Richardson & Ternes, 2007) (BMELV,2008). Fleeger et al., 2003* found out, that the compounds detected in surface waters have a potential negative impact on the aquatic environment. To get a better water quality it is very important to regulate these substances (chapter 2.3). Organic farming is conducive to that, because there it is not allowed to use herbicides *(BMELV, 2008)*. The NORMAN Network listed many compounds of biocides and pesticides to the NORMAN list (e.g., Triclosan, terbutryn, carbendazim, chlorothalonil, dichlorvos, hydrogen cyanide, Irgarol (cybutryne), permethrin, prometryne,) *(Ruedel, 2012).*

4.5 Nanomaterials

Although Nanomaterials have a big application field, these substances are the most unexplored substances of the EPs and it is not much known about the fate and behavior of them in aquatic environments *(Stone, V. 2010).* These substances are relatively new and are at the same time a rapidly growing sector *(Marinella Farré, Gajda-Schrantz, Kantiani, & Barceló, 2009)*. More details about the development of nanomaterials are given in *Moeller et al., 2013*. These materials are in application for *„commercial purposes such as fillers, catalysts, semiconductors, cosmetics,* textiles*, microelectronics, pharmaceuticals, drug carriers, energy storage and anti- friction coatings"*. As mentioned in the *EAWAG News 2009* there are more than 800 products *(Behra, 2009)* in the nanotechnology sector applied for pharma- and medicine technology, energy- and environmental technology, information- and communication technology, manufacturing systems engineering and the textile industry as well as for the building sector *(Moeller et al., 2013). Moeller et al.2013* mentioned that with these substances nearly every class of material could be improved and affected. The size of a Nanomaterial ranges typically between 1 and 100 nm. They can *„be composed of many different base materials (carbon, silicon and metals, such as gold, cadmium and selenium) and they have different shapes" (Marinella Farré et al., 2009).* Due to their small size, nanomaterials show an extremely high surface to volume ratio explaining their high reactivity. The different applications and uses require a careful assessment of potential exposures and risks for humans and the environment. Depending on its substance, form, size and surface, a nanoparticle can have completely different physical, chemical or biological interactions with the environment, e.g. in soils, water bodies and human or with other substances, compared to the bulk material *(Krug, 2005)*. Therefore they might have negative impacts to ecosystems *(Krug, 2005)*. In the following some examples of important nanomaterials are given:

- **Titania**: Titanium dioxide as nanoparticle is used for cosmetics (sun creams), in textiles and for outdoor paints. In these applications it functions as an ultraviolet (UV) protection agent by absorbing the UV-light. Other applications are the production of solar cells and disinfection of waste water. Titania is water-insoluble. Titania particles form agglomerates or aggregates in water and accumulate therefore in the sediment where they are unlikely washed out again. In sewage treatment plants titania particles are only partially retained in the sludge and are thus released to surface waters and soil when the sludge is used as fertilizer *(Kieser et al., 2009, Moeller et al., 2013).*

- **Carbon nanotubes (CNT)**: Carbon nanotubes are hydrophobic, poorly biodegradable particles. They accumulate on boundary surfaces such as water/air or water/sediment. They can influence the behaviour and fate of other organic substances in water. Carbon nanotubes interact with dissolved organic material (DOM) in the aquatic environment and can acquire/exchange their surface coatings/ functionalization *(Moeller et al., 2013).* These interactions affect the presence of organic materials in the water column *(Marinella Farré et al., 2009)*

Greßler and Nentwich, 2012 assert, that *„In the environment, nanomaterials can undergo a* range of chemical processes (Table 8) *that depend on many factors (e.g. pH value, salinity, concentration differences, the presence of organic or inorganic material). The characteristics and properties of a nanomaterial also play a major role".* Therefore, it is not easily to forecast the fate and behavior of the different nanoparticles in the environment. Because of the variety of nanomaterials, they differ in their ecotoxicological properties.

The main facts about environmental fate will be presented for a few nanoparticles. *Jones 2002 and Lyklmea 2005* predict, that *„dispersed nanomaterials within water will behave according to the well-described and understood phenomena which govern colloid-science"*. In addition it is reasonable to assume that they will alter the behaviour of other organic compounds in aquatic ecosystems. It is important to mention that for example Carbon Nanotubes can absorb to some other organic compounds as *(Farré et al., 2009):*

- Bisphenol A
- Phthalate esters
- Dioxin
- Nonylphenol
- DDT and its metabolites

The sorption is currently well explored by *Peng et al., 2003, Gerde et al., 2001.*

In addition, *Neukum, Braun, & Azzam, 2012* claim, that a mobile nanoparticle could act as carrier materials for other emerging substances. They predict that this so called "Co-Transport" may cause higher concentrations of pollutants in groundwater. This fact has been little studied till now and reclaims further investigations.

Table 8 Environmental processes and the behaviour and properties of nanomaterials *(Aitken, Robert J., et al., 2008)*

Environmental processes	**Behaviour/ properties of nanomaterials**
Dissolution	A solid nanomaterial dissolves in a solvent, yielding a chemical solution. Precipitation/Sedimentation: Nanomaterials are separated from a suspension or solution
Speciation	Formation of chemical variants (species) of a nanomaterial that are in a reaction equilibrium with one another
Binding to biotic or abiotic particles	Nanomaterialien interact with other living or non-living materials in the environment-adhesion/ sorption.
Transformation	A nanomaterial undergoes a biological or chemical transformation
Agglomeration/ Disagglomeration	Nanomaterials combine into larger units or are separated again.
Mineralization	Transformation of a carbon-containing nanomaterial into an inorganic state through biotic and abiotic decomposition
Diffusion	Transport of a nanomaterial from a zone of high concentration into one with a lower concentration
Deposition	Deposition of a nanomaterial, e.g. from the air into the water.
Resuspension	Renewed distribution of an insoluble nanomaterial in a liquid or a gas (for example from a surface into gas or from sediment into water) after it was previously separated through precipitation

5 Scenarios for developments in society and implications for pollution of tomorrow

Which pollutants can be expected if future developments in society and climate are taken into account? Possible developments are described in a broad range of scenarios. The scenarios on climate change are well known and published by the IPCC *(IPCC 2013)*. Other studies set the focus on economic, technological and demographic developments. Predicted changes can have implications on the future contamination of the environment by emerging pollutants. These first indications are based on the analysis of a number of published available scenarios from different sectors. They address the following aspects:

- **Scenarios for middle- and long-term developments in society, caused by multiple drivers** (e.g. the UNEP GEO 5 – Global Environmental Outlook; the UN Millenium Ecosystem Assessment (MA); the European Environment – State and Outlook 2010; the Planetary Boundary Approach);
- **Predictions for water use and water cycle** (e.g. The World Water Vision of Earthscan; Water in a changing world (The United Nations World Water Development Report); Water resources across Europe (European Environmental Agency);
- **Predictions for industrial chemicals and hazardous waste** (Costs on Inaction on the sound management of chemicals (UNEP); Trace Contaminants in Water Cycles (Acatech));
- **Developments due to climate change** (the IPPC Special Report Emission Scenarios from UNEP; the SCARCE project);
- **Developments due to demographic change** (OECD Environmental Outlook to 2050);
- **Developments due to technological and/or economic** changes (THOUGHTS Megatrends);
- **Predictions for food production and nutrients** (World Social Science Report from UNEP);

The publications used for this analysis are listed in Table 10. An overview is given in Table 9. It shows the main topics of different thematically analysed scenarios.

Table 9 Topics of scenarios and numbers of repeats addresses them. Total numbers of reports analysed: 34

Topics	Amount
Scenarios for middle and longterm developments in society by multiple drivers	**6**
Developments in water use/ cycle	**7**
Developments in use and impacts of chemicals	**5**
Specific driver: climate change	**4**
Specific driver: demographic change	**2**
Specific driver: technological and economical change	**2**
Specific driver: nutrients	**3**
Further aspects	**5**

Table 9 shows that the number of studies addressing potential developments in society is quite large. However, only in a few cases implications of the predicted developments on emerging pollutants are mentioned explicitly. More frequently general predictions can be found, e.g. regarding future water consumption, food production and consumption behaviour. In some cases it is possible to use these general predictions to draw conclusions on potential future developments of contaminants (e.g. increase of older people and increase in the amount of pharmaceutical use).

The described emerging pollutants named in chapter 4 are linked with the scenarios which will be explained in the next chapters. The most important sectors which are related with EPs are the Chemical, Agriculture and the Pharmaceutical industry.

Up to now, the implications of the increasing distributions of EPs is just poorly discussed.

In the following sections, most important developments in climate, society and technology are described which are predicted in a broad range of scenarios. Indications for connections between these developments and pollutants of tomorrow are discussed. The developments refer to the following changes:

- **Climate change (see section 5.1);**
- **Demographic change in Europe (see section 5.2);**
- **World population growth (see section 5.3);**
- **Technological changes (see section 5.4).**

5.1 Climate Change

Climate change is one of the most intensively discussed future developments. Main references are the emission scenarios published by the Intergovernmental Panel on Climate Change *(IPCC)*, IPCC Working Group III *(IPCC 2013)*. A significant number of scientists agreed, that temperature has risen exceptionally during the past 15-20 years, in air *(Tett et al., 1999)* and also in water *(Barnett et al., 2005)*. Probably there will be consequences for the hydrological system *(Zhang et al.,2007)* and also for the climatic system. Figure 3 shows the observed global change in surface temperature from 1901 – 2012.

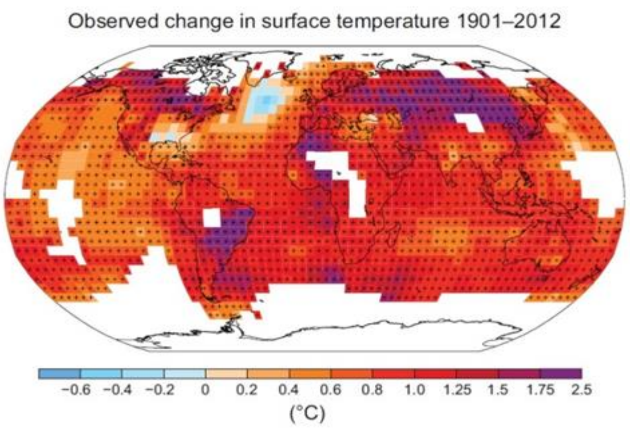

Figure 3 IPCC: Change in surface temperature due to climate change (Stocker & Qin, 2013)

„Climate change is an increasingly urgent problem with potentially far reaching consequences for life on earth and also reports unequivocal global warming with evidence of increases in global mean air and ocean temperatures, widespread snow and ice melt, and rising global sea level" (Noyes et al., 2009). Additionally some regions, like North and South America, Northern Europe, and northern and central Asia are projected that precipitation will increase. Africa and Asia and also the Mediterranean, are expected to have more and more substantial droughts *(Noyes et al., 2009).* Also extreme weather events will rise within droughts and floods with torrential rainfalls, periods with high temperature and storm events *(McMichael, Woodruff, & Hales, 2006) (Böhme, Krüger, Ockenfeld, & Geller, 2002)* Figure 4 shows the number of people affected by extreme weather events. Figure 5 shows the impacts of climate change on ecosystems and also the direct impacts on biota. These impacts affect the transport, the transfer between compartments of the ecosystems and also the transformation of contaminants. The most important topics will be insight in droughts, floods and water scarcity affect the behaviour of contaminants in water.

