UNIVERSITÀ DEGLI STUDI DI PADOVA

Sede Amministrativa: Università degli Studi di Padova

Dipartimento di Ingegneria Industriale

SCUOLA DI DOTTORATO DI RICERCA IN : INGEGNERIA INDUSTRIALE

INDIRIZZO: IGEGNERIA CHIMICA DEI MATERIALI E DELLA PRODUZIONE

CICLO XXVI

NEW MODEL TO ACHIEVE THE WATER MANAGEMENT AS A COMPETITIVE TOOL FOR INDUSTRIAL PROCESSES

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Abstract

The issue of freshwater use and related impacts is central to international debate. The reason is that freshwater, even though renewable, is a scarce resource with limited availability in a growing number of regions all over the world. The consequent increasing competitiveness on freshwater resources is recognized to affect companies by exposing them to several environmental and market risks. In this contest, businesses clearly showed interest in freshwater management tool so that, in recent year, the scientific community has been working on the development of suitable models and methods. Even though several experiences can be identified in the literature, most significant researches are taking place within the framework of the Life Cycle Assessment, an internationally accepted methodology to assess potential environmental impacts of products, processes and organizations. When focusing on freshwater related issue it is also known as Water Footprint assessment.

Current methods, specifically developed to address this issue, present limits in term of transparency, completeness and comprehensiveness. These limitations prevent companies to understand their water environmental hot-spots and therefore to set effective environmental and market performance improvement strategies.

The present research focuses on the development of a new model to achieve the freshwater management as a competitive tool for industrial processes. To do so the specific objective of the research was to develop a set of indicators to overcome identified limits and to test its applicability in real case studies.

To define the set of indicators, the methodology of the research took into consideration the Life Cycle Assessment framework adopting the criteria agreed within the UNEP-SETAC (United Nation Environmental Program – Society of Environmental Toxicology and Chemistry) Water Use Life Cycle Initiative; to test and discuss its applicability and effectiveness, the methodology of the multiple case studies was adopted. The case studies were selected considering their significance in term of freshwater scarcity and their capability to represent life cycle processes in different locations and therefore to address the issue of regionalization. The four products studied in this research were: a water collection system, an organic oat beverage, an organic strawberry jam and a tomato sauce.

The development of the set of indicators is addressed in the first part of the research. To guarantee transparency and effective life cycle impact assessment analysis, the entire environmental impact chain was modelled in order to separately address consumptive and degradative freshwater use. To guarantee completeness and comprehensiveness and therefore to avoid potential environmental burden shifting, a so called water footprint profile covering accepted freshwater related impact methods, was created.

The applicability and effectiveness of the proposed set of indicators is presented in the second part of this work. The four case studies were conducted according to the Life Cycle Assessment stages. Results of the applicability of the proposed set of indicators highlighted the importance of regionalization and comprehensiveness and allowed to understand the importance of considering degradative and consumptive freshwater use separately. It was in fact possible to define environmental impact reduction strategies in each of the case studies presented.

The research activities were carried out at the Department of Industrial Engineering (Dipartimento di Ingegneria Industriale-DII) at the University of Padova (Italy) and at the Golisano Institute for Sustainability of the Rochester Institute of Technology (New York State –USA).

The results of the research activities are summarized in 5 chapters.

Chapter 1 includes an introduction of the issue of freshwater scarcity and presents the evolution of models to address freshwater use and related impacts starting from the virtual water assessment to the most recent development within the Life Cycle Assessment framework. Limits of current models and methods are presented. Objective and structure of the research are also described.

Chapter 2 reports on materials and methods used in the present research, from the description of the general framework of Life Cycle Assessment studies to the specific criteria used in the indicators definition. Set of developed indicators is therefore presented by specifying procedures for their application and describing the solutions adopted to conform to internationally accepted requirements (such as ISO 14046).

Chapter 3 presents the results of the application of the identified set of indicators in four different case studies. To identify potential strategies for companies and to test the effectiveness of the proposed set of indicators, a sensitivity and contribution analysis on results is performed.

Chapter 4 presents the discussion on results with reference to published literature, the UNEP-SETAC Water Use Life Cycle Initiative criteria, the ISO 14046 principles and objectives of the research.

Chapter 5 reports on the conclusion and perspectives for future research.

Sommario

Il tema dell'utilizzo dell'acqua dolce e degli impatti ambientali a esso associati sono centrali all'interno del dibattitto internazionale. La ragione principale di quest'attenzione sta nel fatto che l'acqua dolce, sebbene rinnovabile, sia presente in quantità limitata in un numero crescente di regioni in tutto il pianeta. La conseguente accresciuta competizione per accedere a queste risorse ha delle conseguenze concrete nel mondo delle imprese che si trovano a dover affrontare rischi di natura ambientale e di mercato. In questo contesto, le aziende hanno mostrato un notevole interesse verso gli strumenti per la gestione delle risorse idriche tanto da spingere la comunità scientifica a moltiplicare gli sforzi per lo sviluppo di modelli e metodi adatti a garantire un utilizzo più sostenibile di queste risorse. Sebbene si possano identificare diverse esperienze in letteratura, gli sviluppi più significativi si sono avuti all'interno del contesto del Life Cycle Assessment, una metodologia ampiamente accettata a livello internazionale per la quantificazione e valutazione dei potenziali impatti ambientali di prodotti, processi ed organizzazioni. Quando ci si concentra sul tema risorse idriche questo approccio è conosciuto con il nome di Water Footprint.

I modelli attuali, sviluppati nello specifico per trattare questa problematica, presentano dei limiti in termini di trasparenza, completezza e comprensività. Queste limitazioni non consentono al mondo delle imprese di comprendere i propri hot-spot ambientali riguardanti l'acqua e quindi di definire opportune strategie ambientali e di mercato per il miglioramento della competitività di prodotti e processi.

La presente ricerca si focalizza sulla creazione di un modello innovativo per tradurre la gestione dell'acqua dolce in uno strumento per la competitività dei processi. L'obiettivo della ricerca è stato quello di sviluppare un set di indicatori per superare i limiti evidenziati e quindi verificarne l'applicabilità in dei casi di studio reali.

Nella definizione del set di indicatori, la metodologia della ricerca ha preso in considerazione il contesto metodologico del Life Cycle Assessment (analisi di ciclo di vita) nel rispetto dei requisiti presentati in materia da parte dell' UNEP-SETAC Water Use Life Cycle Initiative. Per mettere alla prova e discutere l'efficacia degli indicatori così creati è stata adottata la metodologia del caso di studio multiplo. La scelta dei casi di studio è stata compiuta in funzione della loro criticità in tema di utilizzo della risorsa idrica e in funzione della loro capacità di presentare processi localizzati in regioni con condizioni climatiche e di disponibilità di acqua dolce differenti. I quattro prodotti scelti per questa ricerca sono: un sistema di collettamento e recupero delle acque piovane, una bevanda a base di avena biologica, una marmellata di fragole biologiche ed una salsa di pomodoro per il condimento della pasta.

Lo sviluppo del set di indicatori è affrontato nella prima parte della ricerca. Per garantire la trasparenza e l'efficacia dell'analisi degli impatti di ciclo di vita, l'intera catena di valutazione

ambientale è stata modellata al fine di quantificare separatamente gli effetti del consumo e dell'uso degradativo dell'acqua dolce. Per garantire completezza e comprensività, così da evitare il problema del burden-shifting, è stato sviluppato un Water Footprint Profile che considera i metodi più accettati e diffusi nella quantificazione degli impatti ambientali relativi all'acqua dolce.

L'applicabilità ed efficacia del set di indicatori è presentata nella seconda parte della ricerca. I quattro casi di studio sono stati condotti nel rispetto dei requisiti del Life Cycle Assessment. I risultati dell'applicabilità del set di indicatori proposto, ha messo in luce l'importanza della regionalizzazione e della comprensività e hanno permesso di capire l'importanza di valutare in modo separato il consumo e l'uso degradativo dell'acqua dolce. In ogni caso di studio è stato possibile determinare una strategia per la riduzione dei consumi di acqua dolce.

Le attività di ricerca sono state condotte presso il Dipartimento di Ingegneria Industriale dell'Università di Padova (Italia) e presso il Golisano Institute for Sustainability del Rochester Institute of Technology (New York State –USA).

I risultati della ricerca sono presentati in cinque capitoli.

Capitolo 1: include un'introduzione al problema della scarsità d'acqua dolce e presenta l'evoluzione dei modelli per considerare l'utilizzo di acqua dolce ed i relativi impatti a partire dal concetto di virtual water fino alle recenti evoluzioni all'interno del contesto del Life Cycle Assessment. Sono quindi chiariti i limiti dei modelli e metodi attuali. Infine sono presentati gli obiettivi e la metodologia di ricerca.

Capitolo 2: riferisce in merito ai materiali e metodi adottati dalla ricerca, dalla descrizione del modello generale degli studi di Life Cycle Assessment fino ai criteri considerati per la definizione degli indicatori. Questi sono poi presentati specificandone procedure applicative e soluzioni di conformità agli standard accettati a livello internazionale tra cui l'ISO 14046.

Capitolo 3: presenta i risultati dell'applicazione del set di indicatori in quattro diversi casi di studio. Per la definizione delle strategie di riduzione degli impatti sull'acqua dolce e per verificare l'efficacia degli indicatori, è stata condotta un'analisi di sensitività e contribuzione specifica in ogni caso di studio.

Capitolo 4: presenta le discussioni dei risultati ottenutici con riferimento ai modelli pubblicati in letteratura, ai criteri dell' UNEP-SETAC Water Use Life Cycle Initiative, dei principi della norma ISO 14046 e degli obiettivi della ricerca.

Capitolo 5 presenta le conclusioni e le indicazioni per futuri sviluppi della ricerca.

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Deposited on the 31st of Jannuary 2014

1. Introduction

1.1. Global freshwater resources: the issue of availability

Water is recognized to be one of the most important natural resources to support life of humans and ecosystems (Falkenmark and Folke, 2003). Its availability is critical to meet basic human needs and support economic and cultural activities such as agriculture, food, energy and industrial production, basic sanitation, household uses or sewage water transport (WWAP, 2012). However, even if water is a renewable resource, it is a limited one. In fact the 70% of planet earth is covered with water but only the 0,01% is freshwater directly available for the above mentioned human needs and for life of ecosystems (Revenga et al., 2000) (Fig.1).

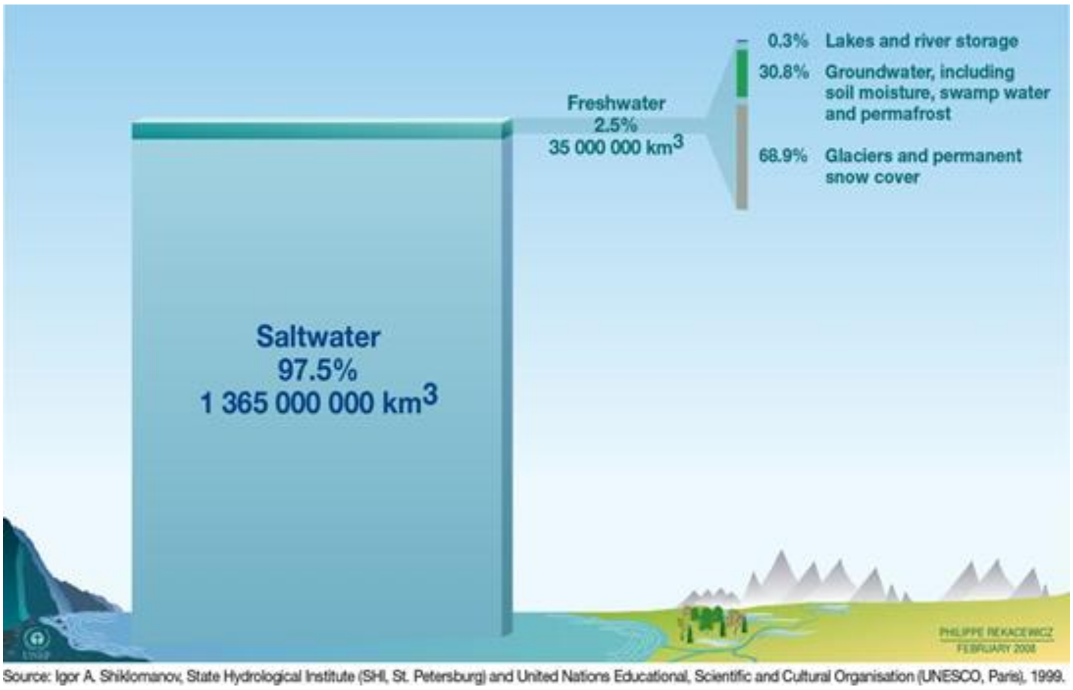

Figure 1-1 Global freshwater availability (UNEP, 2008)

The amount of freshwater is regularly renewed by rainfall and snowfall and is therefore periodically available following the timing and mechanisms of the so-called water cycle (UNEP, 2005); Fig.2 represents the general steps of the world water cycle reporting on volumes of water that periodically flow through it. The main processes responsible of the water cycle are: precipitation, vapor transport, evaporation, evapotranspiration, infiltration, groundwater flow and runoff. Even if the mechanism of water cycle is the same all over the world, due to specific local conditions freshwater is available with consistent variability in different regions. This depends on local climate variability in space and time (length and presence of dry and wet seasons) that influence the balance between evaporation and runoff; the quantity of ground and surface water locally available; the different accessibility of freshwater resources (e.g. glaciers and ice-cap are 70% of the world's freshwater but are located far from human habitation and are not readily accessible for human use) (UNEP,2008).

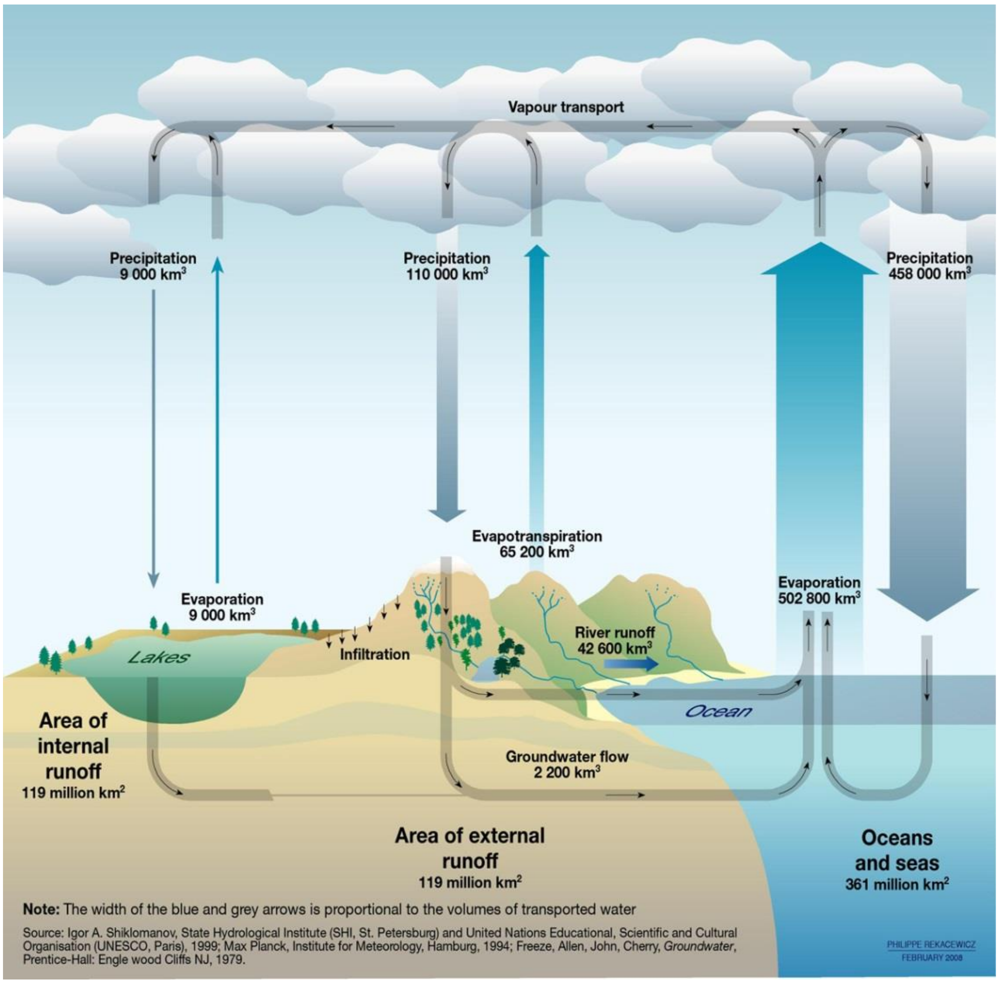

Figure 1-2 The Hydrological water cycle (UNEP, 2008)

Several issues affected the actual availability of freshwater worldwide. Latest statistics confirmed that the 50% of freshwater resources have been depleted over the last 30 years causing a big environmental concern known as local water scarcity (WWAP, 2012). Water scarcity, as defined by the Water Scarcity index developed within the United Nation Environmental Programme (UNEP, 2008), occurs when the amount of water withdrawn from lakes, rivers or groundwater is so great that water supplies are no longer adequate to satisfy all human or ecosystem requirements, resulting in increased competition between water users and other demands (UNEP, 2008). Fig.3 represents the distribution of scarcity around the world confirming that a consistent part of world population nowadays lives in water stressed regions. The consequences are potentially so serious that international community recognized the necessity to start actions against water scarcity at different levels all over the world. The United Nations Framework on Climate Change (UNFCC), recognize freshwater scarcity as one of the main issues that relates climate changes to society and is working to develop ad hoc adaptation strategies (UNFCCC, 2011). The United Nations also included water accessibility as one of the Millennium Goals to solve poverty (UN, 2013). The European Union in 2007 launched the EU water policy in order to ensure access to good quality water in sufficient quantity for all Europeans, and to ensure the good status of all water bodies across Europe (EC, 2007). Four main drivers are recognized to have significantly influenced this issue over time: climate changes, population, urbanization growth and economic development (WWAP, 2012). The increase of greenhouse gases emission and related climate changes are affecting the mechanism of hydrological cycles resulting in different local evapotranspiration, soil moisture, and run-off flow (Bates et al., 2008). Increase of world population results in bigger water needs for several human uses both from a quantity and improved quality perspective. In the last century, the world population has tripled and it is expected to rise from the present 6.5 billion to 8.9 billion by 2050, before levelling off; water use has been growing at more than twice the rate of population increase in the last century resulting in an increasing number of regions that are chronically short of water. By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under conditions of water stress. The situation will be exacerbated as rapidly growing urban areas place heavy pressure on local water resources (WWAP, 2012) by focusing the demand for water among an ever more concentrated population and changing the way inland water can be managed and reaches the gouge. Economic development results in an increased water demand for energy, food and industrial production that are also known as the main cause for water quality degradation (WWAP, 2012). Another consequence of these drivers is increase competitiveness for water.

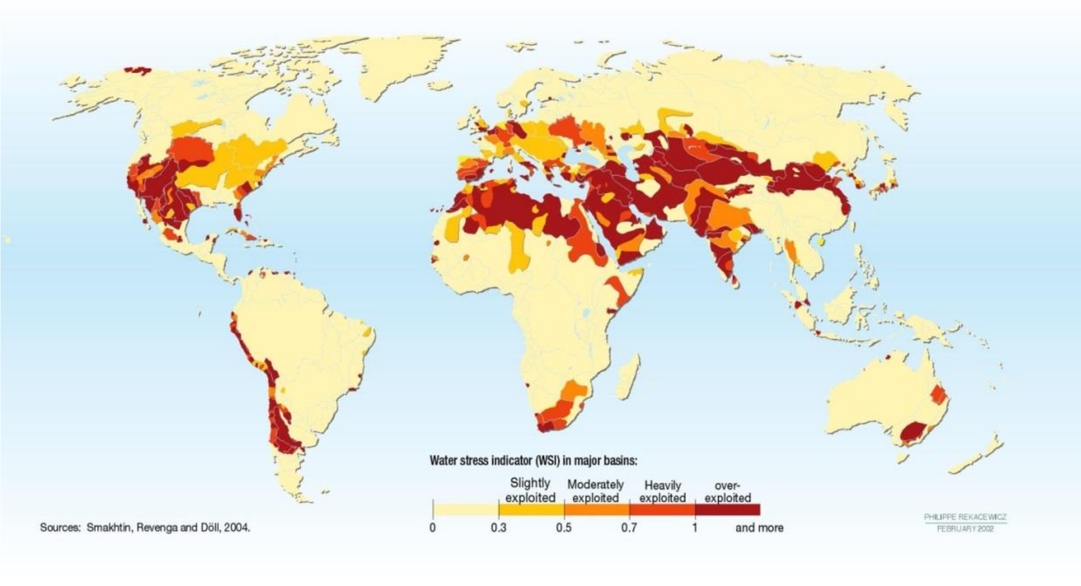

Figure 1-3 Water Scarcity Index (UNEP, 2008)

1.2. Freshwater use and company competitiveness

Water is withdrawn from natural environment for several uses that are generally related to five different categories. The first in term of water consumption is food and agriculture, that is responsible for the 70% of the overall withdrawn water. Crops production followed by livestock requires huge amount of water and contributes to water quality degradation and therefore to local water scarcity (FAO, 2009). The greatest water consumption related to this category results from evaporation and product incorporation of freshwater used for crop irrigation; trends confirms the importance of this resource also for the future with a growing demand related to the increase needs of world population (WWAP, 2009; Brunisma, 2009). Another significant water user category is the human settlements one. This category covers almost the 10% of overall global water withdrawal (WWAP, 2009) and more often results in over-abstraction leading to higher resource access competition and challenging ecosystem functioning. Moreover when groundwater withdrawal is concerned, other related environmental problems shall be considered such as falling water tables, water quality degradation and land subsidence. Another significant consequence of human settlements, is the pressure derived from wastewater and water pollution. Recent statistics confirmed that over the 80% of waste water worldwide is not collected or treated, resulting in high level of pollution (Corcoran et al., 2010). This situation is especially representative of emerging countries were water is recognized to be even more scarce (WWAP, 2012). Another user category to be considered is the ecosystem. This covers a central role in a correct and sustainable functioning of the hydrological cycle. Recent rethinking of the contribution of ecosystems to water availability shifts its role from a water demand subject to a water service supplier (WWAP, 2012).