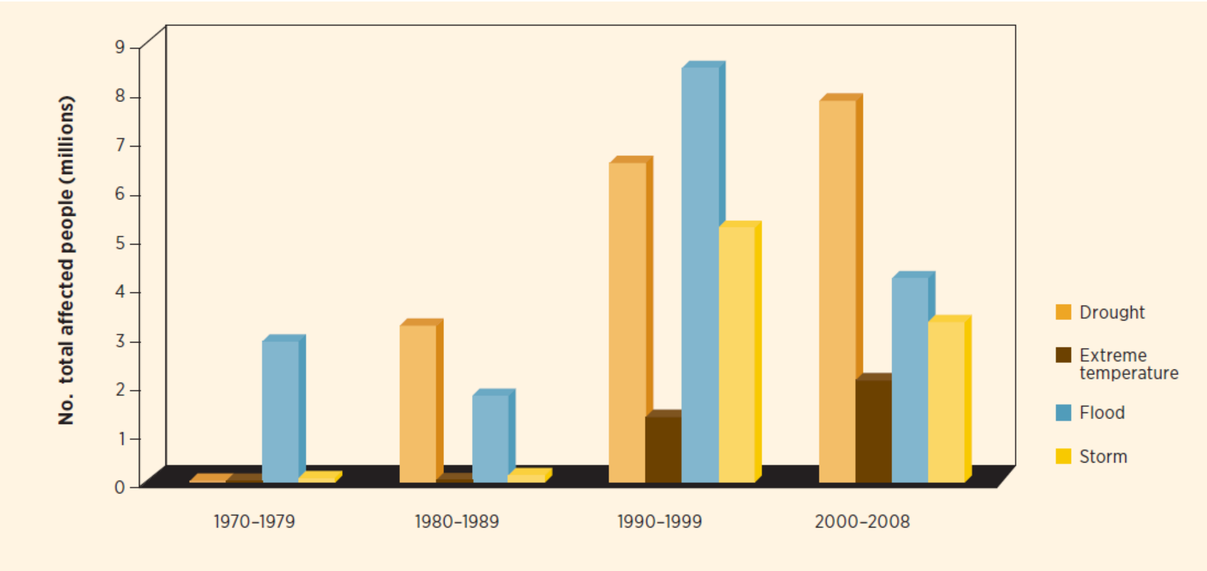

Figure 4 Number of people affected by extreme weather events in the UNECE region between 1970-2008 *(UNESCO, 2012)*

These developments can be seen in the Mediterranean basin. *Barceló and Sabater 2010* claimed that the Mediterranean *„is one of the world's regions most vulnerable to global change"*. *Giorgi and Lionello 2008* predict that this region is one of the most important regions where oncoming problems in water availability could be seen. IPCC forecasts that this region will have increasing temperature in summer, more droughts and also stronger rainfall. *Calbó 2010* also predicts that the average river discharge will decrease. Water temperature and the frequency of large floods will increase in future *(Calbó 2010)*. In 1999 *Gasith and Resh* found out that typical characteristics of rivers under Mediterranean climate have/ will have low water flow in summer, but large floods in autumn and winter. Therefore we think that this scenario could be taken for other worldwide hydrological scenarios. Droughts and floods, water scarcity, changing in water temperature and also storm intensity will have consequences on the occurrence of EPs.

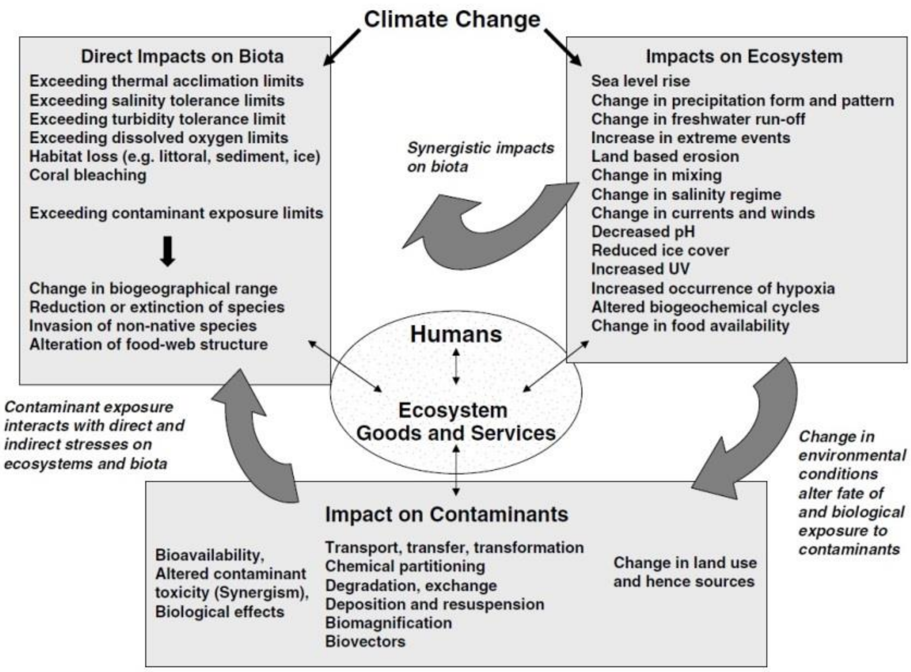

Figure 5 Overview of climate change impacts on ecosystem and biota (Schiedek, Sundelin, Readman, & Macdonald, 2007)

Noyes et al., 2009 predict that *„Climate change will have a powerful effect on the environmental fate and behavior of chemical toxicant*". As it can be seen in Figure 5 there are a lot of biotic and abiotic factors influencing the behavior of chemicals. Further abiotic and biotic factors are physical, chemical, and biological drivers of reaction and exchange between the atmosphere, water, soil/sediment, and also biota. Examples are air-surface exchange, wet/dry deposition, and reaction rates as photolysis, biodegradation or oxidation

in air *(Noyes et al., 2009). Schmitt- Jansen et al., 2007, Buser H. et al., 1998 and Schneider, 2004,* predict that solar irradiations have impacts to some pharmaceuticals as Diclofenac, Ibuprofen or the X-Ray contrast medium Iopromid. Example phototransformation of the anti- inflammatory drug Diclofenac: *Schneider, 2004* found out, that the phototransformation substances of Diclofenac, 8-Chlorcarbazol-or-8 Hydroxycarbazol Derivate or Diphenylamin-derivate, are more stable than Diclofenac *(Agüera et al., 2005)*. The most negative aspect is that phototransformation products mostly are more toxic than Diclofenac itself for e.g. *Scenedesmus vacuolatus.*
(*Schmitt- Jansen et al., 2007).* In addition*, Schmitt- Jansen et al., 2007*, found out, that there are several photolysis products produced under UV-light.
The number of pollutants is large, since the chemical reaction of chemicals can be manifold and extensive. However there is a link between droughts, water scarcity and its linkage to pollutants in water. In the following the main consequences of climate change relating to emerging pollutants will be described. Figure 5 shows the increasing numbers of these change impacts.

Consequences of water scarcity and droughts

The European Commission distinguish between water scarcity and droughts. Due to climate change upcoming weather extremes will increase.

„Water scarcity occurs where there are insufficient water resources to satisfy long-term average requirements. It refers to long-term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system. "
„Droughts can be considered as a temporary decrease of the average water availability due to e.g. rainfall deficiency. Droughts can occur anywhere in Europe, in both high and low rainfall areas and in any seasons. The impact of droughts can be exacerbated when they occur in a region with low water resources or where water resources are not being properly managed resulting in imbalances between water demands and the supply capacity of the natural system."

Water scarcity will increase and also expected droughts. This development could have negative impacts to the flow river regime *(Barceló & Sabater, 2010)* and also for the chemical quality of water systems *(Navarro-Ortega, Sabater, & Barceló, 2012). Muñoz et al., 2009* discovered that water has a high concentration of nutrients, pesticides, surfactants, pharmaceuticals, and estrogenic compounds if there is available scarcity. *„During droughts,* *dilution capacity decreases, increasing the risk of pollutants in the environment, which might affect the functioning of the river ecosystem" (Navarro-Ortega, Acuña, et al., 2012) (Navarro-Ortega, Sabater, et al., 2012)* found out that because of pollutant inflows the nutrient and pollutant concentrations will rise under lower water river flows. At present this is urgent in arid or semi- arid regions as the Mediterranean basin. But in future it could be an intense problem for other regions of the world. So the only river flow would arise through treated sewage effluents like nowadays in the tested area of the SCARCE project *(SCARCE CONSOLIDER)*. In addition, due to water scarcity and droughts, in arid regions the contaminants could be concentrated in river waters. Increasing of this problem it will get a risk for the environment *(Navarro-Ortega, Tauler, Lacorte, & Barceló, 2010).* Water is still used for drinking purposes and agriculture. But if water scarcity will increase, wastewaters must being reused for these applications. This development could increase and chemical compounds might be transported from waste water treatment plants to river waters. There they affect the chemical and biological quality of these waters *(Navarro-Ortega, Sabater, et al., 2012) (Barceló & Sabater, 2010).* This would have a negative impact for the hydrological cycle. It is expected that this will lead to more dissemination of pollution, because the required purification of emerging pollutants in waste water before reuse often does not take place.

Not only water scarcity and droughts will affect water quality. Also storm intensity will increase because of climate change. Because of storm intensity and torrential rainfalls, floods can get common in river systems as droughts.

Consequences of torrential rainfalls and floods

Extreme weather events like rainfalls will affect river flows as well. *Whitehead et al., 2009* identified, that rivers will react with an increase change of the streampower. Sediments can be deposited to lakes and have a big impact to freshwater habitants like lakes or streams. Beside to that, the scientists found out, that it is possible that rainfall changes will affect the mobility and the dilution of contaminants in rivers. The dilution characteristic is the other way around as described for Consequences of droughts. Dangerous floodplains are expected within possible flooding of sewage plants or extruded agriculture land. Pesticides or other contaminants could be mobilized and washed away to surface water. As an example *Chiovarou and Siewicki 2007* measured the two insecticides Carbayl and Imidacloprid. Chemical contamination of aquatic systems during storms have been of different intensity. It has been found that the concentrations of both insecticides increase with increasing storm intensity *(Noyes et al., 2009).*

But flooding implicates also another risk. Contaminated water can deposit pollutants to agriculture land. Therefore it is necessary to consider both sides. Productive livestock or agriculture plants could absorb these contaminants *(Böhme et al., 2002)*. That would be one way for EPs to enter in food chain by depositing on sediments.

In summary it can be concluded, that floods and droughts would have negative impacts. In an Interview, *Tümpling 2014 (Zentrum für Umweltforschung)* predicts, that the amount of precipitation will almost stay constant for Germany. But the length of dry spells and also intense rains will increase. For this reason the increase of low water line and also flooding in many regions is predicted, leading to an increase of the amount of water required for agriculture lands during dry spells. Water must be withdrawn out of the rivers which have a low water line. At the same time the quantity of waste water entering river systems will not decrease, because the frequency using the shower, toilet, washing will stay constant. One possible risk is that the amount of waste water during low water line will increase. As a consequence, the concentrations of EPs increase as described before. *Navarro- Ortega et al., 2010* predict that *„urban, industrial and agricultural activities release a cocktail of compounds of toxicological relevance, such as pesticides (Fernández et al., 1999), surfactants (Ying et al., 2002) and hydrocarbons" (Tolosa et al., 1996)* and others. *Tümpling* added that it can become more difficult to meet the objectives of the Water Framework Directive.

<u>Consequences of elevated water temperatures</u>

Barcelo et al., 2010 predict that it is possible that under climate change temperature in low river flow conditions will increase. This can lead to a synergetic effect: increasing amounts of emerging pollutants and also rising water temperatures. Wildlife will suffer from this second stress facto, together with multiple other stress factors, life in water will suffer from a so called "cocktail effect" in future.

Climate change can have further manifold implications on terrestrial and aquatic ecosystems. A constant increase of surface water temperature can alter or influence the environmental fate of chemicals, e.g. bioaccumulation, degradability and mobility. Due to these changes, the exposure of biota to these contaminants can change. Elevated water temperatures may alter the biotransformation of contaminants to more bioactive metabolites and impair homeostasis and also the toxicity of contaminants may be enhanced with increasing temperatures *(Boone and Bridges, 1999; Capkin et al., 2006; Gaunt and Barker, 2000; Silbergeld, 1973) (Noyes et al., 2009)*. *Schiedek et al., 2007* described that higher water *„temperature has long been known to modify the chemistry of a number of pollutants resulting in significant alterations in their toxicities e.g. for fish".*

Higher water temperature is a further stressor for water living animals. Consequently this will influence the uptake rate of pollutants by higher ventilation and the metabolic rate e.g. in fish *(Kennedy and Walsh, 1997)*. Another example for a synergetic effect is described for the Baltic *„amphitod Monopreia affinis react with temperature and the fungicide fenarimol with in increased numbers of females with dead eggs" (Schiedek et al., 2007).*

A further overview about the interactions between various classes of chemicals and different environmental factors as temperature in aquatic organisms can be looked up in (*Heugens et al., 2001) (Schiedek et al., 2007).*

5.2 Demographic Change in Europe

According to predictions for the next 40 years, total population in Europe will stay constant. For Germany, a reduction of population is predicted (from 82 million in 2005 to 72 million inhabitants in 2050). Figure 6 shows the demographic development in Germany *(Prognos & Öko-Institut, 2009), (DESTATIS, 2011).* Also *(bpb 2011)* predict the same scenario for whole Europe.

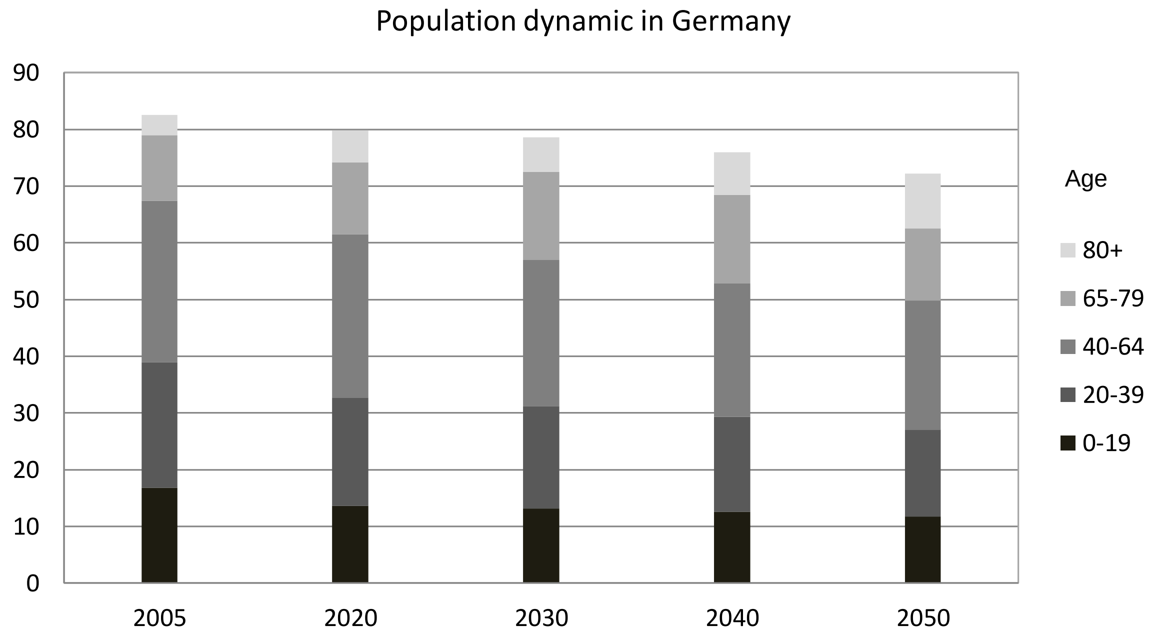

Figure 6 Total Population and its Demographic change in Germany until the year 2050 in millions (Prognos & Öko- Institut, 2009)

Figure 6 shows the decrease of the total population, an increase of people between 65 years and older, and a nearly unchanging trend of youths and children in the age from 0-19. The numbers in the age group between 20- 39 years and 40- 64 years diminish continuously. The group of 65-79 years old people will grow until the year 2040 and then decrease slowly while the 80 years old generation will grow. *(Berkermann et al., 2007)* prognosticate that the growth of people older than 65 will have an increase by 38% until 2030 while the people under 20 years old will have a decrease by 17 % until 2030 *(Sigman, Henk, Natahlie, Nils Axel, & Xavier, 2012).* As a consequnece diseases which are typical for elderly people as heart- circulation disease, cancer or diabetes will increase *(Schwabe & Paffrath, 2013).* This development will induce many changes in the health system. *Berkermann et al., 2007,* predict that there will be an increasing demand for pharmaceuticals with increasing mean age.

This could have been several implications for future emerging pollutants mainly pharmaceuticals. As described in chapter 4.1 pharmaceuticals can have negative impacts to ecosystems. To have a high expectation of life, elderly people will need more pharmaceuticals *(Sueddeutsche, 2010).* It is foreseeable that the consumption of pharmaceuticals will increase mostly in hospitals *(Pinnekamp, 2013)* and elderly homes, but also in privately owned-homes. Many pharmaceuticals are named from NORMAN (List of Emerging Contaminants) and in Table 2 as emerging pollutants. Pharmaceuticals like Lipidregulators (e.g. Bezafibrates) or antiinflammatory (e.g. diclofenac) are mainly used by elderly people *(Schwabe & Paffrath, 2013)*. Other widely-used groups will be diabetic medicaments *(Berkermann et al., 2007)* and antibiotics, also mainly used from elderly people. X-ray contrast medium and Antineoplastics used in chemotherapy are further examples for groups of pharmaceuticals mostly consumed in hospitals but also in practical surgeries *(Heberer, 2002)*. It is reasonable to assume that the consumption of these pharmaceuticals will further increase. *SauberPlus* (Table 5) and *Berkermann et al., 2007* both predict that demographic change and pharmaceuticals consumption is linked together. Because of their structure, several of these substances are difficult to remove from waste water. They can enter aquatic and terrestrial ecosystems *(Heberer, 2002)* and even in small concentrations drinking water *(Kümmerer et al., 2008).*

5.3 World population growth and urbanization

In 2050 world population is projected to grow to 8.9 billion *(UN, 2004)*. The world population is mainly growing in developing countries such as Africa, South America and Asia. Figure 7 shows the expected areas of population growth and decline between 2000- 2080. The trend of a declining population in Europe is noticeable (mentioned in chapter 5.2 (Demographic change)). Due to population growth it is conspicuous that the number of inhabitants in big cities will increase rapidly. In 1975 only 38 % of the world population lived in cities. Presently around 50% are living in cities and in 2030 around two- thirds of the global population are predicted to live in cities *(United Nations, 2009).* UNESCO forecasts that 60 % will live in cities in 2030 *(UNESCO, 2003).*

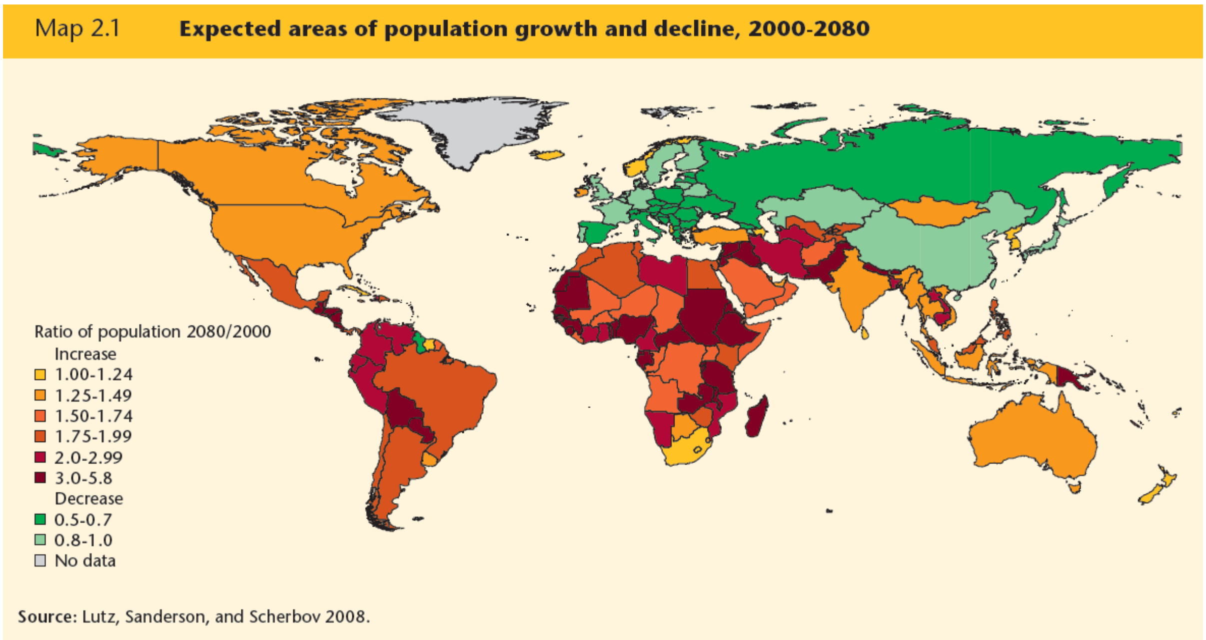

Figure 7 Population in major areas, estimates and medium scenarios: 2000-2080 (UNESCO & Earthscan, 2009)

This phenomenon is called urbanization and will entail many problems for the environment. In the following the linkage and impacts of urbanization on EPs will be described.

Problems as waste water, -waste management and also traffic regulation in cities will gain in importance. Urban development means also an increase of ground sealing which have negative impacts for environment. It is *„accompanied by the transformation of natural land surfaces into impervious surfaces, such as streets, parking lots, roofs and other types of structures that block the percolation of rainwater and snowmelt into soil" (UNESCO & Earthscan, 2009).* UNESCO and Earthscan 2009 predict that these constructions can have dangerous impacts as an *„intense flow of water over the land, carrying polluting materials into receiving water systems, degrading water quality and causing local pollution problems".* Ground sealing can increase the frequency and intensity of floods. Floods can transport pesticides, surfactants, pharmaceuticals and other emerging pollutants to river systems *(Fernández et al., 1999, Ying et al., 2002, Tolosa et al., 1996)* (see also chapter 5.1).