The other two remaining sectors are the energy and the industry,that result to be particularly affected by shortage of water. Most of energy resources require water during different production steps and affect water quality. Moreover energy is used to make water available to end users (e.g. pumps, pipes). This is called the energy-water nexus and is recognized to be a key challenge for global water management in order to guarantee production of energy and availability of water worldwide (WWAP, 2012). The third user category to be discussed, is the industry one. From a statistic perspective industry and energy are usually accounted together and are actually responsible for the 20% of global withdrawal. Even if such value varies with the level of economic development of the country understudy, water is recognized to be a main issue for industries worldwide due to the following related risks:

- .physical Risks: related mainly to the access to water resources and water related services. Water Intensive productions are particularly affected by this issue (WWAP, 2012);
- compliance risks: related for example to changes in regulation and administrative procedures (WWDR, 2012);
- market risks: related to the corporate responsibility and reputation on the market (WWDR, 2012);
- financial risks: related to the costs of water and energy (WWDR, 2012).

When focusing on industries another key issue is recognized to be water quality: different industries have different water quality needs and differently affect quality of water bodies (UNEP, 2007). If water resources are not well managed and treated; impacts on humans and ecosystems can be identified and shall be treated (Ridoutt and Pfister, 2010). The global business community increasingly recognizes the water challenge, and clearly asked for guidance, tools, standards and schemes to enable more sustainable practices and to understand how to reduce impacts on water resources (WBCSD; 2010)

1.3. Impacts related to water and current assessment models

It is worldwide agreed that the sustainable management of freshwater resources should include a deeper comprehension of human and ecosystems interactions through the analysis of water related impacts (WWAP, 2012). This analysis shall adopt several dimensions:

- a regional one, to understand the effects of freshwater use on local environment (e.g. basin or watershed level) (Ridoutt and Pfister, 2010);
- an international and global dimension: that is described through climate change, trans-boundary basins, global trade and international investment protection, and equity issues (Hoekstra, 2011);
- a so-called life cycle dimension: to consider all the processes that take place along the value chain of human related activities (from extraction of raw materials to waste management) and the potential environmental impacts related to water (Lundqvist et al., 2008).

This last dimension proved to be particularly important as 90% of freshwater use is associated with the life cycles of products and services (Ridoutt and Pfister, 2010). Focusing on environmental impacts related to water, two big different families can be identified: impacts related to quantity, also referred as availability, and impacts related to quality (WWAP, 2009) (Figure 4). If the latter have been widely addressed within several methods by the scientific community, the former, with the emerging issue of water availability and scarcity, only recently became central to scientific debate (Kounina et al.2013). Figure 4 represents the two families and their interactions, showing main causes of impacts and related consequences. In particular, it has to be noticed that availability results to be influenced both from quantitative use and water quality degradation.

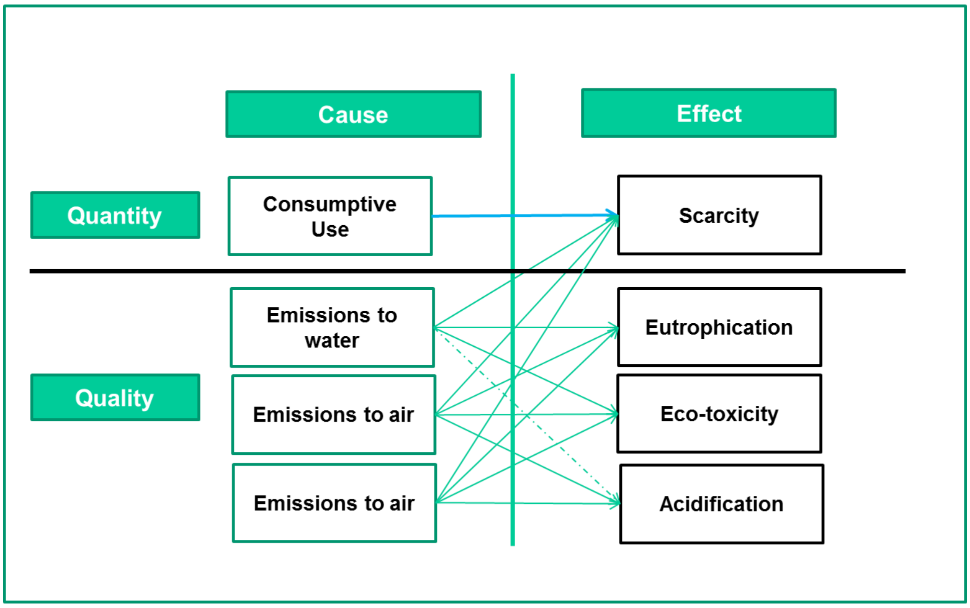

Figure 1-4 General framework of Impacts related to water

Within this framework, the international community recognized the development of tools to better manage water and understand the impacts that product, processes and organization have on water resources to be a priority (WWAP, 2012; ISO, 2013a).

1.3.1 Water quality degradation: impacts and assessment models

Main impacts related to water quality degradation are recognized to be: eutrophication (Bennet et al., 2001), ecotoxicity (Rosenbaum et al., 2008) and acidification (Jolliet et al., 2003). These impacts have been widely studied adopting the related regional (when relevant), global and life cycle perspectives.

Freshwater Eutrophication is a significant environmental issue affecting many regions of the developed countries. It can be defined as the nutrient enrichment of waters that stimulates an array of symptomatic changes, among which increased production of algae and macrophytes, deterioration of water quality and other changes such as the reduction in the value of the exploitation which occurs in an area (Christensen et al., 1993; WWAP, 2012). Eutrophication is the result of Nitrogen (N) and Phosphorus (P) pollution that causes oxygen depletion in freshwater and coastal surfaces. Main processes responsible for eutrophication are: use of N-based and P-based pesticides in agriculture; storm water runoff that carries pollutant from hard surfaces to water bodies; wastewater that results in emission of organic materials; fossil fuel combustion emissions that contribute to the presence of N and P in the atmosphere (Hauschild and Wenzel, 2002; WWAP, 2012). Current environmental assessment methods calculate the effect of nutrient enrichment as the magnitude of emissions expressed in the form of their contribution in term of nitrogen or phosphorus equivalent to the atmosphere (Bennet et al., 2001; Hauschild and Wenzel, 2002; Goedkoop et al., 2012). Eutrophication affects human health (by creating dangerous toxins and compounds-drinkable water) and ecosystems (such as the so-called death zones and toxins that enter the food-chain).

Freshwater eco-toxicity refers to the spectrum of effects and impact mechanisms that emissions of toxic substances have on the environment (Hauschild and Wenzel, 2002; Rosenbaum et al., 2008). A few important examples are emissions of strongly toxic metals, persistent organic substances or organic substances. Current methods measure eco-toxicity as the magnitude of the effect on the functioning of ecosystems. Ecotoxic substances are classified in function of their persistence, ability to bio accumulate, quantity and human and ecosystem exposure (Hauschild and Wenzel, 2002).

Freshwater acidification is an environmental concern that assumed significant dimension in the last decades and can be defined as an impact which leads to a fall in the system's acid neutralizing capacity (ANC) (De Vries and Breeuwsma, 1987) such as a reduction in substances able to neutralize hydrogen ions. It is an effect of emissions to the atmosphere and consequent deposition on water of sulfur dioxide (SO_2) and nitrogen oxides (NO_x). The main process responsible for the emission of such compounds is the combustion of fossil fuels (e.g. hard coal) for the production of energy. Such substances have a limited lifespan, typically of the order of days, therefore their influence is regional with limited extent from the point source of emissions (Hauschild and Wenzel, 2002). Acidifying substances have actual effects (immediate fall in the ecosystem ANC) and potential effects (possibility of subsequent release to the ecosystem and subsequent decrease of ANC). Current methods measure acidification as the sum of this two contribution (Hauschild and Wenzel, 2002; and Jolliet et al., 2003). Acidification harms ecosystems (such as life of fishes) and human health (in the form of fine sulfate and nitrate particles that can be transported long distances by winds and inhaled deep into people's lungs).

Another consequence of water quality degradation is a reduction of freshwater availability for humans and ecosystems use (Boulay et al., 2011) (Figure 1-4). This issue will be discussed within the chapter 1.3.2 that presents the evolution of methods to assess environmental impacts of freshwater use on water availability.

1.3.2 Water availability: impacts and assessment models

Only in recent years the issue of water availability has become central to international debate calling for the scientific community to develop methods to better manage water resources and to understand consequences of freshwater use by human beings (WWAP, 2012). Shortage of water in fact can result in several impacts that go from humans' malnutrition to changes in ecosystems quality.

In this paragraph, the main experiences related to understanding the environmental consequences of freshwater use are presented: from virtual water, firstly introduced by Allan et al. 1998, to the water footprint concept introduced by Hoekstra et al. 2011, to the recent development within the framework of Life Cycle Assessment community (Bayart et al. 2010; ISO, 2013a).

Figure 1-5 reports on some of the most important steps in the evolution of methodologies and models to address the impacts related to water availability. It can be immediately deduced that scientific community moved from development of accounting methods, designed to better support management of water, to more complete impact assessment methods (Boulay et al., 2013). Details of such and other literature references will be discussed in the following paragraphs.

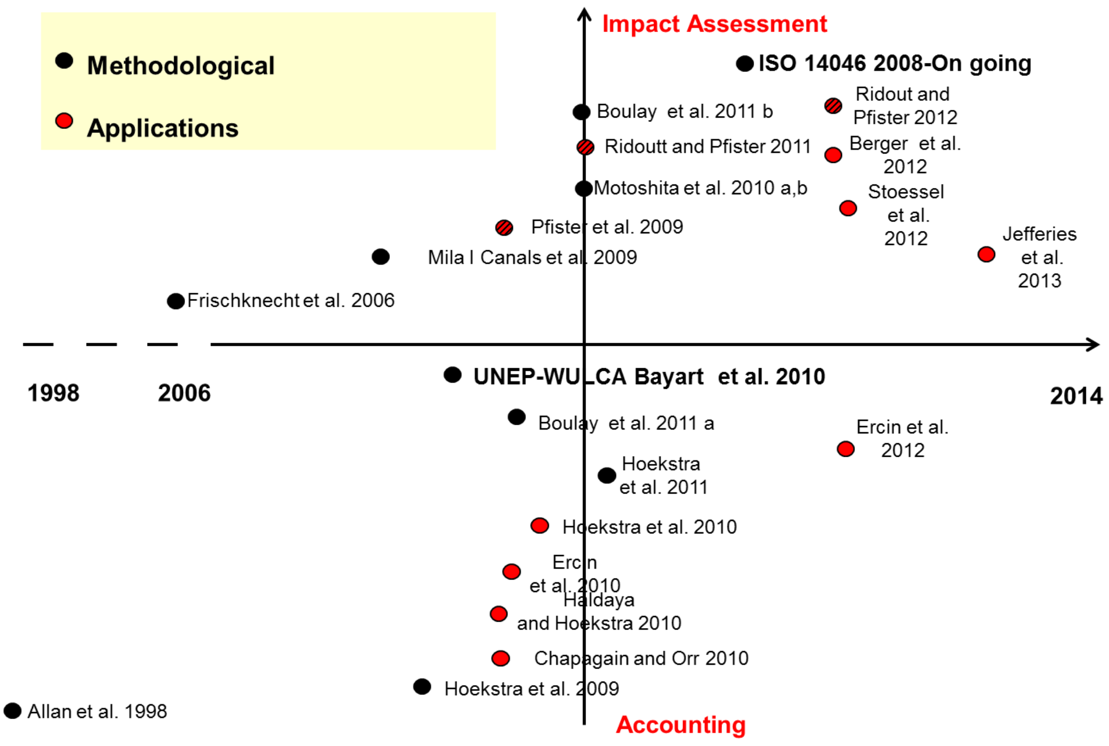

Figure 1-5 Evolution of methods related to water

1.3.2.1 The Virtual water model

A first attempt to formulate a method to support a better comprehension of environmental consequences of freshwater use, is the Virtual Water concept introduced by Allan (Allan, 1998) and defined as the water consumed for the production of food and industrial products; such concept has been introduced as potential solution to increase water use efficiency worldwide by shifting the production of high intensive water use products towards countries were water is not scarce and trading such products to regions were water availability is limited and recognized to be a big concern (Hoekstra and Hung, 2002). A first attempt to translate such concept into an operative method, was made by Hoekstra and Hung (2002). They expressed virtual water in liter of water per mass of unit of product. Several efficiency aspects need to be considered in this assessment and are reported in Table 1-1 (Zimmer and Renault, 2002).

Considering the above mentioned characteristics, virtual water only partially answer the three different dimensions described in chapter 1.3: adoption of local dimension is considered through the consideration of local water availability to support decision making on location were to produce the different products; adoption of global dimension is considered through the representation of global virtual water trade; life cycle dimension: partially considered in terms of activities included in the quantification of virtual water and represented by three efficiency categories described in Table 1-1.

Table 1-1 Efficiency aspects to be considered in Virtual Water Assessment

Efficiency aspect	Description
Water efficiency	Includes water evaporated (evapotranspiration in case of crop-based products) and lost (defined as water that does not recharge the basin understudy or cannot be recycled within it)
Production efficiency	Includes the understanding of different yield in the case of crop-based products or ratio between input and output of other productions over time. In the case of crop-based products such efficiency varies along time depending on several factors such as climate conditions
Consumption efficiency	This is related to the production of waste along the value chain and during the use of different products

Several applications of this concept have been published in particular to represent virtual water trade associated with food products such as crops or livestock (Hoekstra, 2003; Hoekstra and Hung, 2002). Virtual water had the merit to contribute to the discussion on water scarcity at global level but presents some evident limits when going further into impact assessment. It does not consider environmental impacts of water use on water availability or any other impact category related to water quality degradation. Even if its quantification is recognized to support water management on a global scale, it cannot be considered an impact assessment method (WWAP,2012), therefore it does not allow companies to understand their environmental hot-spot and set performance improvement strategies.

1.3.2.2 The Water Footprint Accounting model

Based on the principles and practices of Virtual Water, in 2002 Hoekstra introduced the concept of Water Footprint: an indicator of freshwater appropriation by humans, with the aim to quantify and map direct and indirect water use and show the relevance of involving consumers and producers along supply chains in water resources management (Hoekstra and Chapagain, 2008). It is a multidimensional indicator of freshwater use, applicable to products, processes, organization, populations and nations (Hoekstra et al. 2011) that include information on quantity and quality of used water.

A first operative version of the method to determine Water Footprint has been published in 2009 by Hoekstra et al. (2009). It is the first method related to water to fully adopt a life cycle dimension on processes to be considered in the assessment (Boulay et al., 2013). The study consists of three steps:

- the goal and scope definition: in which the objective and the subject of the study are clearly stated and determined;
- the water footprint accounting: that consists in the assessment of the blue, green and grey water footprint. The sum of these footprints is the final water footprint accounting result.

Three different chains of water use can be identified and contribute to the quantification of the total water footprint of the object understudy:

- The blue water footprint: accounts for surface or groundwater withdrawn that is not returned to the same basin because of water evaporation, product incorporation or discharge in other catchment area; it is determined through the use of equation 1.1 and result in a balance of volume that enter and leave the system/process understudy (Hoekstra et al., 2011);

$$WF_{Blue} = Vin - Vout \qquad \text{eq. 1.1}$$

Where:

V_{in} is the volume of water entering the system expressed in m^3 or liters.

V_{out} is the volume of water discharged in the same catchment area of origin expressed in m^3 or liters.

- The green water footprint: is relevant to crop processes and refers to the measure of rainwater that once stored in soil undergoes evapotranspiration and therefore does not runoff and recharges the basin. See equation 1.2 (Hoekstra et al., 2011);

$$WF_{Green} = V_{evaporated} + V_{in\ product} \qquad \text{eq. 1.2}$$

Where:

$V_{evaporated}$ is the rainwater evaporated because of plant evapotranspiration process expressed in m^3 or liters;

$V_{in\ product}$ product is the volume of rainwater content of the product resulted from plant growth expressed in m^3 or liters.

- The grey water footprint: measures the level of pollution of discharge water through the adoption of a dilution approach (also known as distance to target approach) to quantify the volume of water whose quality is degraded due to pollutants emissions to water. In the case of several pollutants, the grey water footprint is calculated for each of the pollutants and the highest of the resulting values is selected. See equation 1.3.

$$WF_{Grey} = \max(WF_{Grey,i}) = max\left(\frac{L_i}{C_{max,i} - C_{nat,1}}\right) \quad \text{eq. 1.3}$$

Where:

L_i is the load of i-esime pollutant related to the volume of discharged water;
C_{max} is the max concentration of i-esime pollutant allowed by the reference system;
C_{nat} is the natural concentration of i-esime pollutant in the natural receiving body

The total water footprint is the result of the sum of the above mentioned indicators. Figure 1-6 represents the model described through the use of the above mentioned indicators. Blue and green indicators accounts for volume that does not recharge the water basin because of human interventions, however they do not report an impact assessment. Grey water can be considered an impact assessment method to represent degradation of water that occurs because of water use. However, as the method does not clearly define common standards for water quality the concept should be regarded as rather vague. Depending on the thresholds for pollutants chosen as common standards, the amount of grey water will vary substantially (Berger et al., 2010). An important improvement compared to virtual water is the inclusion of information on location and time of withdrawn and discharge. Even if not used to make analysis on impacts on scarcity they can give an idea if water withdrawn occurred in scarce region and period of dryness.

Several studies have been published on the application of Water Footprint. Most of these are focused on water intensive products such as food or energy (Mazzi et al., 2013). For example Ercin et al. (2012) performed a Water Footprint accounting at corporate level of a beverage company, including processes of the company and of its supply chain. These processes results to have the biggest contribution to the final water footprint. Another paper from Ercin et al. (2012) is focused on the water footprint of soy milk and soy burger produced from different raw materials (organic and non-organic soy) and origin (Canada, China, and France). The water footprint is represented at the level of accounting and a comparison between such products and their correspondent meat products is presented. This study confirms the importance of adopting a supply chain perspective when studying freshwater use.

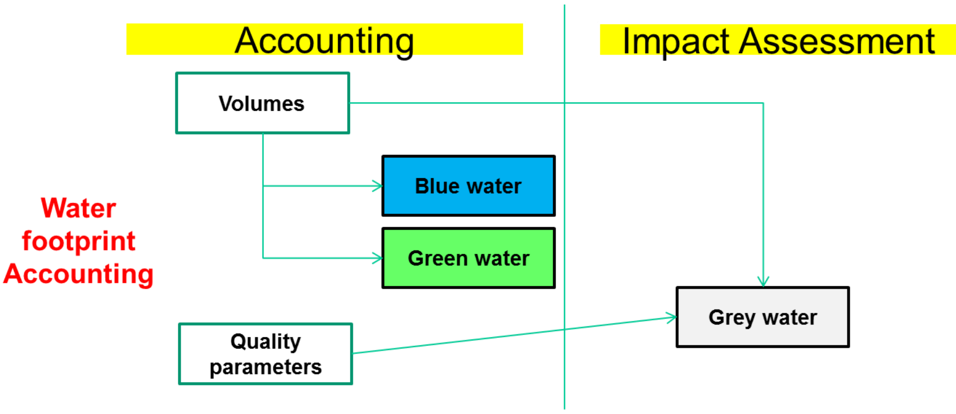

Figure 1-6 Water Footprint Accounting model

1.3.3.3 The Water Footprint Sustainability model

A further evolution of the Water Footprint Accounting concept from Hoekstra et al. (2011) has been published under the tool of Water Footprint Sustainability Assessment. It consists in a set of indicators pertaining to different sustainability categories such as environment, economy and social and is aimed on giving responses related to freshwater-use to be adopted by policy makers (Hoekstra et al., 2011). Analysis of economic and social impacts is out of the scope of the present research; therefore only indicators related to environment will be presented and discussed.

Water footprint Sustainability Assessment analysis on environments is built on the Water Footprint Accounting method; it considers the same application and adopts the same life cycle perspective, however it goes further using qualitative and quantitative information on locations and time to determine environmental impacts. The water footprint in a catchment is environmentally unsustainable and thus creates an environmental hotspot when environmental water needs are violated or when pollution exceeds waste assimilation capacity (Hoekstra et al., 2011).

A Water Footprint Sustainability Assessment is structured in 4 steps:

- the goal and scope definition: in which the objective and the subject of the study are clearly stated and determined;
- the Water Footprint Accounting: following the approach described in the previous chapter;
- the Water Footprint Sustainability Assessment: consists in the assessment of the contribution that blue and green has on scarcity footprint and the assessment of the Water Pollution level of local water basin; in the full method also indicator related to social and economic issues shall be considered;
- The Water Footprint Response formulation: is the analysis of results and definition of intervention strategies to improve water use sustainability.

In the Water Footprint Sustainability Assessment three impact indicators are defined:

- The blue water scarcity footprint (WS_{blue}): is the measure of the blue water compared to the blue water availability described through equation 1.4 in function of location x and time t (Hoekstra et al., 2011);

$$WS_{blue}\,(x,t) \;= \frac{WF_{Blue}\,(x,t)}{R_{nat}(x,t)-EFR(x,t)} \qquad \text{eq. 1.4}$$

Where:

WF_{Blue} (x,t) is the Blue Water footprint of the product/process/organization under study related to location x and time t expressed in m^3/time or liters/time;

R_{nat} (x, t) is the natural run-off in location x during the t time expressed in m^3/time or liters/time;

EFR (x,t) is the environmental flow requirement expressed in m^3/time or liters/time also defined as quantity and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems (Hoekstra et al., 2011).

The Blue Water Scarcity is expressed in %. Values over 100% mean an unsustainable use of water resources;

- The green scarcity footprint: is the measure of green water that is used with a rate over the local green water availability (Hoekstra et al., 2011). A green water scarcity of 100 per cent means that the available green water has been fully consumed. Scarcity values beyond 100 per cent are not sustainable;

$$WF_{Green}(x,t) = \frac{WF_{Green}\,(x,t)}{ET_{green}(x,t)-ET_{env}(x,t)-ET_{unprod}\,(x,t)} \qquad \text{eq. 1.5}$$

Where:

WF_{Green} (x,t) is the Green Water footprint of the product/process/organization under study related to location x and time t expressed in m^3/time or liters/time;

ET_{Green} (x, t) is the total evapotranspiration of rainwater from land in location x during the t time expressed in m^3/time or liters/time;

ET_{env} (x, t) is the evapotranspiration from land reserved for natural vegetation in location x during the t time expressed in m^3/time or liters/time;

ET_{unprod} (x, t) is the evapotranspiration from land that cannot be made productive in location x during the t time expressed in m^3/time or liters/time;

- The Water Pollution level (WPL): measure the level of pollution of discharge water in location x during t time. When the water pollution level exceeds 100 per cent, ambient water quality standards are violated. See equation 1.6

$$WPL = \frac{WF_{Grey}(x,t)}{R_{act}(x,t)} \qquad \text{eq.1.6}$$

Where:

WF_{Grey} (x,t) is the Grey Water footprint of the product/process/organization under study related to location x and time t expressed in m^3/time or liters/time;

R_{act} (x, t) is the actual run-off in location x during the t time expressed in m^3/time or liters/time;

Figure 7 represents the model that lies behind the methodology of the water Footprint Sustainability Assessment. Adding specific parameters on scarcity makes these indicators suitable for an impact assessment responding also to time-related and geographical-located specific characteristics. Water Footprint Sustainability Assessment is recognized to adopt consumption to availability approach using water consumptions indicators characterized with local geographical conditions giving also time values that can be represented on a month basis.