Urbanization requires a well managing of waste water. Waste water can create pressure on local freshwater *(UNESCO & Earthscan, 2009).* Purification systems are very important to get a good water quality. Increase of population results in an increase in waste water volume. Integrated management of the water system for households and industry is needed. A good waste water treatment, decrease of pollution, conduction of rainfall and prevention against floods are necessary for a well-planned management in cities *(UNESCO, 2003).*

Another important topic in big cities is waste management *(UNEP, 2012).* Waste and waste dumps are already gearing up towards becoming major problems. It cannot be assumed that suitable waste management will be in place on a global scale. In this situation, disposal flows with emerging pollutants such as plasticizer or deposits from pharmaceuticals can directly enter ecosystems and surface water *(UNESCO & Earthscan, 2009).*

Furthermore it is necessary to manage food production for covering nutrition of a growing world population. By increasing sustainable agriculture *(EEA, 2005)* with a reduced use of pesticides and its management. The major source of aliment provision comes from agriculture within farming, cattle breeding, aquaculture and forestry *(UNESCO, 2003).* Therefore water management adjusts one of the biggest challenges for this development. As mentioned before it would be important to pay attention for the water quality. By reusing sewage water a future circulation of agrochemicals and other emerging pollutants is expected in regions with water scarcity (see chapter 5.1).

Another point is that Megacities are likely to cause major changes in the lifestyles of the inhabitants. *„The age of the population will influence the consumption, ,,production patterns" and behaviour (UNESCO & Earthscan, 2009).* E.g., plastic packaging is putting forward a source of EPs. Also higher consumptions of human care products, pharmaceuticals and probably of food additives are foreseen in cities due to urbanization *(UNESCO & Earthscan, 2009 Part 1, Chapter 2).*

5.4 Technological changes

Technological developments take place in a large number of sectors continuously. New products or new functions of existing products are generated. In many cases, these changes become possible due to the use of specific substances. Permanent water resistance of outdoor textiles is an example for such a functionality.It has been realized with the use of per- and polyfluorinated chemicals (PFCs) *(Greenpeace e.V. 2012).* Such new developments can cause new contaminations of surface water, if these substances are released during production, service life, recycling, reuse or disposal of the products. Therefore future technological changes can lead to new and also more emerging pollutants.

Technological developments can take place in all branches. They are difficult to predict. In the following sections some examples are given for pollutants which are emerging due to changes in technology. Two cases can be distinguished:

- Substitution of problematic substances due to regulation
- Technological developments with new uses of chemicals and materials

5.4.1 Substitution of problematic substances due to regulation

An important driver for future emerging pollutants is the substitution of problematic substances by substances with similar emission behaviour. Phthalate used as plasticizers are a well-known example. As mentioned before (Chapter 4.2.2) plasticisers are used for many daily life products e.g. plasticized PVC, packaging and sport articles *(BMUB, 2009)*.

Recent monitoring studies show an increase in concentrations of phthalates (diisononyl phthalate (DINP) and diisodecyl phthalate DIDP)), used as substitutes for phthalates which have been restricted by law (LfU, 2012 and UBA, 2007). The regulation of phthalates under REACH has been shown in Table 4. Substitutes for DEHP are DEHT, DINCH, DOZ or TEHTM *(Brutus, Calero, Corden, Esparrago, & Mackay, 2013).* But also these substances have to be assessed carefully. It has been found that these substances have data gaps for neurotoxicity, endocrine activity or cancer *(Becke* *r, 2013)*. *Brutus et al., 2013* report that there are even naturally substitutes as bio plastics derived from renewable biomass sources (e.g. vegetable oils).

Similarly, long-chain per- and polyfluorinated hydrocarbons (PFCs) are replaced by short-chain 2- 4 PCFs (*(Greenpeace e.V. 2012)* and *(UBA, 2009))* – which are already detected in the environment in increasing concentrations *(Benskin et al., 2012)*. Some of these substances are bio accumulative, some are persistent, and some are toxic for humans and/or biota as described in chapter 4.2.3. *(Farre et al., 2008)*.

These "new" phthalates and short chain PFCs are not yet all regulated under a legal framework such as REACH. Therefore producers can place these critical substances on the market.

The third group of substitutes belongs to the group of flame retardants. Hexabromobenzene (HBB) and bis (2, 4, 6-tribromphenoxy) ethene (BTBPE) are newly emerging pollutants - and substitutes for polybrominated biphenyls. These substitutes were recently found in surface waters as well as in wild animals *(Moskeland, 2010)*. The flame retardant Hexabromocyclododecane is another example of a substance for which substitutes can be expected in near future. As a persistent, bio accumulative and toxic substance, future use of HBCDD will be forbidden in the European Union after August 2015. The substance is listed in REACH Annex XIV. After this so- called "sunset date" a specific authorization is required for the use of HBCDD. For more details see the following subsection *(ECHA, webpage)*.

5.4.2 Technological developments with new uses of chemicals

Substances for insulation

Some substances used for insulation materials are already emerging pollutants according to the NORMAN list. Examples are HBCDD Hexabromocyclododecane and biocides such as Terbutryn used as a Herbicide and 2-Octyl-2H-isothiazol-3-on, named in a Swiss study from Eawag *(Walser, Burkhard, Zuleg, & Boller, 2008).* These substances can be found in surface waters. Terbutryn can be released by rain water from insulation mats. It contaminates ground-, surface-, and drinking water. At present there is no purification method for these substances in waste water treatment plants. They are emitted to the receiving water bodies after the sewage treatment plants *(UBA, 2008).* Currently and until 2015 large amounts of HBCDD are allowed to be used in insulation materials for buildings *(UBA, 2008).*

These substances can become important future emerging pollutants, if buildings are replaced or renovated. This is likely to happen within the next 30-50 years. In a best case scenario, all the walls will be disposed as toxic waste. But if not, HBCDD and also Terbutryn from historical uses will contaminate ecosystems, groundwater and surface water for a long time even if the future use if forbidden due to REACH.

Substances used in convenience products

Another area with new technological developments are convenience products focused on lifestyle: convenience food or convenience in human care products *(Ziegler, Reitbauer, & Rizzo, 2007).* For these convenience products, substances as Sucralose or Triacetin are used as food additives and as aroma. This could increase the consumption of products containing these substances.

Two other factors supporting the application of sucralose and other sweetener are probably demographic change and also urbanization. As described in chapter 5.2 people getting older and suffering more under diseases as diabetic. Popular diabetic products are made with sucralose or other sweetener instead of sugar. This could increase the consumption of sucralose in future.

In addition, technological developments in packaging for human care products can lead to new EPs. It is assumed that industry aimes to make packaging more efficient (and maybe more biodegradable). Packaging of biodegradable substances could be more produced for a better environment *(UBA & Ifeu, 2012).* The use of future specific substances can be expected to fulfil these functional requirements. In addition it would be an advantage to produce more biodegradable or recycled materials to reduce the inputs of contaminants. Another trend of the society is and will be that Triclosan, *„professionally used as a biocide, but also in household products and cosmetics such as toothpastes, or in textiles* will be grow in application and will increase in surface water *(Ruedel, 2012)*.

Nanomaterials

The sector of nanotechnology is and will be a rapidly growing market. Nanomaterials are used in many sectors to produce human care products, medicine-, food- and packaging materials, UV-preservatives, building and construction- and other products. Figure 8 illustrates the broad use of some nanomaterials-/ particles for different product sectors.

It is expected that production and use of nanomaterials will grow further. Examples for nanomaterials with a high production volume are *(Moeller et al., 2013):*

- Carbon- Nano- Tubes (CNTs)
- Carbon black
- Titania (titanium dioxide)
- Ferrous oxide
- Silver
- Silica
- Zincoxide

Figure 8 from *Keller& Lazareva 2013* shows the estimated annual mass flow of some well-known engineered nanomaterials and their further lifecycle. The impacts of nanomaterials to the environment is a current important research topic.

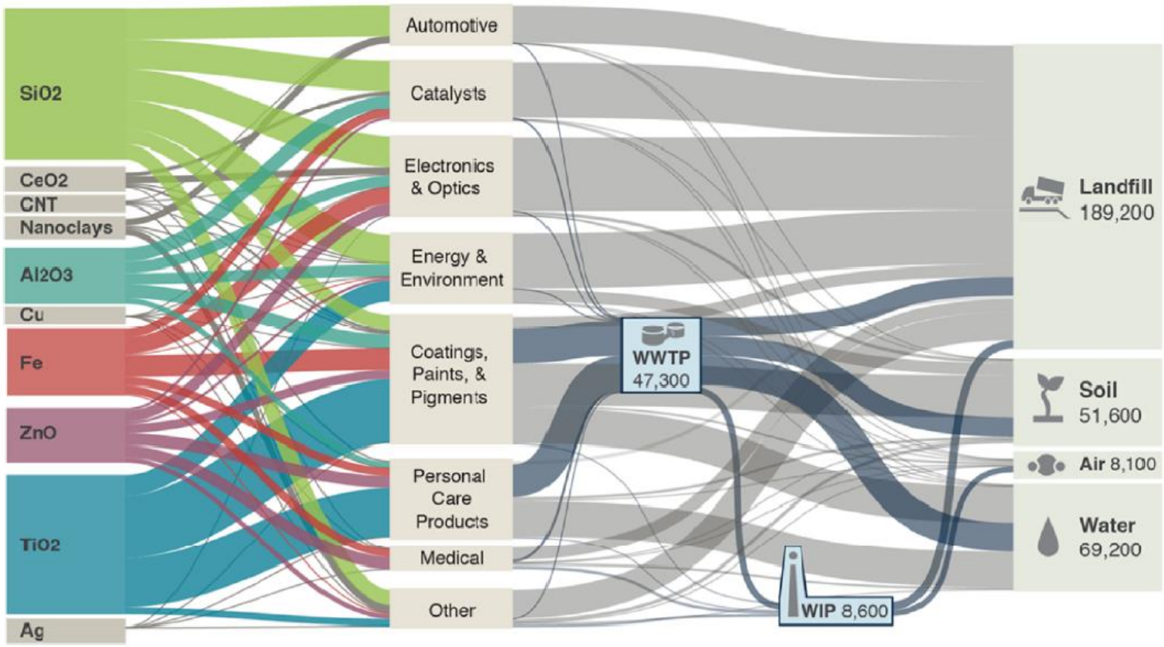

Figure 8 Estimated global mass flow of engineered nanomaterials (in metric tons per year) from production to disposal or release, considering high production and release estimates as of 2010. Source: (Keller & Lazareva, 2013)

Even if the major part of materials is deposited in landfills, a remarkable part of the total production is emitted to soil, air and water.

Due to the increasing use of Nanomaterials-/particles in different sectors, it can be expected that specific Nanomaterials-/ particles will be found as new emerging pollutants in surface water. Nanoparticles are spread *„ either to a wastewater stream and treatment or to a municipal solid waste handling " or in „ many other countries of the world wastewater is released with no treatment to canals and water bodies" (Keller & Lazareva, 2013)* . *Kaegi et al., 2008* also found out, that Nanoparticles as Titania can be washed out from house walls and enter surface waters in detectable concentrations. This was approved by *Mueller and Nowack 2008* within a simulation. With increasing relevance of nanomaterials the described impacts will gain importance in the future.

6 Conclusion

Future developments in society as well as in technology and also the climate change may have negative impacts on pollution. In this master thesis, 34 reports on developments in society (see Table 10) have been analysed regarding potential implications on future emerging pollutants. The analysis presented in chapter 5 leads to the conclusions, that it is possible – at least to a certain degree – to predict future EPs by such an analysis.

There are product groups from societal behaviours or technological changes which have robust indications for increased importance to pollution.

The demographic change could impair EPs in a negative way. Due to the higher life expectancy in the next decades, the amount of pharmaceuticals circulating in sewage treatplants and in the end in ecosystems will increase with high probability. The world population growth and ongoing urbanization will lead to an increase of the distribution of EPs in the environment. Relevant substances as pharmaceuticals, PFCs, phthalate or plastic substances could be mitigated in waste water or waste by appropriate waste water management procedures.

Future technological progress may enable to find suitable alternatives for currently used EPs as phthalates, PFCs, flame retardants or nanomaterials, but also these new substances might have negative impact on the ecosystem.

Climate change can influence the dissemination of EPs worldwide. It is difficult to analyse the behaviour of EPs in by influencing of climate change. But, since frequency and intensity of flood events, droughts or water scarcity will increase in future, these events can affect e.g. the dissemination of EPs in environment. These societal, technological or environmental changes can influence EPs in ecosystems and should be predicted by the following analysis.

To make future predictions for relevant EPs it would be useful to analyse and to list the toptwenty pharmaceuticals for older people regularly.

Additionally to the analysis of the demographic change also future human lifestyle would be necessary to know to predict future EPs.

To analyse more EPs it would be important to evaluate constantly the REACH candidate list, in which possible pollutants are named. Further on innovations in sectors related to chemicals could be evaluated more and unexpected areas as Fracking or Key enabling

Technologies are of high importance. As it can be seen there are some scenarios for which predictions on substances are difficult and not foreseeable.

There is no doubt, that more and more EPs are circulating in surface water and constitute a global pollution. The onset of such negative outcomes and their trends can already be observed today. The main groups of EPs, pharmaceuticals, industrial chemicals, consumption products, pesticides, biocides and nanomaterials were analysed in this master thesis. By evaluation more than 140 publications and, three interviews, a detailed overview of EPs and its impact to environment was established. For each group of EP the first detection, production, use, entering to ecosystems and ecotoxicology were analysed. Every group of chemicals has negative impacts and pose a threat to environment and also to humans. But in summary it is not yet clear which EPs have the most negative impacts on the environment. Since this is not clear whether an adequate basis exists for the outcomes of ecotoxicology, it should assume that the most negative effect is that there is a cocktail effect of all chemicals together.

7 Outlook

The developments of future pollutants and their effects, described in chapter 5, could be mitigated with political, societal and technical efforts. In the following an outlook on these efforts is given based on the literature review within this work (see references in chapter 9 and studies in Table 10). In summary it can be emphasised that without a critical thinking and a rethinking of economy, growth and environmental protection the pollution will not be mitigated.

To achieve a better research control of emerging pollutants, important challenges in science should be considered and approached in future. The literature analysis presented within this work revealed the poor knowledge about the behaviour and ecotoxicology of all the transformation products *(Schirmer et al., 2011). Marinel La Farré et al., 2008* found out that, *„there is a lack of ecotoxicological information about some groups of emerging pollutants, but there is particularly a lack of knowledge of the effects that can be produced in the receiving environments by their metabolites and Transformation products".* In addition, as mentionend before, *(Agüera et al., 2005)* and *(Schneider et al., 2004)* statet that transformation products can be more toxic as the base substance.

The behaviour of chemicals in all environmental compartments as soil, air and water and the different between the substances (see also Figure 5) should be observed. For instance, *(Schiedek et al., 2007)* found out, that the behaviour of chemicals in air, water and soil are interlocked and should be more considered.

An EP in the soil surface can bind to aerosol through raising dust, or through rainout deposit into water. The other way around, an EP in water can go through volatilisation to the air and than being deposited to soil through rainout.

Additionally sustainable chemistry in production should be strengthened to mitigate the hazardous substances in ecosystems since fast biodegradable chemicals have only minor impact on their surrounding *(K.Kümmerer; University Lüneburg Institute for sustainable chemistry).*

The government of Denmark published a report with the title "Chemicals action plan 2010-2013, Safety in Denmark" *(Government of Denmark, 2010)*. In this report the Danish government expresses its intention to reinforce the transition to sustainable chemicals. For example the goverance wants to improve the research by focusing on endocrine disruptors and the cocktail effect, also fostering more monitoring and inspection and *„Intensive studies* *of chemicals in consumer products will continue and there will be active communication to the consumers"*. This action plan could be taken as a basis for other countries.

It can added that wastewater treatment should be upgraded in centralized sewage plants. Sewage plants as in the project SchussenAktivPlus[4] should multipresent promoted and also implemented. In addition it should be obligatory and statutory, that localized treatment facilities are situated directly in hospitals and in homes for the elderly where high medication occurs. Gathering and restraining these substances would cause more effort, but the gathered substances could be disposed in a proper way. These development would significantly contribute to a better water quality.

To achieve better prediction of future pollution, working groups[5] are modelling the dissemination of pollutants while forecasting the circulation of pollutants. For an overview about the pollutants in surface water, projects as RISK-IDENT or NORMAN compile an EU-wide database. They also research on better analytical systems which can analyse pollutants in an evermore accurate determination. Reducing the amount of EPs in the environment requires to mitigate the release of pollutants at the source: e.g. cosmetic industries, galvanic industry, ,application of biocides and pesticides, handling of nanomaterials.

Particularly with regard to regions with a high population and industry density, the avoidance of emissions of pollutants would be necessary to achieve a sustainable protection of the quality of drinking water *(Bergmann, A. et al., 2011).*

With all these developments and changes in politics, technology and science it is possible to reduce future EPs in environment. If it is assumed that the scenarios described in chapter 5 will occur it would be possible to predict the impact of these changes in society, climate and technology on the occurrence of EPs. Modelling could make an important contribution to predict future EPs in surface water and the environment.

Last but not least it should be mentionend that changes in politics, technology, human behavior, habits and an increasing public awareness for a more sustainable lifestyle could contribute to the mitigation of EPs in surface water. In the end while the directives (chapter 2.3) should be more tightend and adhered all over the world, a better water quality would be accrued within a better appreciation for the environment and human health.

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[4] http://www.schussenaktivplus.de/ (received 25.03.2014) SchussenAktivplus: reduction of micropollutants and of potentially pathogenic bacteria for further water quality improvement of the river Schussen, a tributary of Lake Constance, Germany

[5] http://fate.jrc.ec.europa.eu/modelling/chemic als (received 25.03.2014); RISK IDENT

8 Bibliography: references, personal communications, abstracts

Agüera, A., Pérez Estrada, L. A., Ferrer, I., Thurman, E. M., Malato, S., & Fernández-Alba, A. R. (2005). Application of time-of-flight mass spectrometry to the analysis of phototransformation products of diclofenac in water under natural sunlight. *Journal of Mass Spectrometry*, *40*(7), 908-915.

Aitken, Robert J., et al., 2008, Engineered Nanoparticles: Review of Health and Environmental Safety (ENRHES). Final Report.

Barceló, D., & Sabater, S. (2010). Water quality and assessment under scarcity: Prospects and challenges in Mediterranean watersheds. Journal of Hydrology, 383(1-2), 1–4.

Becker, M. (2013). Green Chemistry and Commerce Council.Chemical Hazard Assessments of Alternative Plasticizers for Wire & Cable Applications.

Behra, R. (2009). Sythetische Nanopartikel und ihre Wirkung. EAWAG News, 67 d, 22–24.

Benskin, J. P., Muir, D. C. G., Scott, B. F., Spencer, C., De Silva, A. O., Kylin, H., … Yamashita, N. (2012). Perfluoroalkyl acids in the Atlantic and Canadian Arctic Oceans. Environmental Science & Technology, 46(11), 5815–23.

Bergmann, A. (2011). Organische Spurenstoffe im Wasserkreislauf (acatech Materialien Nr. 12).Rheinisch westfälisches Institut für Wasser.München.

Berkermann, U., Eckert-Kömen, J., Heffels, A., Kramer-Huber, K., Matuschke, M., & Steiner, M. (2007). Die Gesundheitsbranche : Dynamisches Wachstum im Spannungs- feld von Innovation und Intervention (p. 63).

BLAC (1999) Bund/Länderausschuss für Chemikaliensicherheit. Arzneimittel in Untersuchungsprogramm. Hamburg. 1-41.

BLAC (2003) Bund/Länderausschuss für Chemikaliensicherheit. Arzneimittel in der Umwelt - Auswertung der Untersuchungsergebnisse. Freie und Hansestadt Hamburg - Behörde für Umwelt und Gesundheit. Bericht an die 61. Umweltministerkonferenz (UMK) am 19./20. November 2003 in Hamburg; Publikationsfreigabe durch die 32. Amtschefkonferenz (ACK) am 06. November 2003 in Berlin. 1-173

BMLEV. (2008). Nationaler Aktionsplan zur nachhaltigen Anwendung von Pflanzenschutzmitteln (p. 75). Bonn.

BMUB. (2009). BMU - Gesundheit und Umwelt - Chemikaliensicherheit - Phthalate. Retrieved February 07, 2014, from http://www.bmub.bund.de/themen/gesundheit-chemikalien/gesundheit-und-umwelt/chemikaliensicherheit/phthalate/

Böhme, M., Krüger, F., Ockenfeld, K., & Geller, W. (2002). Elbe-Hochwasser 2002 Schadstoffbelastung nach dem Elbe Hochwasser 2002.

Bornehag, C. G., Sundell, J., Weschler, C. J., Sigsgaard, T., Lundgren, B., Hasselgren, M., & Hägerhed-Engman, L. (2004). The association between asthma and allergic symptoms in children and phthalates in house dust: a nested case-control study. Environmental health perspectives, 1393-1397.

Boxall, A. B. A. (2012). New and Emerging Water Pollutants arising from Agriculture (p. 49). York.

Bpb. (n.d.). Bevölkerungsentwicklung und Altersstruktur | bpb. Retrieved 23.01.2014 from http://www.bpb.de/nachschlagen/zahlen-und-fakten/soziale-situation-in-deutschland/61541/altersstruktur

Brunn, H. & Rimkus, G.G. (1997) Synthetische Moschusduftstoffe - Anwendung, Anreicherung in der Umwelt und Toxiko- logie. Teil 2: Toxikologie der synthetischen Moschusduftstoffe und Schlußfolgerungen. Ernährungs-Umschau, 44, 4-9.

Brutus, J., Calero, J., Corden, C., Esparrago, J., & Mackay, C. (2013). RIVM.Dutch National Institute for Public Health and the Environment. Analysis of alternatives for a group of phthalates. Final Report (p. 134). London.

Bucheli T.D., Müller S.R., Voegelin A., Schwarzenbach R.P. (1998): Bituminous roof sealing membranes as major sources of the herbicide (R,S) -mecoprop in roof runoff waters: potential contamination of groundwater and surface waters. Environmental Science & Technology 32, 3465–3471.

Burkhardt, M., Junghans, M., Zuleeg, S., Boller, M., Schoknecht, U., Lamani, X. & Simmler, H. (2009). Biozide in Gebäudefassaden–ökotoxikologische Effekte, Auswaschung und Belastungsabschätzung für Gewässer. Umweltwissenschaften und Schadstoff-Forschung, 21(1), 36-47.

Cadogan, D. F., & Howick, C. J. (2012). Plasticizers. Ullmanns Encyclopedia of Industrial Chemistry, 27.

Chiovarou, ED, Siewicki, TC. Comparison of storm intensity and application timing on modeled transport and fate of six contaminants. Sci Total Environ 2007;389(1): 87-100

Christen, V., & Fent, P. K. (2009). Umweltforschungsplan des Bundesministeriums für Umwelt , Risk assessment of highly active human pharmaceuticals in the environment : Identification , development and application of a new concept for their identification, (August), 1–94.