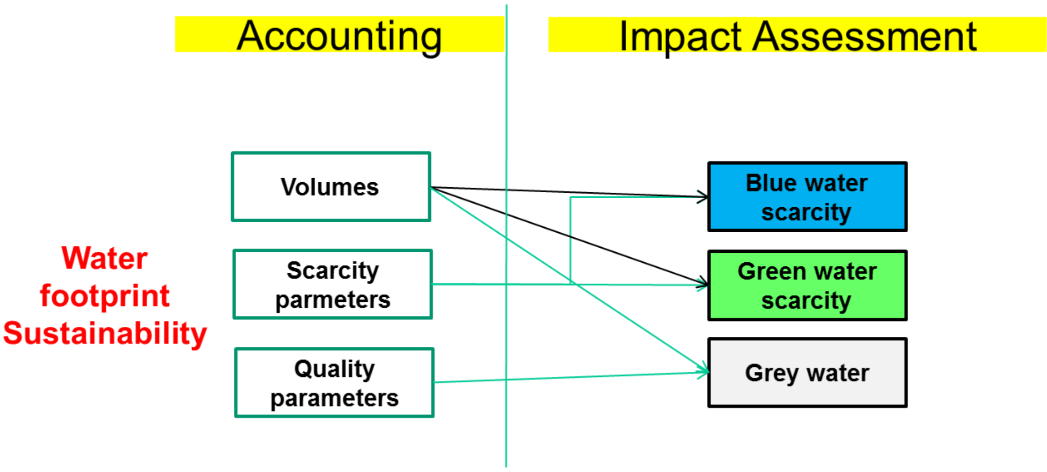

Figure 1-7 Water Footprint Sustainability Assessment Model

Limited application of this method is presented in literature due to the complexity of considering a full range of aspects such as economic and social ones. However some relevant experiences at product level focusing on environmental aspects have been published. Chapagain and Orr (2010) presented the water footprint of an industrial food product: the Nestlé's 'Bitesize Shredded Wheat' that was used as pilot study to develop Water Footprint methodology presented by Hoekstra et al. (2011). The study performs the so called sustainability assessment limited to the water scarcity issue. Manzardo et al. (2012) has recently presented a case study where two different approaches in assessing water footprint of an organic strawberry jam pot are adopted: the one from Hoekstra et al. (2011) and the one from Ridoutt et al. (2010). In this case the water footprint accounting and scarcity assessment have been performed including all the ancillary processes and products (such as packaging transportation, etc.). Such processes resulted to have a relevant contribution to final product water footprint therefore it confirms the need of adopting life cycle perspective when looking at the impacts related to water.

The Water Footprint Sustainability assessment has the merit to advance the analysis toward the assessment of impacts related to water. However it presents some limits: it does not assess the comprehensive spectrum of environmental impacts related to water such as eutrophication, eco-toxicity and acidification (ISO, 2013a; Ridoutt et al., 2010; Jeswani and Azapagic, 2011); the WPL answer needs to have a measure of degradation footprint, however it does not represent environmental impacts such as scarcity, moreover it does not give guidance on standard parameters to be used as reference for the assessment, therefore results are usually subjective (Jeswani and Azapagic, 2011); even if the environmental relevance of the green water scarcity footprint is not confirmed, It may be relevant in some cases when land use change occurred (ISO, 2013b), however no methods are able to address these changes therefore green water is usually not well accepted in the literature (ISO, 2013a).

1.3.2.4 The Water Footprint within Life Cycle Assessment model

Latest development of the Water Footprint concept took place within the Life Cycle Assessment framework (ISO, 2006; 2013a). LCA methodology, established in the early sixties in order to study the energetic burdens associated with certain industrial products (Hunt and Franklin 1996), has evolved over the years to be today the most comprehensive method of potential environmental impacts assessment of products, services, process or organization adopting a life cycle dimension (ISO 2006). Environmental impact assessment methods developed to be applied within LCA ,only partially addressed water issues in the past, focusing only on water quality degradation indexes such as eco-toxicity (Hauschild and Wenzel, 2002; Rosenbaum et al., 2008), eutrophication (Bennet et al., 2001; Hauschild and Wenzel, 2002; Goedkoop et al., 2012) and acidification (Hauschild and Wenzel, 2002; and Jolliet et al., 2003). The introduction of Water Footprint concept within the LCA methodology is intended to complement and enhance life cycle impact assessment (LCIA), and to obtain a more complete estimate of life cycle impacts on water introducing methods to address the issue of water scarcity. In the past few years, to address this challenge, several studies have been published. The United Nationa Environmental Program (UNEP) and the Society for Environmental Toxicology and Chemistry (SETAC) Life Cycle Initiative in 2007 launched the Water Use within LCA project (WULCA) whose goal focuses on providing practitioners, from both industry and academia, with a coherent framework within which to measure, assess and compare the environmental performance of products and operations regarding freshwater use (Koehler and Aoustin, 2008). According to this framework, published methods related to freshwater use can be categorized according to type of water use or level of assessment (ISO; 2006; Pfister et al. 2009; Bayart et al. 2010; Kounina et al; 2012). Table 1-2 reports on the definition of such categories. Description of the most significant published methods within these categories will follow, discussing on their limits.

Table 1-2 Categorization of LCA methods related to freshwater use

Categorization parameter	Category	Definition
Type water use	Freshwater Consumptive use	use of freshwater when release into the same watershed does not occur because of evaporation, product integration, or discharge into different watersheds or the sea
	Freshwater degradative use	withdrawal and discharge into the same watershed after the quality of the water has been altered
	Freshwater Depletion	Net reduction in the availability of freshwater in a watershed for a given time period. It covers fossil aquifers and flow and fund resources exploited over their renewability rate
Level of assessment	Inventory	Collection of system input and output to be used for the assessment of inventory or impacts assessment indicators
	Mid-point impact assessment	Indicators to address risks related to freshwater use such as scarcity or other environmental impacts related to water quality degradation
	End-point impact assessment	Indicators to address damages that results on three different area of protection (Human health, ecosystems, abiotic resources) from environmental impacts

Inventory

The objective of the inventory is to collect and organize input and output data-system to allow subsequent assessment of impacts or other aspects that allows interpretation of environmental issues related to water availability. In the case of water several Inventory methods have been published. Milà I Canals et al. (2009) propose a method to account all off -stream and in-stream water use that allows quantification of consumptive water use, identify several water categories but does not allow to deeply investigating loss in functionality of degradative use; information on quantity and origins are used but no complete information on quality aspects. Peters et al. (2010) define that water should be considered ‘used’ in the production of goods when it is delivered by unnatural means or it leaves the production site at a lower quality, however such methods is based more on a volume balance perspective and does not allow clear understanding of qualitative aspects. Boulay et al. (2011a) suggests classifying water according to 8 categories representing different quality and answering different needs. This method consider volumes of withdrawn and discharged water and quality through a classification that depends also on origin; it is therefore considered to be the more comprehensive one (Kounina et al., 2013), however it does not include inventory indicators to allow a first screening analysis, recommended for study effectiveness (ISO, 2013). Also Water Footprint accounting method according to Hoekstra et al. (2011) described above is recognized to be an inventory method. Compared to these inventory methods, it has the advantage of clearly defining inventory indicators that are recognized to be useful in water management (Boulay et al., 2013), however presents several limits (Jeswani and Azapagic, 2011) (e.g. grey water definition). Table 3 categorizes such methods with reference to their contribution to the impact chain. Method proposed from Boulay et al. (2011a) is recognized to be the more complete one.

Table 1-3 Categorization of Inventory methods

Categorization parameter	Category	Milà I Canals et al. (2009)	Peters et al. (2010)	Boulay et al., 2011A	Hoekstra et al. (2011)
Type of water use	Freshwater Consumptive use	X	X	X	X
	Freshwater degradative use			X	X
	Freshwater Depletion			X	X

<u>Mid-point</u>

At mid-point level we can identify several methods starting from the Building Swiss Ecological Scarcity (Frischknecht et al. 2006) that however considers only water withdrawal therefore not allowing any impact assessment related to consumptive, degradative use or water depletion. Pfister et al. 2009 propose a method that allows midpoint assessment of water scarcity from consumptive water use and that is made also operative for endpoint assessment. It uses a Water Scarcity Index that considers local availability and temporal variation over time of the year allowing therefore a first assessment of dry and wet periods This index uses a modified withdrawal to hydrological availability factor (WTA*) (calculated as a criticality ratio), which differentiates watersheds with strongly regulated flows (SRF). WTA* introduces a variation factor (VF) which takes into account insufficient water storage capacities or lack of stored water in case of increased water scarcity during specific periods due to both monthly and annual variability of precipitation.

$$WTA^{*} = \sqrt{VF} \times WTA \; for \; SRF \qquad \text{eq. 1.7}$$

$$WTA^{*} = VF \times WTA \; for \; non - SRF \qquad \text{eq.1.8}$$

The formula proposed by Pfister et al. (2009) to calculate the adapted Water Scarcity Index (WSI) is depicted in Equation 1.9 (see Pfister et al. 2009, to see how to evaluate the modified annual freshwater withdrawals to hydrological availability of a specific watershed (WTA*)).

$$WSI = \frac{1}{1 + e^{-6.4 \cdot WTA^{*} \cdot \left(\frac{1}{0.01} - 1\right)}} \qquad \text{eq. 1.9.}$$

The consumptive water use impact on local scarcity can be determined using these factors. An evolution of this method is the one presented by Ridoutt and Pfister (2010): they apply WSI also to the grey water footprint (determined according to Hoekstra et al. 2011) therefore allowing for a first analysis of water degradation effects on scarcity. Another mid-point method is the one proposed by Mila I Canals 2009 and is developed on the inventory method described above. It introduces two midpoint impact categories: the freshwater ecosystem impact (FEI) and the freshwater depletion (FD). It focuses on impact from surface and groundwater evaporative use and land use transformation; however it presents an evident limit by considering only the water evaporated excluding other water uses. FEI take into consideration impacts related to scarcity allowing for the use of different characterization factors/water stress indexes (Falkenmark et al. 1989; Raskin et al. 1997; Smakhtin et al. 2004). The last method to be presented is the one from Boulay et al (2011b). This takes into consideration consumptive and degradative aspects into one single indicator. Equation 1.10 reports on the method called Water Scarcity Indicator. One of its strength is that allows for complete endpoint assessment for the different endpoint area of protection. This indicator is called Water Stress Indicator (WSI).

$$WSI = \propto_{in} \times V_{in} - \propto_{out} \times V_{out} \quad \text{eq. 1.10}$$

α is distinct for different water categories previously described in the inventory method , and is null for water of quality as low as seawater. For surface water, α is based on the CUs/Q90 proposed by Döll 2009 where CUs is the surface water consumed and Q90 is a “statistical low flow” accounting for seasonal variation. For groundwater, it is similarly CUg/GWR, where CUg is the groundwater consumed and GWR is the availability of groundwater resource. These ratios are then adapted to include the local water quality availability based on available data from GEMStat database. This is considered to be a useful indicator,however it presents some representation limits; it is not able to distinguish contribution from degradative and consumptive water use. A recent paper published from Zeng et al (2013) confirms once again the importance of considering both degradative and consumptive water use and to characterize them in a simple way. A method is presented to characterize blue and grey water based on Hoekstra et al. (2011), and present similar limits.

Table 1-4 Categorization of Mid-point impact assessment methods

Categorization parameter	Category	Frischknecht et al. (2006)	Pfister et al. (2009)	Milà I Canals et al. (2009)	Ridoutt and Pfister (2010)	Boulay et al. (2011b)	Zeng et al. (2013)
Type of water use	Freshwater Consumptive use	X partially	X	X partially	X	X	X
	Freshwater degradative use			X	X	X	X
	Freshwater Depletion			X			

End-point

Endpoint methods refer to the end of impact assessment chain that represents consequences of freshwater use in three different areas of protections known as human health, ecosystems and resources. The first fully operative end-point methods are present by Pfister et al. (2009). It is based on Ecoindicator 99 (Goedkoop and Spriensma 2001). Human health impacts are modelled starting from freshwater scarcity assessed through water scarcity index covering the water deprivation for agriculture use leading to malnutrition. For ecosystem quality, net primary production (NPP) which is limited by water availability is modeled through the dependency of vascular plant species biodiversity (VPBD) on water resource, as NPP and VPBD are assumed to be significantly correlated. In the case of resources it adopts the concept of back-up technology assuming that consumptive water use, stressed through the WSI, can be compensated by desalination of sea salt water. Regionalization is possible at the watershed, country and supranational level. Pfister et al. (2009) provide characterization factors at the country level but also at the watershed level. The units with which the impacts are assessed are DALY, PDF·m^2·y and MJ surplus energy for human health, ecosystem quality and resources respectively. This method received critics related to the way impacts on resource are determined. Equation 1.11 represents the indicator to determine impacts related to resources according to Pfister et al. (2009).

$$\Delta R = E_{desalination} * WSI * (V_{out} - V_{in}) \qquad \text{eq. 1.11}$$

ΔR is the surplus energy required to compensate the consumptive water use related to the unit process understudy. WSI is the water scarcity index according to Pfister et al (2009). $E_{desalination}$ is the surplus energy determined through the application of LCA approach to a generic Desalination plant using Cumulative Energy Demand method (Huijbreghts et al, 2006; Scipioni et al., 2012).

Two main limits of this method emerge: desalination plants are not available and cannot be applicable everywhere in the world; in this case we cannot understand local impact on resources. Moreover effects of degradative water use are not considered (Jeswani and Azapagic, 2011) giving only a partial view of impacts related to water use. Another method has been published by Motoshita et al. (2010a; 2010b). This method fully addresses the consumptive and degradative water use to the Human health area of protection; the former is considered through the relationship between agricultural water use, crop productivity and the undernourishment damage related to the change of food consumption. The latter is considered by correlating oral intake of unsafe water with water scarcity assuming that water scarcity lead to limited safe water accessibility). The method provides country-based characterization factors, expressed in DALY per m^3 of water consumed. Boulay et al. (2011b) method to assess Human Health impacts is built on the midpoint category Water Stress index, the main innovation introduced by this method is the consideration of the adaptation capacity and the partition of freshwater use impacts between the impact pathways leading to human health impacts, and the impact pathways leading to compensation (Kounina et al. 2013). Boulay et al. (2011b?) provide country and watershed-based characterization factors, expressed in DALY per m3 of water used for the impacts from malnutrition, aquaculture and domestic uses. The lLast methods developed in literature refer to ecosystem area of protection. Hanafiah et al. (2011) links green-house gas emission and relevant climate changes to water consumption allowing for the evaluation of fish species disappearance; 214 river basins were considered. Zelm et al. (2011) consider the effect that water withdrawal has on lowering groundwater tables and the following disappearance of terrestrial plant species. Table 1-5 represent categorization of developed methods studied.

Table 1-5 Categorization of End-point impact assessment methods

Categorization parameter	Category	Pfister et al. (2009)	Motoshita et al. (2010a; 2010b)	Boulay et al. 2011	Hanafiah et al. (2011)	Van Zelm et al. (2011)
Type of water us	Freshwater Consumptive use	X	X	X	X	X partially
	Freshwater degradative use	X partially	X	X		
	Freshwater Depletion	X partially				

When focusing on the end-point impact assessment methods, is relevant to understand their coverage of the different Are of Protections (Table 1-6).

Table 1-6 Categorization of End-point impact assessment methods

Categorization parameter		Pfister et al. (2009)	Motoshita et al. (2010a,; 2010b)	Boulay et al. 2011	Hanafiah et al. (2011)	Van Zelm et al. (2011)
Area of protection	Human Health	X		X		
	Ecosystems	X			X	X
	Resources	X				

According to literature review (Kounina et al. 2013) if impacts related to water resulting in damages to human health and ecosystems are fairly covered, damages to resource end point category is not, therefore further research is needed (Kounina et al. 2013). Figure 8 represents the general model of impacts related to water within the framework of LCA showing that impacts chain related to resource category is still to be investigated.

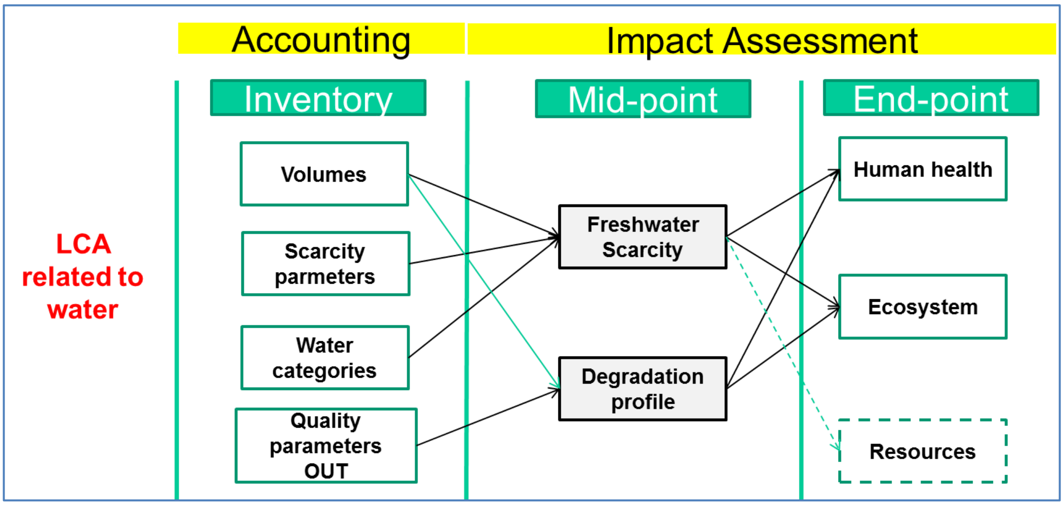

Figure 1-8 LCA model related to water

Some applications of LCA method related to water impacts have been published in several different sectors. Jeswani and Azapagic (2011) consider the corn-derived ethanol produced in 12 countries and discusses different methods for inventory modelling and impact assessment for water use in life cycle assessment. The paper compares the impacts of freshwater consumption in the different countries: the results show a huge variation between different methods and demonstrate the need for a standardized methodology to assess the impacts of water use on a life cycle basis. Berger et al. (2012) applied LCA to address the impacts that European cars have on water to identify hot-spot related to water. Production processes had the biggest impacts on water consumption but other processes such as metals extraction have relevant impacts on other aspects such as ecosystems. This study confirms the importance of comprehensiveness. Pfister et al. (2011) applied LCA methods related to water to global power production confirming that this sector is one of the most water intensive one. Stoessel et al. (2012) applied LCA method including impacts related to water to the production of different food products. Results of this study were used by the retailer to support the purchasing decisions and improve the supply chain management, proving that Water Footprint within LCA can contribute to supply chain efficiency and therefore companies' competitiveness. Jefferies et al. (2013) presented a study to compare different methods proving that water footprint accounting can support better management of water but impact assessment is mandatory to prevent damages to humans and ecosystems.

1.4. Research needs and limits of current models

According to literature review presented in previous paragraphs, several methods belonging to different models are available to cover impacts related to freshwater use. From the application of these methods significant limits emerged negatively impacting on the competitiveness of companies (ISO, 2013). To make the assessment and reporting of water related impacts more transparent, ISO launched in 2008 a process of standardization called "Environmental management — Water footprint — Principles, requirements and guidelines" (ISO, 2013). Actually in the DIS stage (discussion paper available for stakeholder's consultation) it gives the principles and framework to perform a Water Footprint study applicable to products, processes and organization. Water Footprint according to ISO 14046 is a method that complement LCA standards ISO 14040 (ISO, 2006) covering specific environmental concerns related to water such as availability and scarcity. In fact, historically speaking, LCA methodology underestimated impacts related to freshwater use (ISO, 2013) showing limits at inventory, midpoint and end point assessment level (Mazzi et al., 2013); focusing on methods, even if effects of degradative water use are partially covered through eutrophication, eco-toxicity, acidification, there is no clear method that specifically address the impacts related to scarcity (Zeng et al., 2013)

According to UNEP-SETAC WULCA initiative (Bayart et al., 2010) and other important references (Berger and Finkbeiner, 2010; Kounina et al., 2013; Boulay et al., 2013), research for new models related to water, shall be developed within ISO 14046 general framework therefore respecting principles and characteristics reported in table 1-7.

Table 1-7 ISO 14046 framework to be considered in method developments

	Definition
Life Cycle perspective	All stages of the life cycle of products/processes from raw materials to the end of life or all the activities of the organization shall be considered.
Environmental focus	All potentials environmental impacts related to water shall be considered
Transparency	Sufficient and appropriate information is disclosed in order to allow users of the water footprint assessment to make decisions with reasonable

	confidence
Completeness	All data which provide a significant contribution to the water footprint are included in the inventory.
Comprehensiveness	A water footprint considers all environmentally relevant attributes or aspects of natural environment, human health and resources related to water (including water availability and water degradation).
Geographical aspects and resolutions	The water footprint assessment is conducted at a scale and resolution (e.g. a drainage basin, a catchment, or even a sub-catchment), which gives relevant results and takes into account the local context.

Table 1-8 casts the light to the limits of current methods and models when compared to the framework of 14046. Such limits emerged from literature review presented in previous paragraphs.