Christen, V., & Fent, P. K. (2009). Umweltforschungsplan des Bundesministeriums für Umwelt , Risk assessment of highly active human pharmaceuticals in the environment : Identification , development and application of a new concept for their identification, (August), 1–94.

Daughton, C. G., Ternes, T. A. (1999). Pharmaceuticals and personal care products in the environment: agents of subtle change? Environ Health Perspect 107 Suppl 6, 907-938

DESTATIS. (2011). Demografischer Wandel in Deutschland.Bevölkerung- und Haushaltsentwicklung im Bund und in den Ländern (pp. 1–40).

Dulio, V. (2009). Network of reference laboratories for monitoring of environmental substances, (1), 1–22.

ECHA. (n.d.). Authorisation List - ECHA. Retrieved February 07, 2014, from http://www.echa.europa.eu/addressing-chemicals-of-concern/authorisation/recommendation-for-inclusion-in-the-authorisation-list/authorisation-list

ECPI. (2010). Plasticisers and Flexible PVC Information centre. European Council for Plasticizers and Intermediates. Retrieved January 23,2014, from http://www.plasticisers.org/

ECPI. (n.d.). Phthalates, Plasticisers and Flexible PVC Information Centre - Low Phthalates. Retrieved February 18, 2014, from http://www.plasticisers.org/en_GB/plasticisers/low-phthalates

Erythropel, H. C., Maric, M., & Cooper, D. G. (2012). Designing green plasticizers: influence of molecular geometry on biodegradation and plasticization properties. Chemosphere, 86(8), 759–66.

European Environment Agency. (2005). The European Environment.State and Outlook 2005. Copenhagen.

Exner, E., Seemann, S., Barjenbruch, M., Hinkelmann, R., & Nr, M. (2011). Wasserinstitutionen in Deutschland: Institutionen mit Verantwortlichkeiten für auf Wasser bezogene Aspekte, acatech Materialien Nr.13 (p. 45). München.

Farré, M. La, Pérez, S., Kantiani, L., & Barceló, D. (2008). Fate and toxicity of emerging pollutants, their metabolites and transformation products in the aquatic environment. TrAC Trends in Analytical Chemistry, 27(11), 991–1007.

Farré, M., Gajda-Schrantz, K., Kantiani, L., & Barceló, D. (2009). Ecotoxicity and analysis of nanomaterials in the aquatic environment. Analytical and Bioanalytical Chemistry, 393(1), 81–95. doi:10.1007/s00216-008-2458-1

Fent K.,Weston A.A., Caminada D. (2006): Ecotoxicology of human pharmaceuticals. Aquatic Toxicology 76 (2006). 122-159.

Fent K: Effects of pharmaceuticals to aquatic organisms. In Pharmaceuticals in the Environment. Kümmerer K. Hrsg. Berlin, New York: Springer Verlag; 2008:175-203.

Fernández, M.A., Alonso, C., González, M.J., Hernández, L.M., 1999. Occurrence of organochlorine insecticides, PCBs and PCB congeners in waters and sediments of the Ebro River (Spain). Chemosphere 38 (1), 33–43.

Fleeger, J.W., Carman, K.R., Nisbet, R.M., 2003. Indirect effects of contaminants in aquatic ecosystems. Sci. Total Environ. 317 (1–3), 207–233.

Fraunhofer UMSICHT. (n.d.). Grüne Woche biobasierte Weichmacher - Fraunhofer UMSICHT. Retrieved February 18, 2014, from http://www.umsicht.fraunhofer.de/de/presse-medien/pressemitteilungen/2014/gruene-woche-biobasierte-weichmacher.html

Fukuwatari, T., Suzuki, Y., Sugimoto, E., Shibata, K., 2002. Identification of a toxic mechanism of the plasticizers, phtahlic acid esters, which are putative endocrine disrupters: Time-dependent increase in quinolinic acid and its metabolites in rats fed di(2-ethylhexyl)phthalate. Biosci. Biotechnol. Biochem. 66, 2687–2691.

Garrison A.W., Pope J.D., Allen F.R. (1976): Analysis of organic compounds in domestic wastewater.In: Keith, C.H. 8Ed.), Idenification and Analysis of organic pollutants in water. Ann Arbor Science, Michigan, USA, 517-566.

Gerde P, Muggenburg BA, Lundborg M, Tesfaigzi Y, Dahl AR (2001): Respiratory epithelial penetration and clearance of par- ticle-borne benzo[a]pyrene. Res Rep Health Eff Inst 5–25

Giesy, J. P.; Kannan, K. Global Distribution of Perfluorooctane Sulfonate in Wildlife. Environ. Sci. Technol. 2001, 35, 1339- 1342.

Giorgi F, Lionello P (2008) Climate change projections for the Mediterranean region. Glob Planet Chang 63:90–104

Gonvernment of Denmark. (2010). Chemicals action plan 2010- 2013, Safety in Denmark- international cooperation (p. 41). Copenhagen.

Götz, K., Benzing, C., Deffner, J., Keil, F., Harder-Birzle, B., Strelau, L., & Siegl, C. (2011). Handbuch Kommunikationsstrategien zur Schärfung des Umweltbewusstseins im Umgang mit Arzneimitteln (p. 74).

Greenpeace e.V. (2012). Chemistry for any weather.Greenpeace tests outdoor clothes for perfluorinated toxins report.

Greßler, S., & Nentwich, M. (2012). Nano and Environment – Part II : Hazard potentials and risks (pp. 1–5).

Heberer, T. (2002). Occurrence, fate, and removal of pharmaceutical residues in the aquatic environment: a review of recent research data. Toxicology Letters, 131(1-2), 5–17. Retrieved 3 March 2014, from http://www.ncbi.nlm.nih.gov/pubmed/11988354

Heugens, E.H.W., Henriks, A.J., Dekker, T., van Straalen, N.M., Admiraal, W., 2001. A review on the effects of multiple stressors on aquatic organisms and analysis of uncertainty factors for use in risk assessment. Critical Review in Toxicology 31, 247–284.

Hölzer, J., Midasch, O., Rauchfuss, K., Kraft, M., Reupert, R., Angerer, J., Kleeschulte, P., Mar- schall, N., Wilhelm, M. (). Biomonitoring of per- fluorinated compounds in children and adults exposed to perfluorooctanoate-contaminated drinking water. Environ Health Perspect 2008; 116: 651-7

Horn, O., Nalli, S., Cooper, D., Nicell, J., 2004. Plasticizer metabolites in the environment. Water Res. 38, 3693–3698.

http://www.phthalate-frei.de/historie-der-phthalate; retrieved 18 February 2014

IKSR, CIPR, & ICBR. (2002). Auswertungsbericht Industriechemikalien (p. 10). Koblenz.

Jones, R.A. 2002, Soft condensed matter. Oxford University Press, New York.

Kaegi, R., Burkhardt, M., Sinnet, B., Boller, M. (2008): Nanoparticles detected in the runoff of an urban area, in: NanoEco – Nanoparticles in the Environment Implications and Applications. Book of Abstracts, Monte Verità, Ascona, Switzerland

Keller, A., & Lazareva, A. (2013). Predicted releases of engineered nanomaterials: From global to regional to local. Environmental Science & Technology

Keller, A., & Lazareva, A. (2013). Predicted releases of engineered nanomaterials: From global to regional to local. Environmental Science & Technology

Kennedy, C.J., Walsh, P.J., 1997. Effects of temperature on xenobiotic metabolism. In: Wood, C.M., McDonald, D.G. (Eds.), Global Warming – Implications for Freshwater and Marine Fish. Cambridge University Press, pp. 303–324.

Kern, K. (2004). Umweltauswirkungen von Arzneimitteln- Bestandsaufnahme und Reformbedarf (p. 26). Leipzig.

Kümmerer, K. (Hg.): Pharmaceuticals in the Environment. Springer, Heidelberg, New York 2008

Kortenkamp, Andreas 2012 et. al. State of the Art Assessment of Endocrine Disruptors. Final report.

Koschorreck, J., Lehmann, S., & Naulin, A. (2005). Arzneimittel in der Umwelt. Zu Risiken und Nebenwirkungen fragen Sie das Umweltbundesamt (p. 268). Dessau.

Krug, H. F. (2005). Auswirkungen nanotechnologischer Entwicklungen auf die Umwelt. Umweltchemie Oekotox, (Feynman 1960), 1–8.

Lange, F. T., Scheurer, M., & Brauch, H.-J. (2012). Artificial sweeteners--a recently recognized class of emerging environmental contaminants: a review. Analytical and Bioanalytical Chemistry, 403(9), 2503–2518.

LfU. (2012). Stoffinformationen zu besonders besorgniserregenden Stoffen. Phthalate.Bayrisches Landesamt für Umwelt.

Loos et al (2008). Sucralose screening in European surface waters using a solid-phase extraction-liquid chromatography–triple quadrupole mass spectrometry method. 2008)

Lyklema, J. 2005, “Pair Interactions” in Fundamentals of interface and colloid science, Volume IV, Particulate colloids, eds. Lyklema, J. Elsevier Academic Press, Amsterdam.

McMichael, A. J., Woodruff, R. E., & Hales, S. (2006). Climate change and human health: present and future risks. Lancet, 367(9513), 859–69.

Moeller M., Hermann A., Groß R., Diesner M.O., Küppers P., Luther W., Malanowski N., Haus D., Zweck A. (2013): Nanomaterialien: Auswirkungen auf Umwelt und Gesundheit. Ökoinstitut und Zentrum für Technologiefolgen Abschätzung. Zürich.

Moskeland, T. (2010). Environmental screening of selected new brominated flame retardants and selected polyfluorinated compounds 2009.

Møskeland, T. (2010). Environmental screening of selected” new” brominated flame retardants and selected polyfluorinated compounds 2009. Oslo, Klif.(TA 2625/2010).

Mueller, N. C., Nowack, B. (2008): Exposure Modeling of Engineered Nanoparticles in the Environment, Environmental Science & Technology, 42, 4447–4453.

Muñoz I, López-Doval JC, Ricart M, Villagrasa M, Brix R, Geiszinger A, Ginebreda A, Guasch H, López de Alda MJ, Romaní AM, Sabater S, Barceló D (2009) Bridging levels of pharmaceuticals in river water with biological community structure in the Llobregat River Basin (Northeast Spain). Environ Toxicol Chem 28:2706–2714

Navarro-Ortega, A., Acuña, V., Batalla, R. J., Blasco, J., Conde, C., Elorza, F. J., Barceló, D. (2012). Assessing and forecasting the impacts of global change on Mediterranean rivers. The SCARCE Consolider project on Iberian basins. Environmental Science and Pollution Research International, 19(4), 918–33.

Navarro-Ortega, A., Sabater, S., & Barceló, D. (2012). Understanding effects of global change on water quantity and quality in river basins - the SCARCE project. Environmental Science and Pollution Research International, 19(4), 915–7.

Navarro-Ortega, A., Tauler, R., Lacorte, S., & Barceló, D. (2010). Occurrence and transport of PAHs, pesticides and alkylphenols in sediment samples along the Ebro River Basin. Journal of Hydrology, 383(1-2), 5–17.

Neukum, C., Braun, A., & Azzam, R. (2012). Nanoflow.Mobilität synthetischer Nanopartikel im wassergesättigten und variabel wassergesättigten Untergrund (pp. 1–56).

Noyes, P. D., McElwee, M. K., Miller, H. D., Clark, B. W., Van Tiem, L. a, Walcott, K. C., Levin, E. D. (2009). The toxicology of climate change: environmental contaminants in a warming world. Environment international, 35(6), 971–86.

Noyes, P. D., McElwee, M. K., Miller, H. D., Clark, B. W., Van Tiem, L. a, Walcott, K. C., … Levin, E. D. (2009). The toxicology of climate change: environmental contaminants in a warming world. Environment International, 35(6), 971–86.

Oaks J.L.,Gilbert M., Virani M.Z., Watson R.T., Meteyer C.U., Rideout B.A., Shivaprasad H.L., Ahmed S., Chaudhry M.J.I., Arshrad M., Mahmood S., Ali A., Khan A.A. (2004): Diclofenac residues as the cause of vulture population decline in Pakistan. Nature 427 (6975), 630-633.

Pal, A., Gin K.Y., Lin, A.Y., Reinhard M. (2010): Impacts of emerging contaminants on freshwater resources: Review of recent occurences, sources, fate and effects. Science of the total environment 408 (2010).6062-6069.

Peck A.M. (2006). Analytical methods for the determination of persistent ingredients of personal care products in environmental matrices. Anal. Bioanal. Chem. 2006. 386(4):907-39

Peng, X., Li, Y., Luan, Z., Di, Z., Wang, H., Tian, B., Jia, Z. (2003): Adsorption of 1,2- dichlorobenzene from water to carbon nanotubes, Chemical Physics Letters, 376, 154–158.

Pinnekamp, J. (2013). Innovative Konzepte und Technologien für die separate Behandlung von Abwasser aus Einrichtungen des Gesundheitswesens (pp. 1–88).

PlasticsEurope. (2013). Plastics – the Facts 2013. An analysis of European latest plastics production , demand and waste data (p. 40). Bruessel. Retrieved 10 February 2014 from www.plasticseurope.org

Prevedouros, K., Cousins, I., Buck, R., & Korzenioski, S. (2006). Critical Review Sources , Fate and Transport of Perfluorocarboxylates. Environmental Science & Technology, 40(1).

Prognos, & Ökoinstitut. (2009). Modell Deutschland Klimaschutz bis 2050 (p. 533).

Richardson M.L., Bowron J.M. (1985): The fate of pharmaceutical chemicals in the aquatic environment. J. Pharm. Pharmacol. 37 (1), 1-12.

Richardson, S. D. (2008). Environmental mass spectrometry: emerging contaminants and current issues. Analytical Chemistry, 84(2), 747–78.

Richardson, S. D., & Ternes, T. a. (2005). Water analysis: emerging contaminants and current issues. Analytical Chemistry, 77(12), 3807–3838.

Richardson, S. D., & Ternes, T. a. (2007). Water analysis: emerging contaminants and current issues. Analytical Chemistry, 79(12), 4295–4324.

Richardson, S. D., & Ternes, T. a. (2011). Water analysis: emerging contaminants and current issues. Analytical Chemistry, 83(12), 4614–48.

Rimkus, G.G. & Wolf, M. (1993) Rückstände und Verunreinigungen in Fischen aus Aquakultur. 2. Mitteilung: Nachweis von Moschus Xylol und Moschus Keton in Fischen. Deutsche Lebensmittel-Rundschau, 89, 171-175

Rogers I.H., Birtwell I.K., Kruznyski G.M. (1986): Organic extractables in municipal wastewater of Vancouver, British Columbia. Water Pollutant Research J.Can.21,187-204.

Rote Liste® Service GmbH. 2012. Rote Liste, Arzneimittelverzeichnis für Deutschland (einschließlich EU-Zulassungen und bestimmter Medizinprodukte). Frankfurt/Main : Rote Liste® Service GmbH, 2012.

Ruedel, H. (2012). Environmental monitoring of biocides: an emerging issue? (pp. 3–4).

Rurainski, R.D., Theiss, H.J. & Zimmermann, W. (1977) Über das Vorkommen von natürlichen und synthetischen Östrogenen im Trinkwasser. GWF - Wasser/Abwasser, 118, 287-291

SCARCE (2013). Scarce newsletter Assessing and predicting the effects on water quantity and quality in Iberian Rivers caused by global change, (6), 1–8.

SCARCE CONSOLIDER. (n.d.). Retrieved January 31, 2014, from http://www.scarceconsolider.es/publica/P000Main.php

Scheurer, M., Brauch, H.-J., & Lange, F. T. (2009). Analysis and occurrence of seven artificial sweeteners in German waste water and surface water and in soil aquifer treatment (SAT). Analytical and Bioanalytical Chemistry, 394(6), 1585–1594.

Schiedek, D., Sundelin, B., Readman, J. W., & Macdonald, R. W. (2007). Interactions between climate change and contaminants. Marine pollution bulletin, 54(12), 1845–56.

Schiedek, D., Sundelin, B., Readman, J. W., & Macdonald, R. W. (2007). Interactions between climate change and contaminants. Marine Pollution Bulletin, 54(12), 1845–56

Schirmer, K. (2011). Wasserqualität.Sind Transformationsprodukte eine Umweltrisiko? EAWAG News, 70.

Schlumpf, Margret et. al 2001. In vitro and in vivo estrogenicity of UV screens. Environmental Health Perspectives, (2001) Vol. 109, No. 3, pp. 239-244

Schmitt-Jansen, M., Bartels, P., Adler, N., & Altenburger, R. (2007). Phytotoxicity assessment of diclofenac and its phototransformation products. Analytical and bioanalytical chemistry, 387(4), 1389-1396.

Schneider, C. (2004). Synthetische organische Spurenstoffe in der aquatischen Umwelt und ihr Verhalten im Klärprozess (p. 443). Stuttgart.

Schwabe, U., & Paffrath, D. (2013). Arzneiverordnungs-Report 2013.Aktuelle Daten,Kosten, Trends und Kommentare (p. 1148). Heidelberg: Springer.

Schwaiger J. Mallow U.& Ferling H. 2004. Ökotoxikologische Auswirkungen von Arzneimitteln Langzeitwirkungen bei Fischen; Endbericht zum Forschungsvorhaben 73e 040100 54/733. s.l. : Bayerisches Landesamt für Wasserwirtschaft, Abteilung Gewässerökologische Forschung, 2004.

Sigman, R., Henk, H., Natahlie, D., Nils Axel, B., & Xavier, L. (2012). Health and Environment, in OECD, OECD Environmental Outlook to 2050. Health: The Consequences of Inaction, OECD Publishing. (p. 60).

Stahl, T., Mattern, D., & Brunn, H. (2011). Toxicology of perfluorinated compounds. Environmental Sciences Europe, 23(1), 38.

Stan, H.-J., Heberer, T. & Linkerhägner, M. (1994) Vorkommen von Clofibrinsäure im aquatischen System – Führt die therapeutische Anwendung zu einer Belastung von Oberflächen-, Grund- und Trinkwasser? Vom Wasser, 83, 57-68

Stocker, T. F., & Qin, D. (2013). Climate Change 2013 The Physical Science Basis. Working Gruop I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policymakers.

Stocker, T. F., Dahe, Q., & Plattner, G. K. (2013). Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policymakers (IPCC, 2013).

Stockholm Convention. (2014). Listing of POPs in the Stockholm Convention. Retrieved February 20, 2014, from http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx

Stone, V., Hankin, S., Aitken, R., Aschberger, K., Baun, A., Christensen, F., & Tran, L. (2010). Engineered nanoparticles: Review of health and environmental safety (ENRHES). Project Final Report. European Commission.

Sueddeutsche. (2010). Entsorgung von Medikamenten - Folgen für Mensch und Umwelt. Retrieved January 31, 2014, from http://www.sueddeutsche.de/leben/entsorgung-von-medikamenten-medizin-fuer-die-tonne-1.150729-3

Ternes, T. A., & Knacker, T. (2003). Übersichtsbeiträge Körperpflegemittel in der aquatischen Umwelt, 15(3), 169–180.

Tolosa, I., Bayona, J.M., Albaiges, J., 1996. Aliphatic and polycyclic aromatic hydrocarbons and sulfur/oxygen derivatives in northwestern Mediterranean sediments: spatial and temporal variability, fluxes, and budgets. Environmental Science and Technology 30 (8), 2495–2503.

Triebskorn, R., Köhler, H. (2011).Vorlesungsfolien Einführung in die Ökotoxikologie.Physiologische Ökologie der Tiere.Tübingen.

Umweltbundesamt & ifeu. (2012). Untersuchungen der Umweltwirkungen von Verpackungen aus biologisch abbaubaren Kunststoffen (p. 139). Heidelberg.

Umweltbundesamt. (2007). Phtalate. Die nützlichen Weichmacher mit den unerwünschten Eigenschaften (p. 25). Dessau-Roßlau.

Umweltbundesamt. (2008). Bromierte Flammschutzmittel.Schutzengel mit schlechten Eigenschaften (pp. 1–25).Dessau- Roßlau.

Umweltbundesamt. (2009). Per- und polyfluorierte Chemikalien.Einträge vermeiden.Umwelt schützen (p. 17). Dessau.

Umweltbundesamt. (n.d.). Pflanzenschutzmittel in der Landwirtschaft. Retrieved February 24, 2014, from http://www.umweltbundesamt.de/themen/boden-landwirtschaft/umweltbelastungen-der-landwirtschaft/pflanzenschutzmittel-in-der-landwirtschaft

UNEP. (2012). GEO 5. Global Environmnetal Outlook. Summary for policy makers. Retrieved 20 February 2014, from http://igitur-archive.library.uu.nl/chem/2012-0320-200502/UUindex.html

UNESCO, & Earthscan. (2009). World Water Assessment Programme. The United Nations World Water Development Report 3. Water in a changing World. Paris.London.

UNESCO. (2003). Wasser für Menschen , Wasser für Leben: Weltwasserentwicklungsbericht der Vereinten Nationen. World Water Assessment. Bonn.

UNESCO. (2012). Managing Water under Uncertainty and Risk- The United Nations World Water development Report 4 Volume 1 (Vol. 1).

United Nations. (2004). World Population to 2300.United Nations Department of Economic and Social Affairs/Population Division. New York.

Walser, A., Burkhard, M., Zuleg, S., & Boller, M. (2008). Gewässerbelastung durch Biozide aus Gebäudefassaden (pp. 639–647).

Weihrauch, M. R., & Diehl, V. (2004). Artificial sweeteners—do they bear a carcinogenic risk?. Annals of Oncology, 15(10), 1460-1465.

Wittmer, I. K., Bader, H.-P., Scheidegger, R., Singer, H., Lück, a, Hanke, I., … Stamm, C. (2010). Significance of urban and agricultural land use for biocide and pesticide dynamics in surface waters. Water Research, 44(9), 2850–62.

Wittmer, I., & Burkhard, M. (2009). Dynamik von Biozid- und Pestizideinträgen (p. 4). Dübendorf.

Ying, G.G., Williams, B., Kookana, R., 2002. Environmental fate of alkylphenols and alkylphenol ethoxylates – a review. Environment International 28 (3), 215–226.

Ziegler, D., Reitbauer, S., & Rizzo, L. (2007). Trendreport Convenience (p. 47). München.

Zwiener, C. and Frimme,l F.H. (2004). LC-MS analysis in the aquatic environment and in water treatment – A critical review. Part II. Applications for emerging contaminants and related pollutants , microorganisms and human- acids. Analytical and Bioanalytical Chemistry 378. 862-874.