Table 1-8 Limits of published models

	Virtual Water model	Water Footprint Accounting model	Water Footprint Sustainability Assessment model	Life Cycle Assessment model
Life Cycle perspective	Covered	Covered	Covered	Covered
Environmental focus	Limit emerged: No impacts are considered	Limit emerged: only grey water can be considered a potential impact assessment;	Covered	Covered
Transparency	Limit emerged: no information on degradative aspects	Limit emerged: there is no clear definition of limits to be considered in grey water assessment; no sufficient information to make decisions	Limit emerged: different indicators for different contributions; however only limited information on degradative water use: no availability and other water quality related indicators.	Limit emerged: methods at midpoint level usually address degradative and consumptive water use with only one indicator not allowing understanding the contribution of these two aspects to water footprint.
Completeness	Limit emerged: no information on degradative aspects	Limit emerged: no information on different water use and user affected at the level of inventory; impact assessment partially covered;	Limit emerged: no information on different water use and user affected at the level of inventory; impact assessment partially covered;	Limit emerged: several methods exist however no method fully cover relevant information (e.g. quality parameters, use and user category, inventory indicators for first screening)
Comprehensiveness	Limit emerged: several environmentally relevant attributes or aspects (e.g. eutrophication) are not considered	Limit emerged: several environmentally relevant attributes or aspects (e.g. eutrophication) are not considered	Limit emerged: several environmentally relevant attributes or aspects (e.g. eutrophication) are not considered	Limit emerged: methods relate to resource do not consider contribution from degradative water use; no methods on water depletion are recognized to be fully operatives
Geographical aspects and resolutions	Limit emerged: only qualitative information considered	Limit emerged: only qualitative information considered	Covered	Limit emerged: methods related to endpoint category resources are not regionalized

1.5. Research objectives

According to the limits described in table 1-8, and considering the previous theoretical and operative experiences, the need to develop new models to assess environmental impacts related to water clearly emerges. According to the framework of ISO 14046, the most relevant research needs can be summarized as reported on table 1-9.

Table 1-9 Research needs on impact assessment model related to water

Life Cycle Assessment Step	Research needs
Inventory	Make available a complete and detailed inventory to support comprehensive assessment of impacts related to water; define inventory indicators to clearly represent consumptive and degradative water use.
Mid-point assessment	Develop methods to separately and clearly address how consumptive and degradative water use affect scarcity in order to guarantee comprehensiveness
End-point impact assessment	Need to fully regionalized impacts assessment methods on resources considering also effects of degradative water use

According to the limits and research needs emerged from literature review, the present research had the objective to contribute to the definition of a new model to achieve water saving as a competitive tool for companies through:

1. the definition of a set of indicators to integrate the framework of LCA and ISO 14046 and provide solutions to solve the identified limits at inventory, mid-point, end-point levels;
2. the verification of the applicability of the developed set of indicators in real case studies testing their effectiveness in measuring the performance of life cycle processes related to water.

2. Materials and methods

2.1. Research structure

According to the formulated objectives, this research is quantitative and confirmative; the research method is the multiple case study analysis. This approach is widely adopted in literature in this field. Choice of case studies is based on requirements determined in chapter 2.4.

Research is based on primary data collected directly from companies working in the life cycle of the products studied and secondary data coming from databases recognized by LCA community, statistical data published by authoritative institutions (e.g. end of life products treatment national statistics) and data published in peer review papers. During the description of each case studied origin of data will be detailed.

To answer the research objectives, this study referred to consolidated tools and recommendations described in the present chapter.

2.2. General methodological framework: Water Footprint study

According to the research development framework described in the previous chapter, the research presented in this study followed the structure of ISO 14046 (ISO, 2013) for the assessment of Water Footprint within LCA and therefore ISO 14040 (ISO, 2006). All the case studies that are considered in this research will be presented according to the requirements of ISO 14046. Decisions to use this methodological framework rely on the following reasons:

- Most relevant water related methods developed in recent years, refer to the concept of Water Footprint within LCA (Kounina et a., 2013);
- ISO 14046 (ISO, 2013) investigates the regional, international-global and life cycle dimensions that resulted to be significant according to literature review (Lundqvist et al., 2008; Ridoutt and Pfister, 2010; Hoekstra, 2011);
- Study according to ISO 14046 is based on an international agreed process of standardization.

To support a better comprehension of research results, in this paragraph the steps followed for the conduction of the research are presented and described.

ISO 14046 define a water footprint as a metric(s) that quantify(ies) the potential environmental impacts related to water. The Water Footprint study has 4 steps: goal and scope definition, water footprint inventory analysis, water impact assessment and interpretation (fig. 2.1)

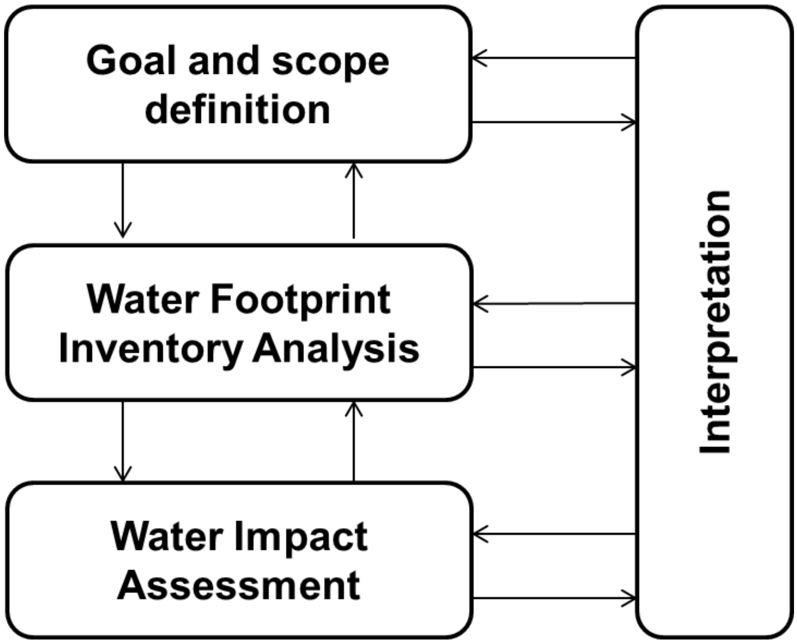

Figure 2-1 Water Footprint Study structure

The goal and scope stage is the first step of the Water Footprint assessment. Several important aspects of the study are defined at this stage; the goals of the study should cover issues such as the reasons for carrying out the study, the intended application and intended audience; the scope of the study includes the definition of the functional unit (unit used as reference that answer to the question: which is the function of the system understudy?), the reporting flow (e.g. unit of mass to which the impacts are reported), selection of impact assessment methods to be applied and therefore impacts covered through the assessment, the data quality requirements and data to be considered for collection (e.g. local conditions, geographic location, seasonal aspects etc.) the system boundaries (all the processes included in the study and any exclusion). Choice of system boundaries can be based on three different perspectives:

- Life cycle perspective: also known as from cradle to grave. In this case all input and output and elementary from the extraction of raw materials till the end of life management should be considered;
- Cradle to gate: following this approach all input and output and elementary flows from the extraction of raw materials to one of the life cycle stages (e.g. excluding processes after the company gate) should be considered;
- Gate to gate approach: in this case, the study can be focused only on one or few life cycle stages such as specific processes of a company part of the value chain.

The Water Inventory analysis refers to the data collection activities. In this stage all inputs and outputs related to water of the processes included in the system boundaries shall be considered. Following practices related to water footprint study inventory analysis (Ercin et al., 2012; Berger et al., 2012; Jefferies et al., 2013), several types of data and information can contribute to the inventory stage and can be grouped in elementary flows, inventory calculation and inventory indicators results (table 2.1)

Table 2-1 Inventory data classification

Group	Description
Elementary flows	Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation (ISO, 2006).
Inventory calculation	Quantification of relevant input and outputs of the system understudy (ISO, 2006)
Inventory indicator results	Indicators to aggregate inventory data without representing impacts that can be used for inventory analysis and related impact assessment.

These data and information are referred to the so called unit process or the smallest element considered in the life cycle inventory analysis. In LCA a unit process can be represented a black box in which inputs are elaborated into outputs (Heijungs and Guineè, 2012)

In this stage data have to be validated according to requirements determined in goal and scope definition. Data collected can also be grouped in two families (ISO, 2013): primary data, collected with direct measure of the system understudy; secondary data: these include data from databases or estimation based on published data. In this research elementary flows, inventory calculation and inventory indicators result will be presented for each of the case studies used. According to the objectives of the research the inventory analysis will include the assessment and discussion of inventory indicators developed.

Water impact assessment is the stage of the water footprint study where inventory data are used to determine environmental impacts related to water according to the methods chosen in the goal and scope definition (ISO, 2013). Impacts are determined through the use of parameters that allow the calculation of impacts assessment results at two different levels: mid-point assessment and endpoint assessment. The former allows a quantification of potential risks referred to environmental impacts related to water; characterization factors are used to convert inventory indicator results into impacts belonging to specific impacts categories. The latter support analysis of impacts related to water in term of damages in three area of protection: human health, ecosystems and resources. According to the objectives of the research a comprehensive impact assessment related to water will be performed at mid-point level; end-point level assessment will be focused on resource category. This assessment will be conducted according to the new set of indicators developed to overcome limits emerged from literature review.

Interpretation stage is the last step of the water footprint study according to ISO 14046 (ISO, 2013) and includes the analysis of inventory and impact assessment results and formulation of strategies and recommendation for performance improvement (ISO, 2013). This stage should also include the analysis of different processes contribution to identify environmental hot-spot, the analysis of data and results, consideration on assumptions and related limitations (ISO, 2013). This stage is recognized to contribute to performance improvement and therefore competitiveness of companies (Boulay et al., 2013). Interpretation of results is performed for all of the case studies included in this research.

2.3. Criteria used in the definition of the set of water use indicators

To determine the set of indicators to integrate the framework of LCA and solve identified limits at inventory, mid-point, and end-point level the criteria and requirements of UNEP-SETAC WULCA initiative (Bayart et al., 2010) reported in this paragraph, have been considered. This framework has been chosen because it is the result of a process of consensus among several researcher working ion the modelling of water use related impacts (Bayart; 2010; Heijungs and Guineè, 2012)

Off-stream freshwater use shall be considered when developing impact assessment methods because it can result in reduced water availability. Two different typology of freshwater use can be identified and shall be considered:

- Consumptive water use: use of freshwater when release into the same watershed does not occur because of evaporation, product integration, or discharge into different watersheds or the sea (Bayart et al., 2010);
- Degradative water use: withdrawal and discharge into the same watershed after the quality of the water has been (Pfister et al., 2009).

To develop water-use indicators at inventory level the following criteria are adopted (Bayart et al., 2010):

- The objective of the inventory stage is the analysis of the consumptive and degradative water use to support the quantification of changes in freshwater availability at mid-point level (Pfister et al., 2009);
- Resources should be classified considering their origin (e.g. groundwater or surface-water) and resource quality (e.g. suitable for industrial use, agriculture use);
- Information of quality of water entering the system should be included;
- Information on quantity leaving the system should be included;
- Inventory should make possible to express the change in availability for different water types;
- Regionalization should be included;

To develop water use indicators at mid-point level the following criteria are adopted (Bayart et al., 2010):

- Should measure change in water availability resulting in increased competition for freshwater resources for present generations and ecosystems and water depletion for future generations;
- Results should be expressed in volumes of water equivalent ($m^3_{equivalent}$ or $l_{equivalent}$);
- Different water types should be weighted considering different parameters in function of either the water type or the water quality;
- State of freshwater scarcity in the area should be considered;
- Time and seasonality aspect should be considered;
- Distance to target approach or functionality approach should be considered when assessing degradative water use;

To develop water use indicators at end-point level with specific reference to resource area of protection, the following criteria are adopted:

- Results should be translated in non-renewable primary energy needs;
- Use of back-up technology should be adopted;
- Results should be expressed following the concept of surplus energy (additional quantity of energy needed to extract non-renewable resources;
- Regionalization at end-point level is necessary.

2.4. Definition of the set of water use indicators

2.4.1 Inventory indicators

ISO defines the inventory analysis (LCI) as the phase of LCA study involving the compilation and quantification of inputs and outputs for all the processes involved in the life cycle of a product. This take place through the collection of elementary flows, the calculation of data and the quantification of indicators results, classification of information and quantification of information are performed.

The proposed inventory indicators set is built on the most representative experiences emerged from literature review on inventory related to water and the recommendation of UNEP-SETAC WULCA presented in the previous chapter.

According to literature review current operative methods related to water are based on the inventory information represented in table 2-2 where an example of an apple growing process is presented (Ecoinvent, 2010).

Table 2-2 Inventory data current approach

Unit process	Volume in	Water quality out (Q_{out})	Emissions to the atmosphere
Apple growing	134 liters	e.g. 30 mg/l of N	e.g. 30 g/m3 NOx; 100g CO2

Quality parameters related to water exiting the unit process and emissions are reported separately for each pollutant released and usually expressed in mg/l or g/m3.

As confirmed by literature review such an inventory allows quantification of volume of water entering the system and water quality degradation indicators deriving from emissions to air and water. Such information are therefore necessary to make methods related to water operative and also partially address the requirements of UNEP_SETAC WULCA (Bayart et al., 2010) with specific reference to water quality out and water volumes entering the systems. Therefore this information is included in the proposed inventory.

Recent publication from Boulay et al. (2011b) integrate this framework adding important information that goes in the direction of answering to the need of making available sufficient information for the quantification of water scarcity adopting a functionality perspective. Table 3-2 reports additional information introduced by Boulay et al. (2011b) to integrate inventory framework presented in chapter 2.3.

Table 2-3 Inventory data integrated by Boulay et al. (2011b)

Unit process	Volume in	Volume out	Water quality in (Q_{in})	Water quality out (Q_{out})
Apple growing	134 liters	34 liters	S1	G3

This inventory allows a more complete set of analysis adding relevant information. Its peculiarity is represented by the introduction of a classification based on water origin (G per groundwater and S per surface water) and also water quality (numbers from 1 to 5) that respond to specific user category. These water categories are reported in table 2-4.

Table 2-4 Water Categories (Boulay et al., 2011b)

	1	2a	3b	3c	3d	4	5	6
Water Quality/Water Use	Excellent	Good	Average	Average (High toxicity, low coliform count)	Average (Low toxicity, high coliform count)	Poor	Very Poor	Unusable
Domestic 1								
Domestic 2								
Domestic 3								
Agriculture 1								
Agriculture 2								
Fisheries								
Industry								
Cooling								
Recreation								
Transport								
Hydropower								

According to UNEP-SETAC WULCA recommendations, however some aspects need to be improved. The first one is the information of water quality entering the system. Classification allows a functionality approach to treat degradative water use, however they do not allow the application of all related methods at mid-point level such as the one proposed by Hoekstra et al. (2011). Therefore water quality parameters of water entering the system are considered in the proposed inventory method.

Qualitative information on location is also to be included in order to allow regionalization at mid-point and end-point assessment.

To address the objective of water inventory according to UNEP-SEATC and Pfister et al. (2009) that is to represent the contribution of consumptive and degradative water use and two support the quantification of changes in freshwater availability at mid-point level, two indicators are introduced, respectively named Consumptive Water Use of t-esime process (CWU_t) (eq. 2.1) and Degradative Water Use of t-esime unit process (DWU_t) (eq. 2.2).

$$CWU_t = V_{in,t} - V_{out,t} \qquad \text{eq. 2.1}$$

Where:

$V_{in,t}$ is the volume of water entering the t-esime unit process understudy;

$V_{out,t}$ is the volume of water exiting the t-esime unit process understudy.

The total CWU of the product understudy is the sum of all the CWU_t reported to functional unit.

This indicator adopts the same formulation of blue water introduced by Hoekstra et al. (2011) to address the volume of resource that is not returned back to the location of origin therefore resulting in a change of local water availability. Total CWU can be expressed in liters or m^3.

$$DWU_t = jV_{out,t} \qquad \text{eq. 2.2}$$

Where:

Parameter j is 0 in the case that no water degradation occurred, is 1 if quality parameters of water out results in a loss of functionality according to water categories presented by Boulay et al. (2011). DWU is developed to represent volume of water that is degraded and as such is not available for the use it had entering the system. DWU can be expressed in liters or m^3.

The total DWU of the product understudy is the sum of all the DWU_t reported to functional unit.

Complete inventory related to water, following recommendation from UNEP-SETAC community is presented in table 2-5.

Table 2-5 Inventory data developed structure

Unit process	Volume in	Volume out	Water quality in (Q_{in})	Water quality out (Q_{out})	Emissions to the atmosphere	j	CWU	DWU
Apple growing	134 liters	34 liters	G2; e.g. N 30 mg/l, P10 mg/l	S1; e.g. N 300 mg/l, P25 mg/l	e.g. 30 g/m3 NOx; 100g CO2	1	100 liters	34 liters

2.4.2 Mid-point indicators

Life cycle impact assessment is a stage of LCA methodology in which inventory results are further developed into assessment of potential environmental impacts (Margni and Curran, 2012). This includes in particular a better comprehension of consequences related to the use of resources and environmental releases. It is therefore used to understand contribution and significance of the impacts associated with products and processes.

According to literature review impacts related to water should be modelled at the mid-point level considering degradation of the resource and consumption of the resource. Methods resulted to lack in comprehensiveness, not considering impacts on availability of water resource (Bayart et al.

2010; Margni and Curran, 2012; ISO, 2013) not clearly showing contribution from degradative and consumptive water use to availability.

To address this issue a new method is developed and new indicators are introduced. These are called: Scarcity Consumptive Water Use (SCWU), Scarcity Degradative Water Use (SDWU), and Water Stress Indicator (WSI). These indicators, following the principle of life cycle impacts assessment, are grounded on information and data collected in the inventory stage.

Scarcity Consumptive Water Use of the t-esime unit process ($SCWU_t$) represents the contribution of consumptive water use to local scarcity. It can be defined as follow:

$$SCWU_t = \propto_{in,t} * CWU_t \qquad \text{eq. 2.3}$$

Where:

CWU_t is the consumptive water use of the t-esime unit process presented in the previous chapter and expressed in liters or m^3.

$\alpha_{in,t}$ is the characterization factor that represent local water scarcity in the region were water is withdrawn of the t-esime unit process. $\alpha_{in,t}$ is is determined according the water scarcity factors developed by Boulay et al. (2011b) and expressed either in [l_{eq}/l] or [m^3_{eq}/m^3]. This reference was chosen because it allows quantification of local scarcity parameters developed at watershed level and because represents the level of competition among users due to the physical stress of the resource, addressing quality and seasonal variations and distinguishing surface and groundwater. This answer a functionality approach recommended by UNEP-SETACS WULCA, availability of water depends on the water category presented in previous chapter: the less functional water is, the more abundant it will be. α_{in} refers to the scarcity of water entering the system because through consumptive water use, the availability of that specific water type is affected.

SCWU is expressed in liters equivalent (l_{eq}) or m^3 equivalent (m^3_{eq}) of water.

The total SCWU of the product understudy is the sum of all the $SCWU_t$ reported to functional unit.

Scarcity Degradative Water Use (SDWU) represents the contribution of degradative water use to local scarcity. It can be defined as follow:

$$SDWU_t = \propto_{in,t} * DWU_t * max\left(\frac{Q_{out,t,i}}{Q_{ref,in,t,i,z}}\right) \qquad \text{eq. 2.4}$$

Where:

DWU_t is the degradative water use of the t-esime unit process presented in the previous chapter and expressed in liters or m^3;

$\alpha_{in,t}$ is the characterization factor of the t-esime process that represent local water scarcity in the region were water is withdrawn. It is the same used in SCWU indicator and represents the scarcity of water entering the unit process because through degradative water use, availability of that specific water type is affected.

$Q_{out,t,i}$ represents the quality of discharged water of the t-esime process for i-pollutant released to water and can be expressed in mg/l of discharged water.

$Q_{ref,in,t,i,z}$ is the maximum acceptable concentration of i-pollutant of the z-water category according to Boulay et al. (2011) of the water entering the t-esime process, expressed in mg/l.

Ratio between $Q_{ou,it}$ and $Q_{ref,i}$ answer the logic of distance to target recommended by UNEP-SETAC. Such a ratio has been introduced to represent the effect of the unit process on water quality parameters. Such ratio, following the applications of similar indicators such as grey water (Hoekstra et al., 2011), should be determined for each of the pollutant and then the max value resulting is the one to be used in the assessment of SDWU.

SDWU is expressed in liters equivalent or m^3 equivalent of water.

It is therefore possible to determine WSI as the sum of the contribution of the consumptive water use to scarcity and degradative water use to scarcity.

$$WSI = SCWU + SDWU \qquad \text{eq. 2.5}$$

It represents the equivalent amount of water of which other competing users are deprived as a consequence of water use. It is expressed in liters equivalent or m^3 equivalent of water.

To address comprehensiveness of other relevant impacts related to water quality degradation, the developed indicators are used togheter with the following indicators chosen based on their level of acceptance by the scientific community (EC-JRC, 2011; ISO, 2013b) see Table 2-6. These indicators address water degradation aspects describing the main impacts, different from availability that human activities have on water.

Table 2-6 Mid-point indicators acceptance

Environmental impact category	Reference
Freshwater eutrophication	Struijus et al., 2009
Water acidification	Jolliet et al., 2003
Water ecotoxicity	Goedkoop et al., 2012

Mid-point indicators related to water therefore result in a set of 5 indicators: SCWU, SDWU, freshwater eutrophication, water acidification, water ecotoxicity.

2.4.3 End-point indicators

Life Cycle Impact assessment at end point level uses inventory data to express the environmental impacts in terms of damages into 3 area of protection named human health, eco-systems and non-renewable resources.

According to literature review impacts related to water in term of non-renewable resources are still to be investigated and improved (Jeswani and Azapagic, 2009; Bayart et al., 2010; Margni and Curran, 2012).

Following the recommendations from UNEP-SETAC WULCA (Bayart et al., 2010) the following end point indicators have been developed.

$$\Delta R = Back\ up\ CWU + Back\ up\ DWU \qquad \text{eq. 2.6}$$

$$Back\ up\ CWU = E_{local,i} * \alpha_{in} * CWU \qquad \text{eq. 2.7}$$

$$Back\ up\ DWU = E_{local,j} * \alpha_{in} * DWU \qquad \text{eq. 2.8}$$

Where:

Back up CWU is the energy needed to back up the CWU of the product understudy

Back up of DWU is the energy needed to back up the DWU of the product understudy

CWU is the consumptive water use inventory indicator presented in the previous chapters and expressed in liters or m^3.

DWU is the degradative water use inventory indicator presented in the previous chapters and expressed in liters or m^3.

α_{in} is the characterization factor that represent local water scarcity in the region were water is withdrawn according to Boulay et al. (2011b)

$E_{local,i}$ is the surplus energy needed to compensate the consumptive water use through the use of the i - esime local back-up technologies.

$E_{local,j}$ is the surplus energy needed to compensate the degradative water use through the use of the j - esime local back-up technologies.

E_{local} to compensate consumptive and degradative water use is determined following common practice in the field (Pfister et al. 2009), through the application of LCA methodology using CED indicators (Huijbreghts et al.,2006; Scipioni et al., 2012). CED represents the surplus energy related to the product understudy. In the case of water back- up technology this represents the energy needed to compensate a liter of consumptive or degradative water use. CED follows the principle and the steps of LCA; to determine this value, practitioners can either refer to referred LCA data base such as Ecoinvent, or apply LCA methodology.

The first step of the definition of E_{local} method goes through the definition of the technologies to be used to compensate consumptive and degradative water use. In order to follow the recommendations of UNEP-SETAC WULCA only technology locally applicable are to be considered in the assessment.

2.5. Applicability and effectiveness: methodological approach

To verify the applicability and effectiveness of the developed set of indicators, according to experience emerged from literature review, it was decided to adopt the multiple case study approach (Corbetta, 1999). This answer the need of a confirmative and quantitative research. Through the use of case study approach it is possible to directly observe strength and weaknesses of the application of the developed indicators.

In order to answer to the research needs and gap emerged from literature, the choice of case studies to be used in this research, is based on specific requirements. First of all, to verify the effectiveness in measuring impacts related to water according to UNEP-SETAC, it was decided to choose case studies that present critical processes related to water such as agriculture process, food process, and water use technologies (Hoekstra et al., 2011; WWAP, 2012). Secondly, to verify if the developed indicators are effective in representing the local conditions (local water availability and seasonality) it was decided to prefer products that presents either life cycle processes located in different regions or that can be applied in different locations.

According to these requirements 4 case studies have been selected (Table 2-7).

Table 2-7 Case studies

Products	Sector	Critical water processes	Location parameter
Water collection system	Water recovery	HDPE recycling Rainwater collection	Applicable in different locations, processes located in Padova (Italy)
Organic Oat Beverage	Beverage	Crop growing and harvesting	Processes in different locations: North and South of Italy, Sweden
Organic Strawberry Jam	Food	Fruit growing and harvesting	Processes in different locations: Bulgaria, Italy
Tomato Sauce	Food	Crop growing and harvesting, use of fertilizers	Processes in different locations: California, North-east of USA, Brazil, Tunisia

Each case study will be presented in details in the result section where the general framework of Water Footprint Studies according to ISO 14046 presented in paragraph 2.1 will be applied.

3. Results: applicability and effectiveness

3.1. Case study 1: Water collection system

The first case study chosen to test the applicability and effectiveness of the developed set of indicators is related to a water collection system produced by a company located in the area of Padova (north east of Italy). This system is used to collect rainwater and make it available for different uses such as gardening or even human use. This product was chosen for several reasons:

- Its function is directly related to water and allows to collect and reuse effective rainwater;
- This system can be applied in several contests and regions.

3.1.1 Goals and scope definition

The goal of this study is to apply the developed set of indicators to conduct a contribution and hotspot analysis of the potential impacts related to water of a unit of water collection system in order to identify water saving potential and water management practice improvement. The assessment is intended to assist the company in determining which aspects of the production processes contribute the most to environmental impacts related to water and, therefore, to identify potential opportunities to improve water use and management within the company.

The company approached for the first time the analysis of environmental impacts related to their production and processes. This study has been performed in accordance with the methodologies and requirements presented in chapter 2.

The Functional Unit (FU) was identified as unit of water collection system of the maximum capacity of 310 l/m^2 that can be applied underground and function as a drening and water collection system. Volumes of water collected and made available for other uses depend on local climate conditions. The more it rains the more the capacity of the system to collect water is. Usually this system is dimensioned on local water needs and rainwater conditions. It is usually applied under impervious surfaces such as car parks or roads but can be also applied under green surfaces. Table 3-1 reports on the main physical characteristics of the product understudy. Figure 3-1 represents one unit of the device understudy. The water collection system is made out of these units and can include water treatment facility and pump according to its use.

Table 3-1 Characteristics of water collection system

Dimensions	**12 x 80 x 40 cm**
Material	**Recycled HDPE**
Weight	**11 kg**
Capacity	**310 l/m2**

Figure 3-1 Module of water collection device understudy

This module is produced from recycled high density polyethylene material coming from separate collection in the province of Padova. The function of the product system is to collect rainwater and make it available for reuse in the same location where it is collected; according to its use, this system can contribute to reuse rainwater either for gardening use or human use (in this case a water treatment process is usually needed). In this study the system to be used for gardening is considered.

In the definition of the product system boundaries, a cradle to gate approach has been considered in order to get a focus on the specific company production processes. This include: HDPE recycling; HDPE selection and injection molding. Also an installation in the province of Rovigo (north-east of Italy) has been considered from where it was possible to collect primary data on its functioning and use; however, based on the fact that preliminary results were non-significant in terms of impacts related to water, the use stage was excluded from this study. Figure 3-2 represents the system boundaries. According to company specification the minimum lifetime of the system is 30 years.

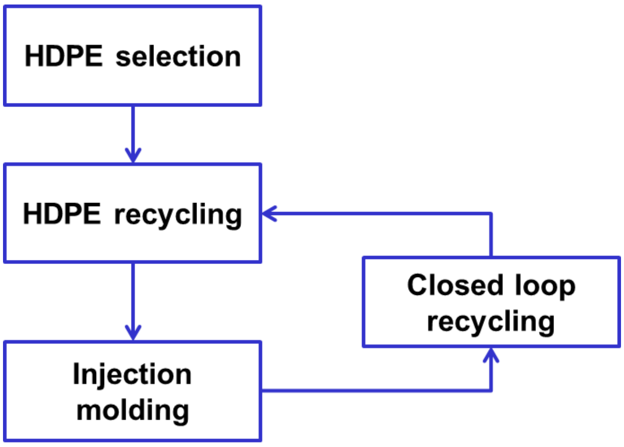

Figure 3-2 System boundaries for the water collection system

For each process unit, the following primary/secondary data have been collected: quantity of water use (withdrawal and discharge); type of water resources; data on water quality in and out of the system, when available; location of water use; seasonal changes in water flows; temporal aspects of water use; forms of water use (If not differently specified, all water used was considered to be a liquid). No significant changes in drainage conditions due to land use change were determined.

Due the specific characteristics of the production processes understudy, considerations on cut-off approach and allocation procedures due to recycling of HDPE follows.
Material recycling is the collection and processing of discarded materials into a form ready for reuse. Recycling can provide the benefit of replacing new material and the entire burden it takes to create the new material with the recycled material and the burdens (such as energy to grind plastic) it takes to recycle the material. In this study the burdens and benefits are allocated to the recycled HDPE product. This is considered to be a system expansion approach (Frischknecht, 2010).

Criteria used in the selection of data to be used in the study are reported in Table 3-2. In this study, cut off criteria of 1% by mass have been used.

Table 3-2 Data Quality criteria

Topic	Criteria adopted in this study
Time period coverage	Primary data from the most recent representative period (2010) were used were available. When only secondary data were available, most recent and representative were chosen. (E.g. climate data consolidated over 30 year period).
Geographical coverage	All primary data are site specific. In the case of secondary data, average production from the country of origin is considered where available.

Topic	Criteria adopted in this study
Technology coverage	Primary and secondary data always refer to the technology in use if not differently specified.
Precision and uncertainty	Most of the data collected are primary with limited uncertainty. In the selection of secondary data it was preferred to use Ecoinvent data sets that also present uncertainty information and data.
Completeness, Representativeness	Completeness measures the percent of primary data collected and used for each category in a unit process. Actual manufacturing data for the product life cycles were collected.
Consistency	Consistency considers how uniformly the study methodology is applied to the various components of the analysis. The developed set of indicators was applied to all components of the product under study consistently, in terms of modeling and assumptions.
Reproducibility	The water footprint modeling has been performed and described such that another water footprint practitioner could reproduce this water footprint.

Unless specified otherwise, secondary inventory data used in this study are from Ecoinvent 2.2 database. Ecoinvent data is maintained by the Ecoinvent Research Centre. Created in 1997, the Ecoinvent Research Centre (Frishknet et al., 2005; Althaus et al., 2007). All emissions data used to address impacts on acidification are taken from Ecoivent. Characterization factors, if not differently specified, are from this version of Ecoinvent.

3.1.2 Life Cycle Inventory

In this chapter, all the data acquired and calculations performed are reported. The paragraph is divided per different process units considered. For each process unit, if not differently specified, all the data used are reported on the reference unit of one module of water collection system of the capacity of 310 l/m^2.

Primary data are collected directly from the producer company. In the case of secondary data however not all the information (such as quality in and quantity out) was available. In these cases a conservative approach is adopted considering all withdrawn water as used (consumptive use), the quality entering the system as of the best quality locally available and the quality leaving the system as of the worst quality available.

3.1.2.1 HDPE selection

The product understudy is made 100% of recycled HDPE coming from municipal waste separate collection. Once collected it is sent to ad-hoc public storage and then pressed, packed and sent to the company. In this stage no direct water use occurs, however, energy consumptions due to the operation of separate collection and HDPE selection need to be considered. Following the system expansion approach, according to Ecoinvent v.2.2 database, the average operation of recycling requires 0,6 kWh on kg of recycled HDPE (Table 3-3), moreover the avoided production of virgin HDPE is to be considered

Table 3-3 Inventory data HDPE selection

Process/material	Inventory data	Reference
Avoided virgin HDPE production	1,00 kg	Polyethylene, HDPE,, granulate, at plant/RER S
Energy	0,60 kWh/kg oh HDPE	Electricity, medium voltage, at grid/IT S

3.1.2.2 HDPE Recycling

This process refers to the operations that take place in the production facility aimed at processing the HDPE coming from the municipal separate collection and make it ready for the following injection molding process. Once arrived at the production site, the HDPE material goes through a secondary selection in order to prevent other material than HDPE to enter the production system. Once selected the HDPE material is mashed in a mill and stored in ad-hoc silos. Once out of the storage, the material undergoes an extrusion and cleaning process in order to obtain a homogeneous granulates material. HDPE is now ready for the following injection molding process.

In this process water is used to cool down the HDPE material once it goes through extrusion. Water evaporates in cooling towers and only partially recovered for secondary use in a close loop cycle. Water lost through evaporation is compensated with ground-freshwater coming from authorized wells. Once used the water is discharged in a surface water body (channel) running close to the production facility. To guarantee machine efficiency lubricating oil is used. Table 3-4 reports on main inventory data used in the process.

Table 3-4 Inventory data HDPE recycling

Process/material	Inventory data	Reference
Recycled HDPE	800,00 kg/h	Primary data
Lubricating oil	0,20 kg/h	Lubricating oil, at plant/RER S
Groundwater in	2500,00 l/h	Primary data
Energy	441,87 kWh	Electricity, medium voltage, at grid/IT S
Discharged water	2312,50 l/h	Primary data

3.1.2.3 Injection molding

In this process HDPE granules are sent into a hopper that introduces the material into the injection molding machine. Firstly the material is pressed into a screw where it is also heated in order to come to operational temperature. The warm HDPE granulates are then sent into a mold with the final shape of the product understudy. Once the material filled up the stamp it is then cooled down through the use of water running into adjacent tubes without touching the product. In this operation water entering the system evaporates and is only partially recovered in cooling towers. Very little scraps result from molding (around 2,7%). This material is re-used within the company, going again

Through the HDPE recycling process previously described. Table 3-5 reports on significant inventory data used in the study. All the water discharged presents the same characteristics of the water that goes into the system; there is a change in water temperature but no other quality parameters

Table 3-5 Inventory data Injection molding

Process/material	Inventory data	Reference
Recycled HDPE	73,00 kg/h	Primary data
Lubricating oil	0,40 kg/h	Lubricating oil, at plant/RER S
Groundwater in	125,00 l/h	Primary data
Discharged water	114,31 l/h	Primary data

3.1.3 Life Cycle Inventory Analysis

Life Cycle inventory analysis is the stage of the study were data collected are aggregated in order to have a first representation of materials and energy flows going in and out of the system. Table 3-6 reports on inventory information to be used according to the inventory method developed and described in chapter 2. Emissions to water and air are reported in ANNEX A. Where no information on discharged water is available (such as from Ecoinvent database) a conservative approach is adopted, considering all the withdrawn water to be consumed. Where no data on quality in and out are available it is assumed that the water going into the system is for the best available quality and the one discharged is of the worst available quality according to Boulay et al (2011a). It is reminded that G stands for ground water and S for surface according to the classification from Boulay et al. (2011a) data are reported on the functional unit of on product understudy.

Table 3-6 Inventory results for one unit of water collection system

Process			Location	Vin (Liters)	Quality class in	αin	Vout (Liters)	Quality Class out	j
Municipal collection	HDPE selection	Polyethilene	Padova (Italy)	8,52E-05	G1	1	0,00	S6	1
		Energy	Italy	0,08	G1		0,00	S6	1
Production	HDPE Selection	Energy	Italy	1,28	G1		0,00	S6	1
		Lubricant oil	Veneto region	0,00	G1		0,00	S6	1
		Water	Grantorto (Padova - Italy)	34,40	G2		31,80	S3b	1
	Injection molding	Electricity	Italy	5,08	G1		0,00	S6	1
		Lubricant oil	Veneto region	0,04	G1		0,00	S6	1
		Water	Grantorto (Padova - Italy)	11,00	G2		9,31	S2	0

Based on the data collected in the inventory stage it was possible to assess CWU and DWU inventory indicators. Results are reported in Figure 3-3.

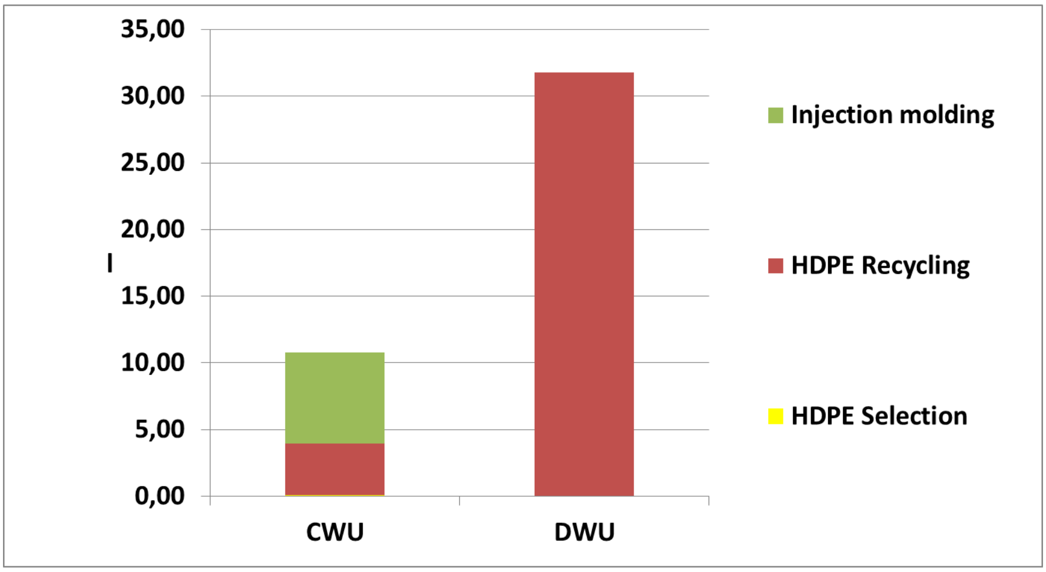

Figure 3-3 Inventory indicator results of the water collection system

The total CWU of water collection system resulted to be 10,79 liters. This quantity refers to the volume of water that is consumed specifically because of product evaporation. The degradative water use resulted to be 31,80 liters of water. This quantity represents the total volume of discharged water whose quality has been altered if compared to the withdrawn one and quality of destination water body. DWU, in this case, resulted to be more significant than the consumptive use. Going deeper in the analysis of inventory results, the total percentage of DWU resulted to come from the HDPE recycling process where water quality is degraded due to the HDPE cleaning operations. Only temperature parameter of water discharged from the injection molding process was altered without resulting in a change of water quality category. Therefore this water could be potentially reused within the company before discharging it. Parameter j allowed the comprehension of which water resulted to have altered quality. Another interesting result is related to CWU. In this production, indirect consumptive water use (the one related to the supply chain) resulted to be non-significant if compared to the direct consumptive one; the process with biggest water consumption is the injection molding process where most of the withdrawn water is released to the atmosphere in the form of vapor.

3.1.4 Life Cycle Impact Assessment

In this chapter the results of the water footprint impact assessment are presented. Impact methods developed at mid-point and end-point level were applied. The final water footprint is presented in a form of a profile consisting of the scarcity consumptive water use, scarcity degradative water use, and eutrophication, eco-toxicity, and acidification footprints. Methods described in materials and methods were applied. For the assessment of eutrophication, eco-toxicity and acidification footprint characterization factors from Ecoinvent 2.2 (Weidema and Hischier, 2010) were considered. To model these impacts software Simapro version 7.3 has been used (REF). This software is commonly used in Life Cycle Assessment studies.

3.1.4.1 Water Stress indicator

According to developed method presented in chapter 3, the WSI method represents the effect of consumptive and degradative water use to local water availability.

The scarcity consumptive water use (SCWU) characterizes the stress (use specific) that the production of one unit of water collection system places on local water resources throughout its entire life cycle. This stress is a result of the consumption of water. Figure 3-4 report the results of the SCWU and related CWU on functional unit.

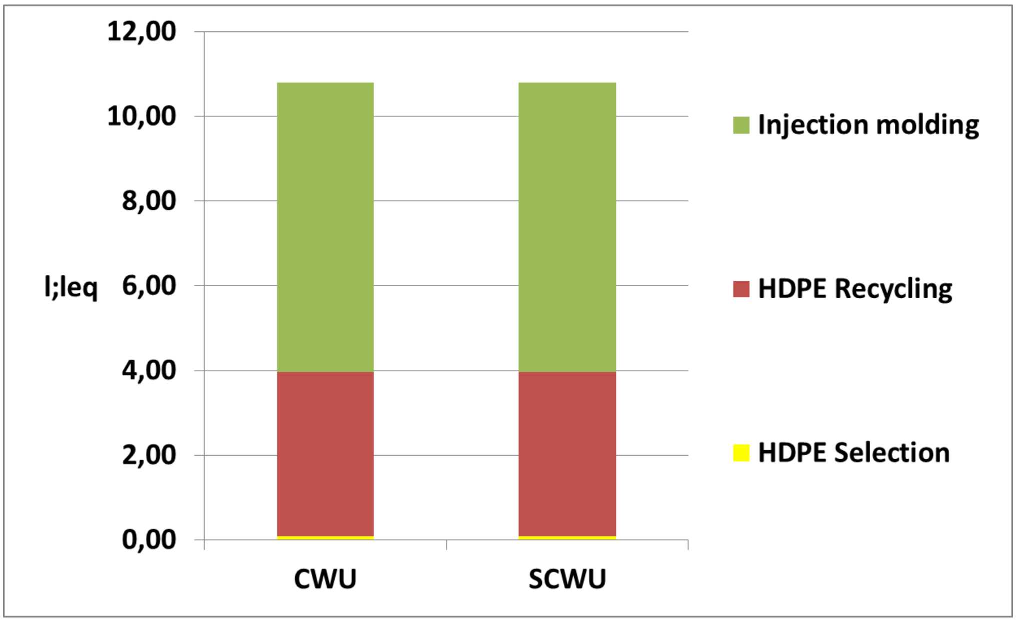

Figure 3-4 SCWU for one unit of water collection system

The total SCWU of the water collection system resulted to be 10,79 l_{eq}. in this case the total consumed volume contributes to local stress according to an α factor of 1. Consideration on SCWU are the same of the CWU.

The scarcity degradative water use (SDWU) characterizes the stress (use specific) that the production of one unit of water collection system places on local water resources throughout its entire life cycle. This stress is a result of the degradation of water quality. Figure 3-5 reports the results of the SDWU and related DWU on functional unit.

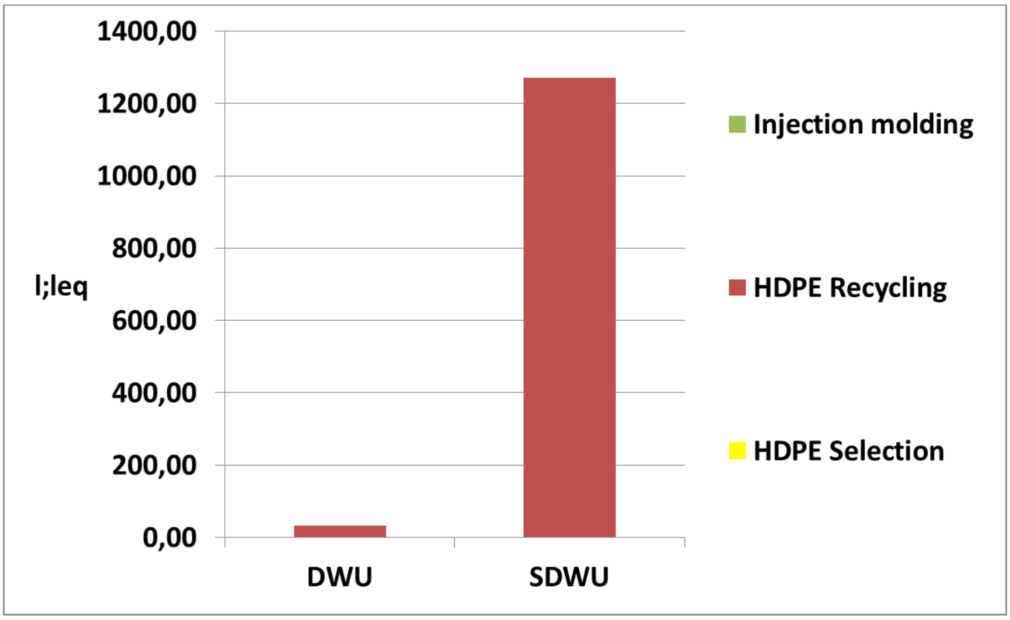

Figure 3-5 SDWU for one unit of water collection system

The total SDWU of the water collection system resulted to be 1.272 l_{eq}. As already described in the previous paragraph, all the impact are attributable to the operation of HDPE cleaning. This value represents the stress related to the degradation of 34,40 liters of water. Due to the use of the distance to target factor, the measure of how much water has been potentially degraded due to the emissions of pollutant to water reservoir (in this case surface water) are represented. Assessment of distance to target factor is based on value of Cu released to water, reported to Cu limits accepted from the specific recipient water body.

In the assessment of water scarcity, SDWU resulted to be more significant than SCWU. The total WSI resulted to be 1.282,79 l_{eq}.

3.1.4.2 Degradation profile

In this section the results of the mid-point impact assessment for several water quality indicators are presented. The life cycle of the water collection system has been modeled through the Simapro version 7.3 software. Figure 3-6 reports the result of the impact assessment in these three categories. It is important to highlight that for HDPE selection and injection molding processes there impacts are related only to indirect water use from energy and ancillary materials (oil) use.

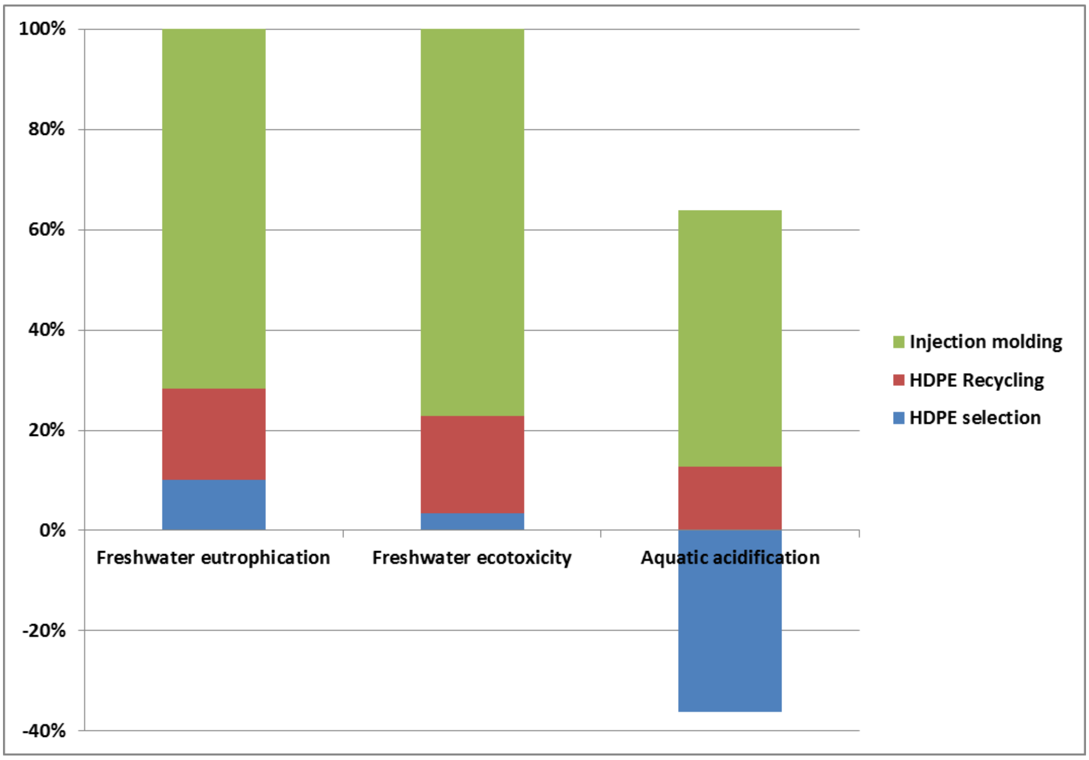

Figure 3-6 Other impacts related to water of one unit of water collection system

The total water eutrophication footprint of the water collection system resulted to be 6,19 E-03 kg of P eq. The major contributor to the eutrophication footprint of the product is the injection molding process. In this case, it is the production of lubricating oil used in this processes that contribute to the emission to water of N and P. The second highest contributor to eutrophication is the result of the production and distribution of energy used in the different processes.

The total water eco-toxicity footprint of one unit of water collection system resulted to be 9,25 E-2 kg 1,4-DB eq. These results confirm the significance of the production of lubricating oil and energy used in the process.

The total water acidification footprint of one unit of water collection system resulted to be 3,99 E-2 kg SO2 eq. This value, due to the system expansion approach takes into consideration the avoided impacts of HDPE production. This process resulted to be particular significance in avoiding impacts to the acidification impacts. This is related to the avoided energy use and related air emissions.

3.1.4.3 End-point impacts on Resources

In this paragraph, results of the application of the method related to Resource area of protection presented in chapter 2, are reported. These impacts are related both to degradative and consumptive water use and refer to back-up technology locally applicable.

To compensate the degradative water use, wastewater treatment facilities have been considered as local back – up technology. Values of $E_{local,j}$ are acquired from Ecoinvent v 2.2 database (Weidema and Hischier, 2010) and chosen based on the size of the wastewater treatment facility locally applicable. To determine applicability of the back-up technology the parameter person equivalent has been used. Table 3-7 reports on $E_{local,j}$ values used to back-up degradative water use; these values are determined using CED method. Where no data on specific locations are available a worst case approach has been adopted considering the wastewater treatment plant with the highest surplus energy values (resulting in the smallest one according to Ecoinvent 2.2).

Table 3-7 $E_{local,j}$ values for water collection system

Process		Location	Person equivalent	$E_{local,j}$ (MJ/l)	Reference
HDPE selection	Polyethilene	Padova (Italy)	233225	4,74E-03	Waste water treatment plant class 1/CH/I
	Energy	Italy	806	6,70E-03	Waste water treatment plant class 5/CH/I
HDPE Selection	Energy	Italy	806	6,70E-03	Waste water treatment plant class 5/CH/I
	Lubricant oil	Veneto region	806	6,70E-03	Waste water treatment plant class 5/CH/I

	Water	Grantorto (Padova - Italy)	5231	6,18E-03	Waste water treatment plant class 4/CH/I
Injection molding	Electricity	Italy	806	6,70E-03	Waste water treatment plant class 5/CH/I
	Lubricant oil	Veneto region	806	6,70E-03	Waste water treatment plant class 5/CH/I
	Water	Grantorto (Padova - Italy)	5231	6,18E-03	Waste water treatment plant class 4/CH/I

To compensate the consumptive water use, according to the characteristics of the area understudy where rainwater rain-water falls regularly (FAO, 2010b), it was decided to model a water collection system based on the water collection device understudy. The methodology described in chapter 2 has been applied: CED method has been employed to assess the surplus energy cost per liter of the production and installation of the water collection system including the energy to produce other materials and devices (such as pumps and tubes, HDPE geo-membrane) used to install the system and to run a domestic water treatment facility (in this case it is assumed that rainwater quality is the same of surface water). Figure 3-7 represent an example of the application of the water back-up technology.

Figure 3-7 Water Back-up system

The collection system is dimensioned on the water requirements of the specific process for the production of 1 unit of water collection system and considers the minimum average yearly precipitation based on the 30 years normalized values (FAO, 2010b). It is assumed that the collection system has a lifetime of 30 years according to company specification. As far as most of the processes take place in the north –east of Italy it is assumed that rain conditions are related to data the collected in Padova. When only general information on locations is available a conservative approach is adopted assuming the worst rainwater conditions available in CLIMAWAT Database (2010b) referred to Italy. Only effective rain is used for compensation (% of rainwater that does not evaporate or run-off).

Table 4-8 reports on the dimensioning of the system.

Table 3-8 Water collection system dimensioning

Process		Rain (local climate conditions) [l/m2]	Process cumulative water use [l]	N° of drening elements
HDPE selection	Polyethilene	51,70	0,08	1,00
	Energy	2,00	0,08	1,00
HDPE SRecycling	Energy	2,00	1,28	1,00
	Lubricant oil	51,70	0,00	1,00
	Water	51,70	2,60	1,00
Injection molding	Energy	2,00	5,08	3,00
	Lubricant oil	51,70	0,04	1,00
	Water	51,70	1,71	1,00

Table 3-9 report the values of $E_{local,I}$.

Table 3-9 Elocal,i values for water collection system

Process		Location	$E_{local,i}$ (MJ/l)
HDPE selection	Polyethilene	Padova (Italy)	0,32
	Energy	Italy	8,13
HDPE Selection	Energy	Italy	8,13
	Lubricant oil	Veneto region	0,32
	Water	Grantorto (Padova - Italy)	0,32
Injection molding	Energy	Italy	7,34
	Lubricant oil	Veneto region	0,32
	Water	Grantorto (Padova - Italy)	0,42

Final values of ΔR are reported in figure 3-8.

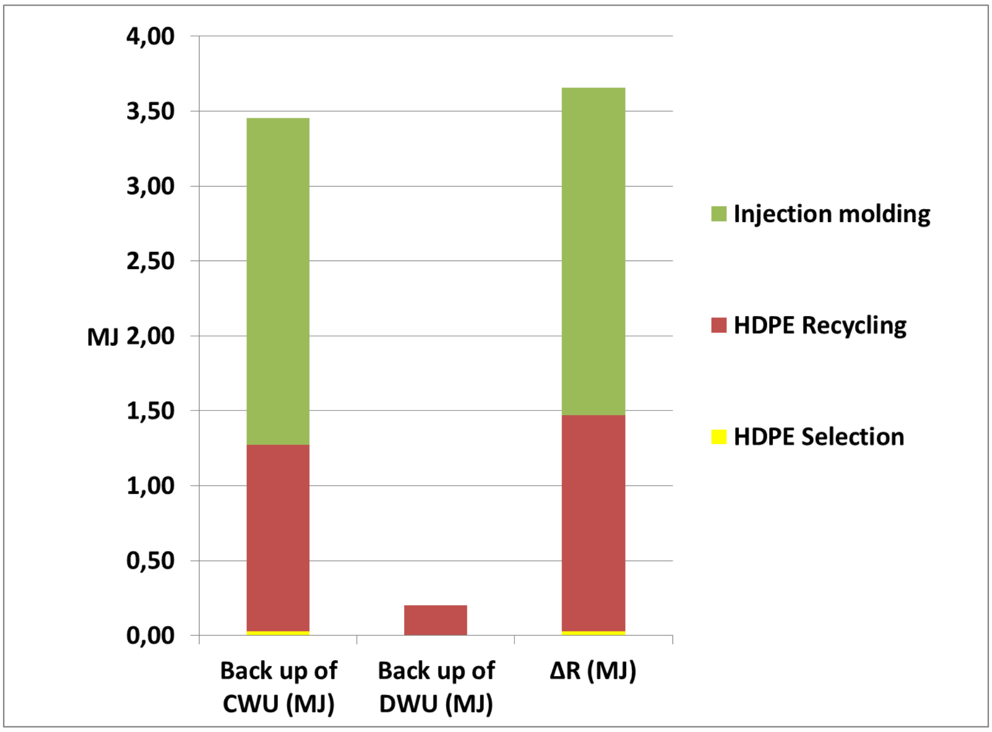

Figure 3-8 Impacts on resources from consumptive and degradative water use of water collection system

Results of impact assessment of resources area of protection shows that compensation of consumptive water use (3,46 MJ) requires more energy than the degraded one (0,20 MJ). Inventory indicator results are confirmed showing that back up of injection molding consumptive use is the most significant one. ΔR resulted to be 3,66 MJ.

3.1.5 Life Cycle Interpretation

In this stage of the study, results are analyzed in order to determine the main environmental hot-spot related to water. Table 3-10 reports on the results of this analysis highlighting the main hotspot and related variables.

Table 3-10 Hot-spot analysis for one unit of water collection system

Level of analysis	**Indicator**	**Hotspots-process**	**Variables that influenced results**
Inventory	CWU	Injection molding	Evaporation of withdrawn water to cool down the product in the stamp
	DWU	HDPE Recycling	Water to cool down HDPE recycled granulates
Mid-point	SCWU	Injection molding	Evaporation of withdrawn water to cool down the product in the stamp; high

Level of analysis	Indicator	Hotspots-process	Variables that influenced results
Impact			scarcity of withdrawn water
	SDWU	HDPE Recycling	Water to cool down HDPE recycled granulates
	Eutrophication	HDPE Recycling	Lubricant oil production and energy use
	Eco-toxicity	Injection molding	Lubricant oil production and energy use
	Acidification	Injection molding	Lubricant oil production and energy use
End-point Impact	Back up of CWU	Injection molding	Evaporation of withdrawn water to cool down the product in the stamp
	Back-up of DWU	HDPE Recycling	Water to cool down HDPE recycled granulates

The hotspots identified, suggest potential water improvement strategies that the company can implement. This strategy can be grouped in two families:

1. Reuse of water discharged from injection molding as cool water in the HDPE recycling operations;
2. Change in the energy mix to prefer less waster intensive technologies.

It would also be interesting to investigate the consequences of using virgin HDPE instead of recycled one.

Table 3-11 Potential actions on water collection system

Potential Actions
• Optimize water use within the company
• Change in the energy mix
• Virgin HDPE used as raw material

Following paragraphs will investigate these potential actions through sesntivity analysis.

Sensitivity analysis: Optimize water use within the company

From the analysis of inventory indicators, the opportunity of reusing the water discharged from the injection molding process emerged. The water quality used in this operation is not altered and can be potentially used for cooling down HDPE granules during recycling.

If the company adopts water reuse system among the two processes a reduction of withdrawn and discharged water can be achieved. Table 3-12 reports the inventory results in this case.

Table 3-12 Inventory results for one unit of water collection system in the case of water use optimization

Process			Location	Vin (Liters)	Quality class in	αin	Vout (Liters)	Quality Class out	j
Municipal collection	HDPE selection	Polyethilene	Padova (Italy)	8,52E-05	G1	1	0,00	S6	1
		Energy	Italy	0,08	G1		0,00	S6	1
Production	HDPE Selection	Energy	Italy	1,28	G1		0,00	S6	1
		Lubricant oil	Veneto region	0,00	G1		0,00	S6	1
		Water	Grantorto (Padova - Italy)	25,09	G2		22,49	S3	1
	Injection molding	Electricity	Italy	5,08	G1		0,00	S6	1
		Lubricant oil	Veneto region	0,04	G1		0,00	S6	1
		Water	Grantorto (Padova - Italy)	11,00	G2		9,31	S2	0

Water reuses results in a smaller withdrawn and discharge. The CWU is not affected as long as it depends on the water that does not return the same water basin. DWU and SDWU resulted to be smaller in this case. This depends on smaller discharged volumes and therefore a smaller quantity of polluted water. A smaller quantity of polluted water resulted also in smaller impacts related to resource area of protection because the volume to be treated resulted reduced. Table 3-13 report on these results.

Table 3-13 Impact assessment results for one unit of water collection system in the case of water use optimization

	Unit	Business as usual	Optimize internal water use	% reduction
DWU	l	31,80	22,41	29
SDWU	l_{eq}	1272,00	899,60	
Back up of DWU	MJ	0,20	0,14	30

No other significant impacts results can be noted: eutrophication, eco-toxicity and acidification impacts in fact resulted to be more influenced by other parameters such as production of lubricating oil and energy production.

<u>Sensitivity analysis: Change in the in energy mix</u>

The use of energy produced according to the Italian energy mix had a negative impact on the water eutrophication, eco-toxicity and acidification footprints. The company can affect the use of hard coal in two ways:

- Changing its own energy mix to use less hard coal;
- Asking its suppliers to avoid using hard coal in their energy mix;

Following a worldwide-established practice, the company could decide to purchase greenhouse gas offsets that finance the generation of renewable energy. From a water footprint perspective (Gerbens-Leenes et al., 2008), the source of renewable energy that presents the best water footprint profile is wind energy. Table 3-14 reports the result of the eutrophication, eco-toxicity and acidification footprints, in the case the company adopts the above mentioned strategy. Results show that the company can offset most of its impacts related to water quality degradation. These results depend on the positive contribution of the avoided impacts related to the use of recycled HDPE that are bigger than the negative contribution of the use of wind-energy.

Table 3-14 Impact assessment results for one unit of water collection system in the case of different energy mix

	Unit	Business as usual	Use of energy off-set by RECs	% reduction
Water eutrophication footprint	kg P eq	6,19 E-03	-7,80 E-6	100
Water eco-toxicity footprint	kg 1,4-DB eq	9,25 E-2	2,91 E-3	97
Water acidification	kg SO2 eq	3,99 E-2	-6,82 E-2	100

	Unit	Business as usual	Use of energy off-set by RECs	% reduction
footprint				

Sensitivity analysis: Virgin HDPE used as raw material

In this section the effects of using virgin HDPE instead of recycled one are investigated. Figure 3-9 represents how the processes of the company would change in this scenario: instead of acquiring HDPE from municipal separate collection (HDPE selection), the company would buy directly the virgin HDPE; the HDPE recycling process would be dedicated only to HDPE scraps resulting from the injection molding process that according to the company are more or less the 2,7% of the total production. In this scenario therefore the 97,3% would come from virgin HDPE.

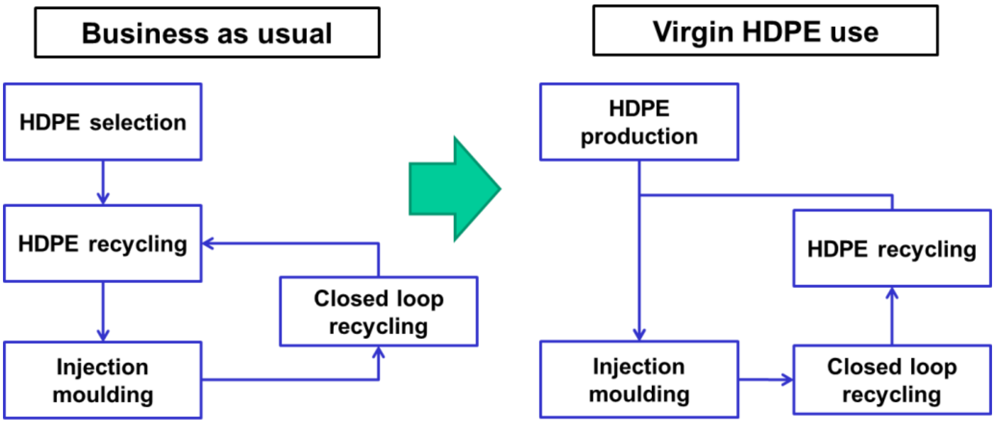

Figure 3-9 System boundaries in the case of virgin HDPE

Table 3-15 reports the result of the developed indicators at inventory, mid-point and end point level, in the case the company adopts the above mentioned strategy. CWU and SCWU and back up of resulted to be bigger than the business as usual scenario because of the water used for virgin HDPE production. In this case CWU would be even bigger than DWU. No changes in DWU and SDWU and back up of DWU can be identified due to lack of specific data in the database. In the case of eutrophication and eco-toxicity impacts resulted to be smaller in the case of virgin HDPE due to an overall reduction in energy use for the process of HDPE recycling. In the case of acidification the use of recycling HDPE is to be preferred due to the contribution of avoided virgin HDPE production impacts.

Table 3-15 Impact assessment results for one unit of water collection system in the case of different energy mix

	Unit	Business as usual	Virgin HDPE	% of variation
CWU	l	10,97	44,59	25
SCWU	l_{eq}	10,97	44,59	25
Water eutrophication footprint	kg P eq	6,19 E-03	4,87 E-3	- 21
Water eco-toxicity footprint	kg 1,4-DB eq	9,25 E-2	8,83 E-2	- 5
Water acidification footprint	kg SO2 eq	3,99 E-2	14,33 E-2	27
Back up of CWU	MJ	3,46	14,10	25

3.2. Case study 2: Organic oat beverage

The second case study investigated to test the applicability and effectiveness of the developed set of indicators, is related to an organic beverage product made of oat and produced by a company located in the province of Rovigo (north east of Italy). Market of organic products has grown fast in recent years so that several studies focus on the environmental consequences of this production (Nemecek et al., 2006; Blengini and Busto, 2009; Wood et al., 2011); however experiences on water use impact assessment are limited (Manzardo et al., 2012). This product was therefore chosen for several reasons:

- It is based on agriculture processes that are recognized to be water intensive;
- Life cycle processes take place in different contests and regions;
- The product is sold in Italy and in other countries such as France, where water footprint is regulated by national law and can be reported directly on the packaging of the product (Commissariat Général au Développement durable, 2011). The issue of water footprint is therefore critical to company competitiveness on such markets

3.2.1 Goals and scope definition

The goal of this study is to apply the developed set of indicators to conduct a contribution and hotspot analysis of the potential impacts related to water throughout the life cycle of an organic oat beverage. The assessment is intended to assist the company in determining which aspects of the product life cycle contribute the most to environmental impacts related to water and, therefore, to identify potential opportunities to improve water use and management along the value chain; another interesting aspect is the opportunity for the company to address other country regulation such as France where water related indicators can be applied on the packaging (Commissariat

Général au Développement durable, 2011). This study has been performed in accordance with the methodologies and requirements presented in chapter 2.

The Functional Unit (FU) was identified as 1000 ml of organic oat beverage packed in a squared beverage carton, produced by an Italian food company located in Rovigo and distributed and consumed all over the world. The function of the product system is the production of the organic oat beverage. The formula of the product understudy is presented in table 3-16.

Product system boundaries are based on the cradle to gate approach; therefore impacts from the extraction of raw materials and ancillary materials to the production and packaging of the final product are considered. System boundaries are reported in figure 3-10

Table 3-16 Content of organic oat beverage

Material	**Quantity (% in final product)**
Water	**87,68**
Organic oat	**10,94**
Sunflower oil	**1,14**
Others	**4,38**

The following primary/secondary data have been collected for each process unit: quantity of water use (withdrawal and discharge); type of water resources; data on water quality in and out of the system, when available; location of water use; seasonal changes in water flows; temporal aspects of water use; forms of water use (If not differently specified, all water used was considered to be a liquid). No significant changes in drainage conditions due to land use change were determined

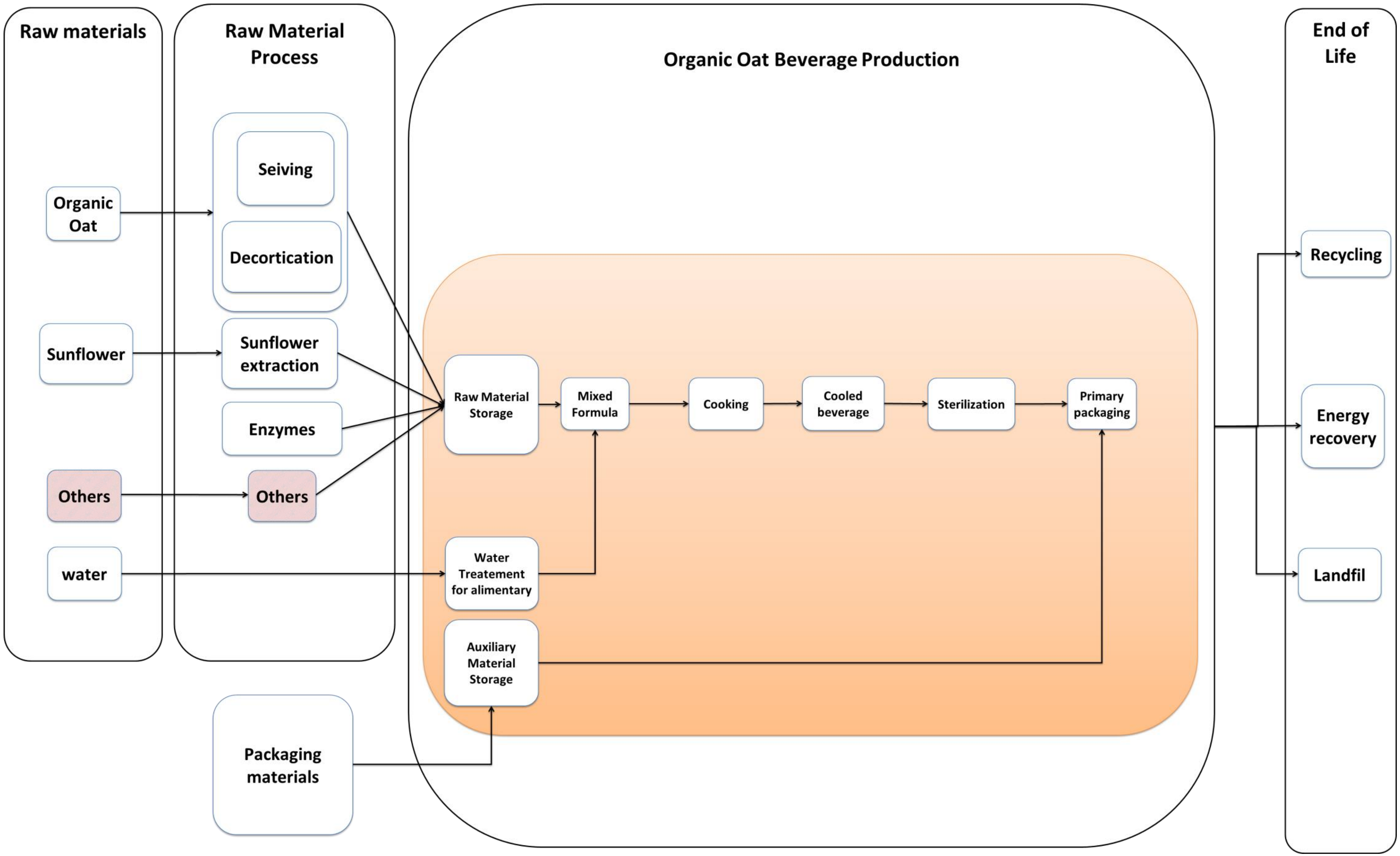

Figure 3-10 System boundaries for the 1000ml of organic oat beverage

Criteria used in the selection of data to be used in the study are reported in Table 3-17. In this study, cut off criteria of 1% by mass has been used.

Table 3-17 Data Quality criteria

Topic	Criteria adopted in this study
Time period coverage	Primary data from the most recent representative period (2011-2012 for agriculture processes 2012 for production processes) were used were available. When only secondary data were available, most recent and representative were chosen. (e.g. climate data consolidated over 30 year period for the growth of oat and sunflower).
Geographical coverage	All primary data are site specific. In the case of secondary data, average production from the country of origin is considered where available.
Technology coverage	Primary and secondary data always refers to the technology in use if not differently specified.
Precision and uncertainty	Most of the data collected are primary with limited uncertainty. In the selection of secondary data it was preferred to use Ecoinvent data sets that also present uncertainty information and data.
Completeness, Representativeness	Completeness measures the percent of primary data collected and used for each category in a unit process. Actual manufacturing data for the product life cycles were collected, Where possible, suppliers provided detailed water and energy usage, material usage, and scrap end of life for their operations. When suppliers were not able to provide information, assumptions were made based on industry practice or information provided by other suppliers. Life cycle inventory data is not included in the life cycle if it represents less than 5% by weight of the product materials and the data is not available. Over 99% of the product mass is included in the LCA. It is expected that the remaining mass will have little to no effect on the outcome of the water footprint results.
Consistency	Consistency considers how uniformly the study methodology is applied to the various components of the analysis. The methodology presented in chapter 2 was applied to all components of the product under study consistently, in terms of modeling and assumptions. Consistency in results has been checked with literature reference.
Reproducibility	The modeling has been performed and described such that another water footprint practitioner could reproduce this water footprint.

Unless specified otherwise, secondary inventory data used in this study are from Ecoinvent 2.2 database (Frishknet et al., 2005; Althaus et al., 2007). All emissions data used to address impacts on acidification are taken from Ecoivent. Characterization factors, if not differently specified, are from this version of Ecoinvent.

4.2.2 Life Cycle Inventory

In this chapter, all the data acquired and calculations performed are reported. The paragraph is divided per different process unit considered.

Primary data are collected directly from the producer company. In the case of secondary data however not all the information (such as quality in and quantity out) was available. In these cases a conservative approach is adopted considering all withdrawn water as used (consumptive use) and the quality entering the system as of the best quality locally available.

4.2.2.1 Organic Oat

One of the most important raw materials used in the production of the product under study is oat. This cereal is grown in San Martino Pensile (Campobasso, south of Italy) where the company owns 270 ha of land dedicated to organic agricultural product growth. Following the common practice of organic agriculture, oat is grown following the crop-rotation practice; it is usually planted in the second half of October and harvested in July. Due to local climate conditions, the crops are mostly rain fed with very little additional water supply requirements. Data reported are primary data based on the 2011 and 2012. The average yield based on historical company data is 3,2 tons/ha

In order to assess the crop water requirements the CROPWAT model (FAO, 2010a) has been used. The CROPWAT software developed by FAO is used to model the water requirements of a crop. The model utilizes data on the climatic conditions, the reference evapotranspiration, the soil and the specific crop characteristics to determine the irrigation requirements of the crop under study. ET0 (evapotranspiration in standard condition) is determined using the Penman-Montheit equation (FAO, 2010a). Effective rain (the rainfall effectively available to the crop) is assessed through the USDA SCS method (option selected within CROPWAT model). Climatic data are taken from the climatic stations located in Termoli (the closest one to the location of the production site) available from (Tab 3-18 and 3-19) and acquired through the use of CLIMAWAT software (FAO, 2010b).

Data on the crop modeling are taken from FAO database (FAO, 2010a) accessible within the CROPWAT software and then modified with primary parameters such as critical dates of different processes and specific crop parameters (roots length, crop-coefficients, soil humidity). Medium soil parameters from CROPWAT are considered.

Table 3-18 Precipitation and Effective Rain in Termoli

Termoli		
	Rain	Eff rain
	mm	**mm**
January	28,80	27,50
February	26,60	25,50
March	26,60	25,50
April	22,50	21,70
May	22,60	21,80
June	25,10	24,10
July	24,10	23,20
August	32,10	30,50
September	44,30	41,20
October	45,30	42,00
November	46,20	42,80
December	41,20	38,50

Table 3-19 Climatic data from Termoli

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	Eto
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
Termoli							
January	5,90	10,00	89,00	336,00	3,40	6,10	0,73
February	7,10	11,80	89,00	569,00	4,70	9,10	1,09
March	840	13,70	71,00	510,00	5,90	13,30	2.50
April	1310	19,10	67,00	358,00	6,80	17,30	3,54
May	1630	22,40	70,00	430,00	8,30	21,30	4,44
June	2160	27,20	69,00	313,00	9,50	23,60	5,37
July	2260	29,40	67,00	323,00	10,40	24,50	5,94
August	2450	30,90	67,00	236,00	9,60	21,60	5,40
September	2220	29,00	71,00	367,00	7,20	15,80	4,57
October	1490	20,20	81,00	229,00	5,50	10,70	2,06
November	12,90	18,20	78,00	240,00	3,80	6,80	1,55
December	7,30	12,60	80,00	254,00	3,10	5,30	1,07
Average	5,90	10,00	89,00	336,00	3,40	6,1o	0,73

No chemical fertilizers are used in the growing of oat; however a quantity of organic fertilizers containing P is used. Data on fertilizer are reported in Tab3-20. Following common practice from Hoekstra et al. (2011) the 10%of the quantity of P leaches into groundwater.

Table 3-20 Data on the use of fertilizers

Substance considered	Application of fertilizer	Reference
P	122,82 kg/ha	Primary data from supplier, 2011

Other relevant inventory data and references are reported in table 3-21

Table 3-21 Other relevant Inventory data Oat

Process/material	Inventory data	Reference
Fuel use for operations	64,72 kg/ha	Diesel at refinery/kg/RER S

3.2.2.3 Sunflower

Another important raw material is sunflower that is used to produce sunflower oil. Sunflowers are grown in San Martino in Pensile (Campobasso - Italy), the same location where oat is produced. In this site, 40 ha are dedicated to growth of sunflowers. Also this crop undergoes crop-rotation; it is usually planted in April and harvested in August. Due to local climate conditions the crop require water supply; a 70% efficiency for standard technology is considered in this case (FAO, 2010a). Data reported, if not differently specified, are primary data based on 2011. The average yield based on historical company data is 2,0 tons/ha.

In order to assess the crop water requirements the same model (CROPWAT) and climate data were used. Specific crop requirements data are of primary origin. Medium soil parameters from CROPWAT are considered. Specific crop water requirements resulted to be 385,00 mm of water with 109,6 mm of water coming from rainwater.

No chemical fertilizers are used in the growing of sunflower, however a quantity of organic fertilizers containing N is used. Data on fertilizer are reported in Tab 4-20. Following common practice from Hoekstra et al. (2011) the 10%of the quantity of N leaches into groundwater.

Table 3-22 Data on the use of fertilizers

Substance considered	Application of fertilizer	Reference
N	146 kg/ha	Primary data from supplier, 2011

Other relevant inventory data and references are reported in table 3-23. Sunflower processing at plant present 99% efficiency.

Table 3-23 Other relevant Inventory data sunflower

Process/material	Inventory data	Reference
Sunflower	1,01 kg	Sunflower, at farm/RER S

3.2.2.4 Marine salt

The third relevant raw material used in the production of the organic oat beverage is salt. An efficiency of 99% in salt production was declared by the supplier. No primary other data were available from supplier therefore database Eco-invent version 2.2 was used (table 3-24).

Table 3-24 Other relevant Inventory data marine salt

Process/material	Inventory data	Reference
Marine salt	1,01 kg	Sodium chloride, brine solution, at plant RER/S
Disposal	0,1 kg	Disposal, municipal solid waste, 22,9% water, to sanitary landfill/CH S

3.2.2.5 Organic Oat production

Once harvested, the oat is sent to a closed facility (30 km) in order to be processed for the next production step. Two mechanical operations take place, the first one is sieving the second is decortication. These operations have a very low efficiency so that 50% of the product entering the system is wasted. However, all the scraps are collected and used to feed animals. This results in avoided impacts of fodder for animals that has been considered in the modelling. No primary data were available from supplier therefore database Eco-invent version 2.2 was used.

Table 3-25 relevant Inventory data Oat production

Process/material	Inventory data	Reference
Decortication	4160 kg	Primary data and Sunflower oil, at
Production	2080 kg	plant RER/S
Fodder	2080 kg	Primary data

3.2.2.6 Sunflower oil production

Sunflowers seed are sent to Termoli where they are processed in order to make sunflower oil. The operations consist in a first cold pressing to make the oil out of the seeds, next deodorization and clarification. No primary data were available from supplier therefore database Ecoinvent v 2.2 assuming emissions equal to the production of Soybean oil (ref Soybean oil, at plant/ RER S).

3.2.2.7 Raw materials transport

Every week during the oat organic beverage production, the company in Rovigo receives from 26 to 30 tons of processed organic oat. Once a month they receive 90 tons of sunflower oil in tanks. Primary data on distances are used and acquired from different transport company delivering raw materials. Secondary data on elementary flows related to water are from Ecoinvent v.2.2.

Table 3-26 relevant Inventory data marine salt

Process/material	Inventory data	Reference
Transport organic oat	553 ton/km	Primary data and Transport Lorry over 16 ton, fleet average/RER S
Transport sunflower oil	540 ton/km	
Transport marine salt	73 ton/km	
Transport beverage carton	125 ton/km	

3.2.2.8 Primary packaging materials

Primary packaging is beverage carton supplied by a company located in Modena and made of polyethylene (5%), aluminum (20%) and paper (75%). The beverage carton is closed with a polyethylene strip and capped with a polypropylene cap. Data on the quantity of material used are of primary origin. Other relevant data are from Ecoinvent v.2.2.

Table 3-27 relevant Inventory data primary packaging

Process/material	Inventory data	Reference
Aluminum Production	2 g	Primary data, Polyethylene terephthalate, granulate, amorphous, at plant /RER S
Disposal (production efficiency)	4%	Primary data different scenario. See end of life
Paper production	22,26 g	Primary data
PET production	6,36 g	Primary data Primary data, Polyethylene terephthalate, granulate, amorphous, at plant /RER S
Disposal (production efficiency)	5%	Primary data different scenario. See end of life
PET production	0,154 g	Primary data, Polyethylene terephthalate, granulate, amorphous, at plant /RER S
HDPE Production	4,419 g	Primary data, Polyethylene, HDPE, granulate, at plant/RER(S
Polypropylene	0,064 kg	Primary data, Polyethylene terephthalate, granulate, amorphous, at plant /RER S

3.2.2.9 Production

Raw materials are shipped to the company in Rovigo where they undergo a first quality and screening control before being stored in controlled climate storage. The production of the beverage starts with the preparation of the formula (table 4-16) within tanks of the capacity of 8.500 kg. Oat, water and salt are mixed. Once prepared, ingredients of the formula are mixed, mashed and cooked. Some additives are added in order to support the process. Scraps of ingredients consist of an average 1 to 4% of material entering the systems. Such waste is treated according to the end of life scenario presented in the paragraph 3.2.3. Once cooled down, the mixed formula is added with sunflower oil and homogenized. The product is then sterilized and finally packed into the beverage carton material described in the previous chapter.

Water is the most important material in these operations. It can be either withdrawn from the ground or coming directly from municipal water facilities and is used within the companies for different purposes. The latter is served to small utilities and used as emergency source in product processing; the former is used as content of the product (see table 3-16) for cooling, cooking processes and for cleaning operations. All activity data (water consumption, materials and energy sue) are of primary origin; emissions to water related to production and transport of energy are secondary data from Ecoinvent v 2.2 (table 3-28).

Table 3-28 Other relevant Inventory data production (comprehensive 2012 production data)

Process/material	Inventory data	Reference
Energy	318.121.261,80 kWh	Referred to overall company production for the reference year, Primary data and Electricity, medium voltage, at grid/IT S

3.2.2.10 End of life

In the end of life stage, the treatment of primary packaging materials after use is considered. The following tables report on the destination and treatment of such materials. Information on end of life of packaging discarded by either the retail store or the consumer refers to the national data of municipal solid beverage carton waste and is supplied by the supplier of beverage cartons. Three main treatments are considered, disposal to landfill, energy recovery and recycling (Table 3-29).

Table 3-29 End of Life treatment of waste and scraps

Process/material	Inventory data	Reference
Recycling	22,76%;	Recycling aluminum/RER S, Recycling PP/RER S, Recycling PET/RER S, Recycling paper/RER S
Energy Recovery	35,00%	Disposal, aluminum, 0% water, to municipal incineration CH/S; Disposal, polypropylene, 15,9% water, to municipal incineration CH S; Disposal packaging paper, 13,7% water, to municipal incineration CH S
Disposal to landfill	42,44%	Disposal, aluminum, 0% water, to sanitary landfill CH/S; Disposal, polypropylene, 15,9% water, to sanitary landfill CH S; Disposal packaging paper, 13,7% water, to sanitary landfill CH S

3.2.3 Life Cycle Inventory Analysis

Life Cycle inventory analysis is the stage of the study were data collected are aggregated in order to have a first representation of materials and energy flows going in and out of the system. Table 4-23 reports on inventory information to be used according to the inventory method developed and described in chapter 2. Due to the huge amount of data, discharged water quality parameters and air emissions parameters are reported in ANNEX B. Where no information on quantity of discharged water is available (such as from Ecoinvent database) a conservative approach is adopted, considering all the withdrawn water to be consumed. Where no data on quality in and out are available it is assumed that the water going into the system is of the best available quality and the one discharged is of the worst available quality according to the classification of Boulay et al (2011a). It is reminded that G stands for ground water and S for surface according to the classification from Boulay et al. (2011a) data are reported on the functional unit of on product understudy.

Table 3-30 Inventory results for 1000ml of organic oat beverage

Process			Location	Vin (Liters)	Quality class in	αin	Vout (Liters)	Quality Class out	j
Raw Materials	Oat Organic	Manure	San martino in Pensilis (Italy)	0,00	-	1,00	0,00	-	0,00
		Lubricant		0,02	unknown	1,00	0,00	G6	0,00
		Fertilizing		0,02	G1	1,00	0,00	G3	1,00
		Harvesting		0,24	G1	1,00	0,11	G3a	1,00
		Tilling		0,11	G1	1,00	0,00	G3a	1,00
		Planting		0,08	G1	1,00	0,00	G3a	1,00
	Sunflower Organic	Growing		16,15	G1	1,00	2,80	G3a	1,00
	Sunflower Oil	Oil		6,70	G1	1,00	0,00	G6	1,00
	Marine Salt	Sodium	Reggiolo (Italy)	4,84	G1	1,00	0,00	G6	1,00
	Oat organic processing	Decortication	Rovigo (Italy)	0,00	G1	1,00	0,00	G6	0,00
		production		1,04	G1	1,00	0,00	G6	1,00
		Energy		0,01	G1	1,00	0,00	G6	1,00
Packaging materials	Aluminum, primary packaging	Aluminum Production	Sondrio (Italy)	35,74	G1	1,00	0,00	G6	1,00
		Disposal (production efficiency)		0,03	G1	1,00	0,00	G6	1,00
	Paper, primary packaging	Paper production	Lund (Sweden)	54,63	G1	0,00	0,00	G6	1,00
	PET, primary packaging	PET production	Mantova (Italy)	13,73	G1	1,00	0,00	G6	1,00
		Disposal (production efficiency)		0,02	G1	1,00	0,00	G6	1,00
	Strip	PET production		3,10	G1	1,00	0,00	G6	1,00
		HDPE Production		2,52	G1	1,00	0,00	G65	1,00
	Cap (PP)	Polypropylene	Mantova (Italy)	4,70	G1	1,00	0,00	G6	1,00

Transport	Transported Oat Organic	Oat Organic	Italy	0,65	G1	1,00	0,00	G5	1,00
		Transport		0,34	G1	1,00	0,00	G5	1,00
	Transported Sunflower oil	Sunflower oil		6,77	G1	1,00	0,00	G5	1,00
		Transport		0,34	G1	1,00	0,00	G5	1,00
	Transported Marine salt	Marine salt		4,88	G1	1,00	0,00	G5	1,00
		Transport		0,05	G1	1,00	0,00	G5	1,00
	Production of beverage carton	production	Modena (Italy)	0,46	G1	1,00	0,00	G5	1,00
Production	Beverage Production	Water	Rovigo (Italy)	1,10	G2	1,00	0,20	S2	0,00
		Energy		0,13	G1	1,00	0,00	G5	1,00
	Packaging	Water		0,08	G2	1,00	0,00	S3	1,00
		Energy		0,01	G1	1,00	0,00	G5	1,00
End of Life	End of Life Aluminum	Treatment Italian scenario (l/FU)	Italy	0,00	S1	1,00	0,00	G5	1,00
	End of Life Paper	Treatment Italian scenario (l/FU)		0,01	S1	1,00	0,00	S5	1,00
	End of Life PET	Treatment Italian scenario (l/FU)		0,04	S1	1,00	0,00	S5	1,00
	End of Life Strip	Treatment Italian scenario (l/FU)		0,00	S1	1,00	0,00	S5	1,00
	End of Life Cap	Treatment Italian scenario (l/FU)		0,00	S1	1,00	0,00	S5	1,00

Based on the data collected in the inventory stage it was possible to assess CWU and DWU inventory indicators. Results are reported in Figure 3-11.

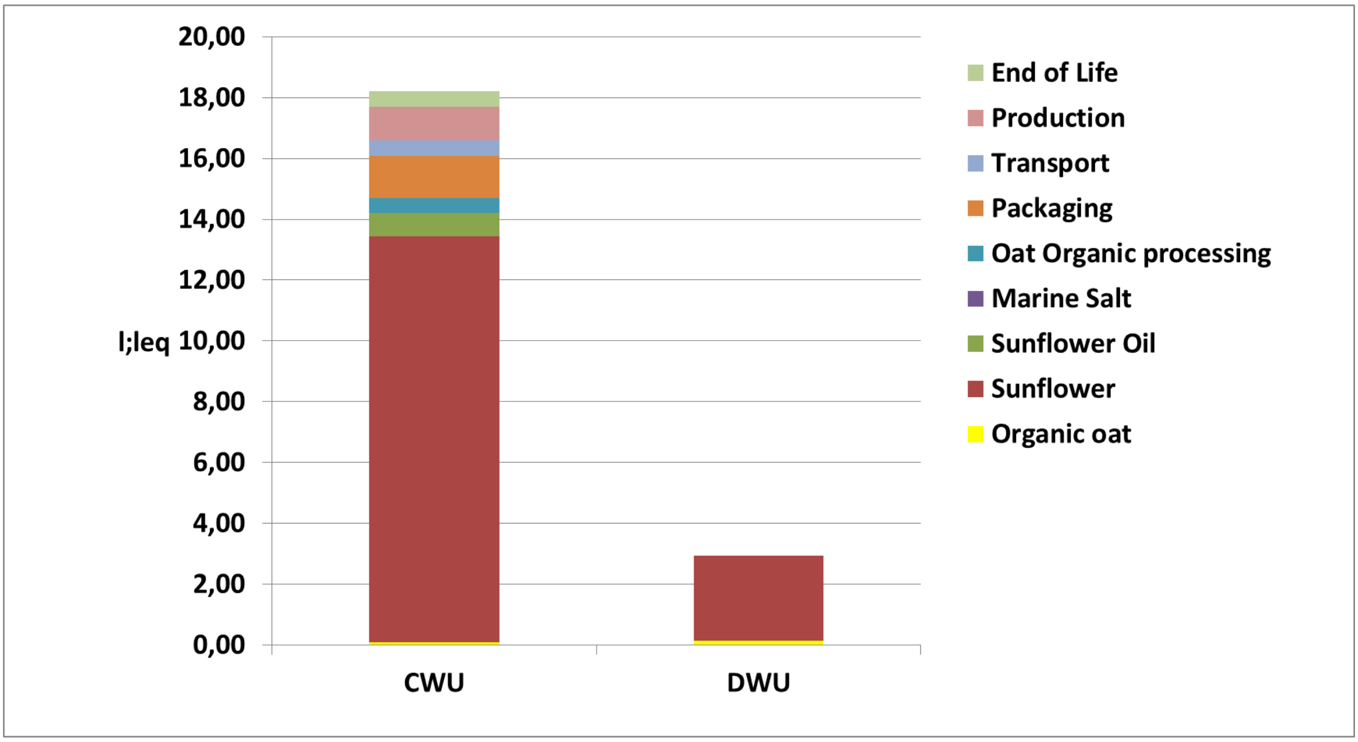

Figure 3-11 Inventory indicator results of 1000ml of organic oat beverage

The total CWU of the organic oat beverage resulted to be 18,21 liters. This quantity refers to the volume of water that is consumed specifically because of product evaporation or water traded to other water basins. The degradative water use resulted to be 2,94 liters of water. This quantity represents the total volume of discharged water whose quality has been altered if compared to the withdrawn one and quality of destination water body. CWU, in this case, resulted to be more significant than the degradative water use. Going deeper in the analysis of inventory results, two processes are responsible of DWU: the production of oat and in particular the production of sunflower. Water used in the beverage production is not degraded at values that result in a change of water quality category. Parameter j allowed the comprehension of which water resulted to have altered quality. The biggest contribution to CWU are related to the use of water for irrigation in the growing of sunflower, the use of water for the production of primary packaging (made for the 75% of paper a water intensive product), the water content of the final product (over 87% of final product weight).

3.2.4 Life Cycle Impact Assessment

In this chapter the results of the water footprint impact assessment are presented. Impact methods developed at mid-point and end-point level were applied. The final water footprint is presented in a form of a profile consisting of the scarcity consumptive water use, scarcity degradative water use, and eutrophication, eco-toxicity, and acidification footprints. Methods described in materials and methods were applied. For the assessment of eutrophication, eco-toxicity and acidification footprint characterization factors from Ecoinvent 2.2 (Weidema and Hischier, 2010) were considered. To model these impacts software Simapro version 7.3 has been used. This software is commonly used in Life Cycle Assessment studies.

3.2.4.1 Water Stress indicator

According to developed method presented in chapter 2, the scarcity cumulative water use method represents the effects of consumptive and degradative water use to local water availability.

The scarcity consumptive water use (SCWU) characterizes the stress (use specific) that the production of one unit of organic oat beverage places on local water resources throughout its entire life cycle. This stress is a result of the consumption of water. Figure 3-12 report the results of the SCWU and related CWU on functional unit.

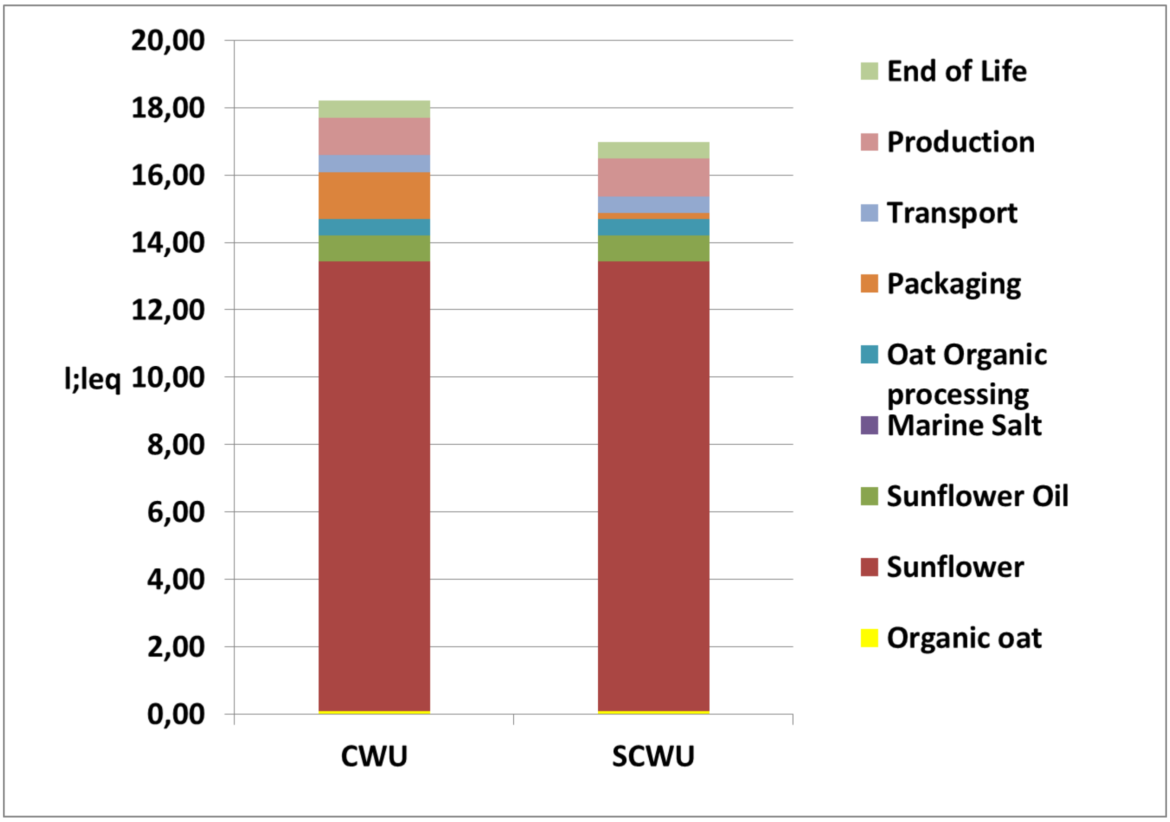

Figure 3-12 SCWU of 1000ml of organic oat beverage

The total SCWU of the water collection system resulted to be 16,99 l_{eq}. in this case the impacts on water availability from consumptive water use resulted to be smaller than the cumulative water use. The reason of these result is that paper is produced in regions where water availability is high, therefore impacts on water resources resulted to be smaller,

The scarcity degradative water use (SDWU) characterizes the stress (use specific) that the production of one unit of water 1000ml of organic oat beverage places on local water resources throughout its entire life cycle. This stress is a result of the degradation of water quality. Figure 3-13 reports the results of the SDWU and related DWU on functional unit.

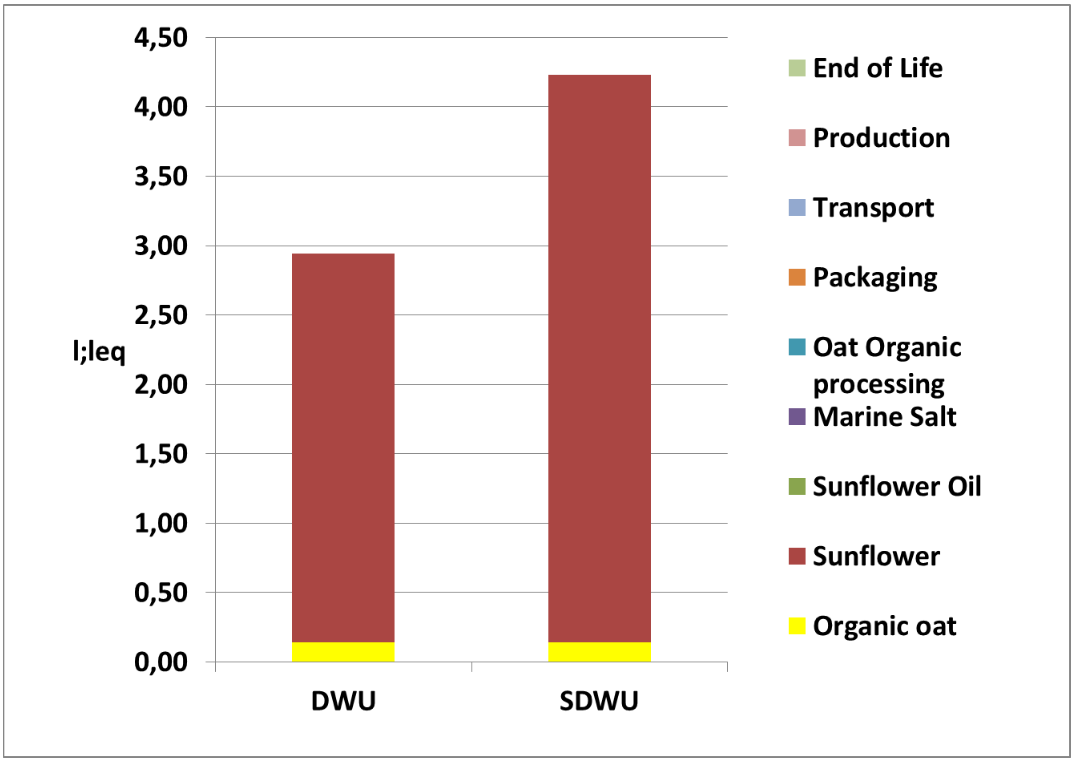

Figure 3-13 SDWU of 1000ml of organic oat beverage

The total SDWU of the organic oat beverage resulted to be 4,23 l_{eq}. These impacts are related to the use of N and P based fertilizers to grow sunflowers and oat. In the case of oat, the runoff assessed through the use of CROPWAT resulted to be limited; therefore leaching of pollutant through the ground to groundwater is little. In the case of sunflower even if the use of fertilizer is similar to the oat one, the volume of irrigation water t is pretty high and resulted in significant emission of N to groundwater. Moreover reporting this impact value to functional unit the smaller yield has to be considered. In this case, assessment of distance to target factor is based on value of N released to water, reported to N limits accepted in agriculture processes (10 mg/l).

In the assessment of water scarcity, SCWU resulted to be more significant than SDWU. The total WSI resulted to be 21,22 l_{eq}.

3.2.4.2 Degradation profile

In this section the results of the mid-point impact assessment for several water quality indicators are presented. The life cycle of the 1000ml oat organic beverage has been modeled through the use of Simapro version 7.3 software. Figure 3-14 reports the result of the impact assessment in eutrophication, eco-toxicity and acidification categories.

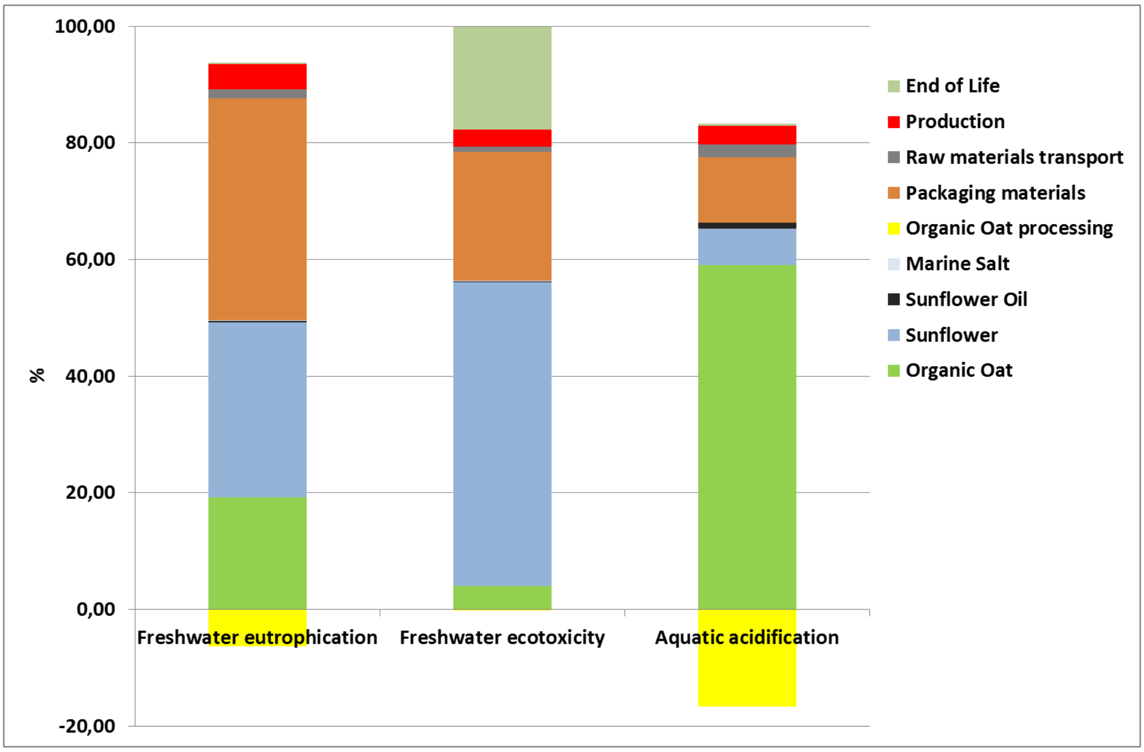

Figure 3-14 Other impacts related to water of 1000ml of organic oat beverage

The total water eutrophication footprint of the organic oat beverage resulted to be 6,01E-05 kg of P eq.. Three processes resulted to have significant contribution to eutrophication: packaging materials, sunflower and organic oat growing. In the case of packaging material is the use of energy and related emissions to present the biggest impacts. In the case of agriculture processes, the use of fertilizer resulted to be significant. Contribution of organic oat processing resulted to be negative. This depends on the avoided impacts related to the reuse of scraps as fodder.

The total water eco-toxicity footprint of the product under study resulted to be 3,28E-03 kg 1,4-DB eq. These results confirm the significance of the production of sunflower oil and related cultivation practices.

The total water acidification footprint of 1000ml of organic oat beverage resulted to be 1,26E-03 kg SO_2 eq. The fuel consumption for organic oat cultivation processes resulted to be significant. Organic oat processing, due to the reuse of scraps, had a negative contribution. This is related to the avoided energy use and related air emissions of fodder production.

3.2.4.3 End-point impacts on Resources

In this paragraph, results of the application of the method related to Resource area of protection presented in chapter 2 are reported. These impacts are related both to degradative and consumptive water use and refer to back-up technology locally applicable.

To compensate the degradative water use, wastewater treatment facilities have been considered as local back – up technology. Values of $E_{local,j}$ are acquired from Ecoinvent v 2.2 database (Weidema and Hischier, 2010) and chosen based on the size of the wastewater treatment facilities locally applicable. To determine applicability of the back-up technology the parameter person equivalent has been used. Table 3-32 reports on $E_{local,j}$ values used to back-up degradative water use; these values are determined using CED method. Where no data on specific locations are available, a worst case approach has been adopted considering the wastewater treatment plant with the highest surplus energy values (resulting in the smallest one according to Ecoinvent 2.2).

Table 3-31 $E_{local,j}$ values for 1000ml of oat organic beverage

Process			Location	Person equivalent	$E_{local,j}$ (MJ/l)	Reference
Raw Materials	Oat Organic	Manure Lubricant Fertilizing Harvesting Tilling Planting	San Martino in Pensilis (Italy)	5231	6,70E-03	Waste water treatment plant class 5/CH/I
	Sunflower Organic	Growing				
	Sunflower Oil	Oil	San Martino in Pensilis (Italy)	5231	6,70E-03	Waste water treatment plant class 5/CH/I
	Marine Salt	Sodium Disposal (production efficiency)	Reggiolo (Italy)	24864	6,18E-03	Waste water treatment plant class 4/CH/I
	Oat organic processing	Decortication production Energy	Rovigo (Italy)	71133	5,37E-03	Waste water treatment plant class 2/CH/I
Packaging materials	Aluminum, primary packaging	Aluminum Production Disposal (production efficiency)	Sondrio (Italy)	24864	5,76E-03	Waste water treatment plant class 3/CH/I
	Paper, primary packaging	Paper production	Lund (Sweden)	71133	5,37E-03	Waste water treatment plant class 2/CH/I
	PET, primary packaging	PET production Disposal (production efficiency)	Mantova (Italy)	71133	5,37E-03	Waste water treatment plant class 2/CH/I
	Strip	PET production HDPE Production				
	Cap (PP)	Polypropylene				
Transport	Transported Oat	Oat Organic	Italy	5231	6,70E-03	Waste water

Process			Location	Person equivalent	$E_{local,j}$ (MJ/l)	Reference
	Organic	Transport				treatment plant class 5/CH/I
	Transported Sunflower oil	Sunflower oil				
		Transport				
	Transported Marine salt	Marine salt				
		Transport				
	Production of beverage carton	Production	Modena (Italy)	71133	5,37E-03	Waste water treatment plant class 2/CH/I
Production	Beverage Production	Water	Rovigo (Italy)	71133	5,37E-03	Waste water treatment plant class 2/CH/I
		Energy				
	Packaging	Water				
		Energy				
End of Life	End of Life Aluminum	Treatment Italian scenario (l/FU)	Italy	5231	6,70E-03	Waste water treatment plant class 5/CH/I
	End of Life Paper					
	End of Life PET					
	End of Life Strip					
	End of Life Cap					

To compensate the consumptive water use, according to the characteristics of the area understudy where rainwater falls regularly (FAO, 2010b), it was decided to model a water collection system based on the water collection system of case study number 1. The methodology described in chapter 2 has been applied: CED method has been employed to assess the surplus energyper liter of the production and installation of the water collection system including the energy to produce other materials and devices (such as pumps and tubes, HDPE geo-membrane) used to install the system and to run a domestic water treatment facility (in this case it is assumed that rainwater quality is the same of surface water).

The collection system is dimensioned on the water requirements of the specific process for the production of 1000ml of organic oat beverage and considers the minimum average yearly precipitation based on the 30 years normalized values (FAO, 2010b). It is assumed that the collection system has a lifetime of 30 years according to company specification. When only general information on locations are available a conservative approach is adopted assuming the worst rainwater conditions available in CLIMAWAT Database (2010b) referred to Italy. Only effective rain is used for compensation (% of rainwater that does not evaporate or run-off).

Table 3-32 reports on the dimensioning of the system.

Table 3-32 Water collection system dimensioning for 1000ml of oat organic beverage

Process	Rain (local climate conditions [l/m2/yr]	Process cumulative water use [l]	N° of drening elements
Oat Organic	33,00	0,09	1,00
Sunflower	21,70	13,35	1,00
Sunflower Oil	21,70	0,75	1,00
Marine Salt	40,00	0,00	1,00
Oat Organic, processed for beverage production	33,00	0,50	1,00
Aluminum, primary packaging	40,90	0,07	1,00
Paper, primary packaging	38,30	1,22	1,00
PET, primary packaging	33,00	0,09	1,00
Strip	33,00	0,00	1,00
Cap (PP)	21,70	0,02	1,00
Transport	33,00	0,50	1,00
Production	33,00	1,12	1,00
End of Life	33,00	0,50	1,00

Table 3-33 report the values of $E_{local,I}$.

Table 3-33 Elocal,i values for 1000ml of oat organic beverage

Process			Location	$E_{local,i}$ (MJ/l)
Raw Materials	Oat Organic	Manure	San Martino in Pensilis (Italy)	0,50
		Lubricant		
		Fertilizing		
		Harvesting		
		Tilling		
		Planting		
	Sunflower Organic	Growing		0,75
	Sunflower Oil	Oil	San Martino in Pensile (Italy)	0,75
	Marine Salt	Sodium	Reggiolo (Italy)	0,41
		Disposal (production efficiency)		
	Oat organic processing	Decortication	Rovigo (Italy)	0,50
		production		
		Energy		
Packaging materials	Aluminum, primary packaging	Aluminum Production	Sondrio (Italy)	0,40
		Disposal (production efficiency)		
	Paper, primary packaging	Paper production	Lund (Sweden)	0,43
	PET, primary packaging	PET production	Mantova (Italy)	0,50
		Disposal (production efficiency)		

Process			Location	$E_{local,i}$ (MJ/l)
	Strip	PET production		0,50
		HDPE Production		
	Cap (PP)	Polypropylene		0,45
Transport	Transported Oat Organic	Oat Organic	Italy	0,50
		Transport		
	Transported Sunflower oil	Sunflower oil		
		Transport		
	Transported Marine salt	Marine salt		
		Transport		
	Production of beverage carton	Production	Modena (Italy)	
Production	Beverage Production	Water	Rovigo (Italy)	0,50
		Energy		
	Packaging	Water		
		Energy		
End of Life	End of Life Aluminum	Treatment Italian scenario (l/FU)	Italy	0,50
	End of Life Paper			
	End of Life PET			
	End of Life Strip			
	End of Life Cap			

Final values of ΔR are reported in figure 3-15.

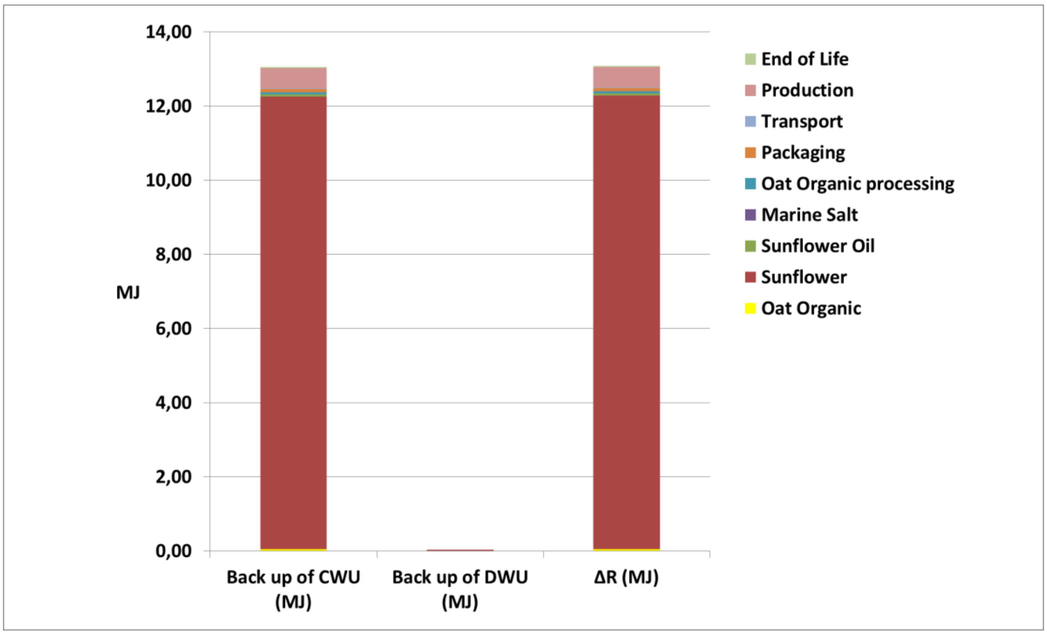

Figure 3-15 Impacts on resources from consumptive and degradative water use of 1000ml of organic oat beverage