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Presentation / Abstract

SETAC presentation and Abstract in:

SETAC Basel (2014): Science Across Bridges, Boders and Boundaries. Abstract Book. S. 110.

www.basel.setac.org (acces on 17.07.2014)

Projects

NORMAN	http://www.norman-network.com/ (access on 06.03.2014)
RISKWA	http://www.bmbf.riskwa.de/de/94.php (access on 06.03.2014)
SCARCE	http://www.scarceconsolider.es/publica/P000Main.php (access on 06.03.2014)
SCENES	http://www.usf.uni-kassel.de/cesr/index.php?option= com_project&task= view_detail & agid=77&lang=de (access on 06.03.2014)
SOLUTIONS	http://www.solutions-project.eu/
WATCH	http://www.eu-watch.org/ (access on 06.03.2014)
WWQA	http://www.usf.uni-kassel.de/cesr/ index.php?option=com _project&task=view_detail &agid=109&lang=de (access on 06.03.2014)

Important websites

List of emerging contaminants http://www.norman-network.net/?q=node/81 (acces 14.07.2014)

9 Appendix

Table 10 Documents on developments in society and scenarios analysed (for chapter 5)

Title		Institution/ Author	Year of publication	Reference (for details: see report)	Main topics
1) Scenarios for middle- and longterm developments in society, caused by multiple drivers					
1.1	GEO 5 for Business- Impacts of a changing environment on the corporate sector	UNEP- United Nation Environment Programme Dave Grossmann	2013	www.unep.org	Environmental change- because of two main drivers population growth and economic development
1.2	GEO 5-Global Environmental Outlook	UNEP	2012		Climate change Population growth Urbanization Water scarcity -And its impacts
1.3	UN Millenium Ecosystem Assessment (MA)	Alcamo et al.			The four MA Scenarios and their direct and indirect drivers
1.4	Measuring Progress- Environmental Goals and Gaps	UNEP	2012		Climate change Chemicals Waste, Water
1.5	The European Environment- State and Outlook 2010	European Environment Agency Jock Martin and Thomas Henrichs and many more	2010	Eea.europe.eu/enquiries	Climate change Nature& biodiversity Natural resources and waste Environment, health and quality of life These are directly/ indirectly linked
1.6	Planetary Bounderies: Exploring the Safe Operating Space for Humanity	Rockström et al	2009		Seven planetary bounderies: climate change, ocean acidification, stratospheric ozone, biogeochemical N and P cycle, global fresh water use, land system change, biological diversity lost
2) Developments in water use and water cycles					

Title		Institution/ Author	Year of publication	Reference (for details: see report)	Main topics
2.1	World Water Vision- Making Water everybody's business	earthinfo@earthscan.co.uk	2000	www.earthscan.co.uk	Future scenarios for water, water business
2.2	Charting our water future Economic framework to inform decision-making	The 2030 water resources group	2009	2030WaterResourcesGroup@mckinsey.com	To get ideas for scenarios
2.3	Water in a changing world The United Nations World Water Development Report 3	UNESCO and others	2009		Drivers of water Changes of water cycle
2.4	GLOWA- Globaler Wandel des Wasserkreislaufes IHP/HWRP Berichte Heft 7	Bundesministerium für Bildung und Forschung	2008		Influence of demographic and technological change for water use, climate change
2.5	Future long term changes in global water resources driven by socioeconomic and climate changes	Alcamo et al	2007		
2.6	Wasser für Menschen/Wasser für Leben	World Water assessment programme			
2.7	Water resources across Europe	European Environment Agency	2009		About water use in future and drivers
3) Developments in use and impact of chemicals					
3.1	Chemicals Action Plan Safety in Denmark	Government of Denmark	2010-2013 Published in 2010	www.mst.dk	Get ideas to use chemicals from other countries
3.2	Costs on Inaction on the sound managements of chemicals	UNEP	2013		Impacts of chemicals for health, environmental and development effects
3.3	Harmful substances and hazardous waste	United Nation Environment Programme Dr David Piper		http://www.unep.org/hazardoussubstances/	
3.4	Ökotoxikologische Bewertung von anthropogenen Stoffen Acatech Materialien NR 10-Georessource Wasser-Herausforderung Globaler Wandel	Thomas Knacker Anja Coors	2011	www.acatech.de	Schadstoffe im Wasserkreislauf und Auswirkungen auf Ökosystem

Title		Institution/ Author	Year of publication	Reference (for details: see report)	Main topics
3.5	Organische Spurenstoffe im Wasserkreislauf Acatech Materialien Nr 12, Georessource Wasser- Herausforderung Globaler Wandel	Axel Bergmann	2011	www.acatech.de	Schadstoffe im Wasserkreisluaf
4) Specific driver: climate change					
4.1	IPCC Special Report Emissions Scenarios, Summary for Policymakers Intergovernmental panel on climate change	IPCC Working group III UNEP WMO- World Meterological Organization	2000		Climate change
4.2	SCARCE- Assessing and predicting effects on water quality and quantity in Iberian Rivers caused by global change	Prof. Damià Barceló (project coordinator) edamia.barcelo@idaea.csic.es Dr. Alícia Navarro-Ortega (projectmanager) alicia.navarro@idaea.csic.es	2009-2014	www.scarceconsolider.es	Change of water quality/quantity
4.3	WATCH- Water and global change	Richard Harding Tanya Warnaars	2011		introduction to the achievements of the WATCH Project Water cycle and its changes
4.4	Modell Deutschland: Klimaschutz bis 2050	Prognos Ökoinstitut eV	2009		
5) Specific driver: demographic change					
5.1	Die demografische Zukunft Europas- wie sich Regionen verändern	Berlin Institut für Bevölkerung und Entwicklung	2008		demographic change in Europe
5.2	OECD Environmental Outlook to 2050- The Consequences of Inaction	Kumi.Kitamori@oecd.org	March 2012	www.oecd.org/environment/outlookto2050	Demographic change and its impact
6) Specific driver: technological/ economical changes					

Title		Institution/ Author	Year of publication	Reference (for details: see report)	Main topics
6.1	Trend Report Convenience- Machen Sie es sich bequem	SevenOne media	2007		Changing living standard, food, trade, human care products, e-commerce, consumer electronics
6.2	THOUGHTS Megatrends	Roland Berger School of Strategy and Education Burkhard Schwenker Tobias Raffel			Different perception- see chances in economic/technology sector because of the scenarios
7) Sector-specific topic: Development in food production					
7.1	Fisheries and aquaculture in Europe	European Commission	2012		aquaculture
7.2	The Food Gap- The Impacts of Climate Change on Food Production 2020	Liliana Hisas Executive Director, FEU-US			About the impacts of climate change on food production in 2020
8) Sector-specific topic: Nutrients					
8.1	Global river nutrient report: a scenario analysis of past and future trends	Seitzinger et al	2009		Including MA scenarios
8.2	World Social Science Report- Changing Global Environment	UNESCO	2013		
8.3	World Water Vision- Making Water everybody's business	earthinfo@earthscan.co.uk	2000	www.earthscan.co.uk	Future scenarios for water, water
9) Further aspects					
9.1	Late lessons from early warning: the precautionary principle 1896-2000 (a retrospection of scenarios)	European Environment Agency	2001	www.eea.eu.int	retrospection
9.2	Towards a green economy in Europe- EU environmental policy targets and objectives 2010-2050	European Environment Agency	2013	Eea.europe.eu/enquiries	About achieving a green economy in Europe with laws and implementations
9.3	World Social Science Report- Changing Global Environment	UNESCO	2013		
9.4	zPunkt Megatrends	zPunkt GmbH		www.z-punkt.de	Abstract of different megatrends

Title		Institution/ Author	Year of publication	Reference (for details: see report)	Main topics
9.5	Science and Decision: Advancing Risk Assessment	National academy of science	2009		Advanced risk assessment / Silver Book of NAS

Table 11 Example of one prepared fact sheet based on scenarios of Table 10

Title	**Water in a changing world**
Author	UNESCO
Time period	2020 ☐ 2030 ☒ X 2050 ☐
Geographical area Areas **Most important**	National ☐ EU ☒ x global x ☐ • Water plays a big role considering its use for energy, food and after all its interaction with climate change (water stress, extreme weather, higher levels of migration) **Part 1 Drivers of the pressures on water** • Demographic • Social • Economic • Governance • Technological • Environmental- climate change **Part 2 clear evidence of the degradation of water quantity and quality** • Increasing water scarcity • Degradation of ecosystems • Pollution of surface- and groundwater through agriculture, industry, • Water use efficiency, pollution mitigation and implementation of environmental measures fall short in most sectors **Part 3 water quality, changes in the global water cycle** • Good water quality as a constraint on water supply Table 10.5 • Many of the more indirect impacts of climate change on surface water are not fully known Table 11.2 • Bridging the observational gap **Part 4 Responses and choices** It is about water management, policy, laws- water governance reform • Risk management-climate change and demographic change makes it more important
Compartments	Water X Air x Soil x Biota x
Main developments	• Water has remained too low on the list of political priorities → changes in human behaviors and activities • Effective policy and legal frameworks are necessary to develop, carry out and enforce the rules and regulations that govern water use and protect the resource • EU Water Framework Directive for water protection and other laws → but financing is often a limiting factor in effectively managing the water sector • In and around urban areas economic competition for water is forcing agriculture to adapt • Sewage treatment must be improved

	• Major investments are need to reverse the decline of hydrologic observation networks, including surface water and groundwater observations and water quality monitoring
How does the environment look like in the future?	• Climate change will create important pressure on water and also forces an processes generated by human activities → demographics and the increasing consumption (food production, changing lifestyles, virtual water,…) • Page 101: population growth, economic growth, urbanization, technological change and changing consumption patterns are the main factors influencing water use • Population and income growth- increase in water demand –must be a better governance and management practice, also climate change will place some key aquifers under additional pressure • Pollution is expected to increase as a result of economic development driven by urbanization, industries and intensive agriculture systems • Information about pollution loads and water quality is lacking in many countries because of inadequate monitoring systems • Global warming will result in an intensification, acceleration or enhancement of the global hydrological cycle • Observed trends in precipitation, changes in evaporation and evapotransporation, soil moisture, runoff and streamflow trends,groundwater trends permafrost trends, snow trends, trends in glaciers, • Climate change will affect water quality and ecosystem, health through higher water temperatures, lower water levels, more floodings and changes in lake stratification patterns
Content of scenarios	<u>Part 1 Demographic drivers</u> • Population dynamics create pressures on local freshwater resources through increased water demand and pollution • Changes in the natural landscape associated with population dynamics can create additional pressures on local freshwater resources and the need for more water-related services <u>Economic drivers</u> • Growth and changes in the global economy are having far-reaching impacts on water resources and their use • Growing international trade in goods and services can aggravate water stress in some countries while relieving it in others through of virtual water-> imported agricultural commodities <u>Also social and technological drivers</u> <u>Climate Change and possible futures</u> • Main impact of climate change on humans and the environment occur through water • Climate change is a fundamental driver of changes in water resources and an additional stressor through its effects on other external drivers • Climate change differs from the other drivers – increased water scarcity • Pollution and degradation of water quality

	• In 2030 47% of world population will be living in areas with water stress • Changes in average streamflow, extreme events groundwater, erosion, landslide, river morphology

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Eigenständigkeitserklärung:

Hiermit versichere ich, dass ich die vorliegende Arbeit selbständig verfasst, keine anderen als die angegebenen Quellen und Hilfsmittel benutzt und wörtlich sowie inhaltlich übernommenen Stellen eindeutig gekennzeichnet habe.
Diese Arbeit war weder vollständig noch in wesentlichen Teilen Gegenstand eines anderen Prüfungsverfahrens.

Tübingen, den ....

Unterschrift: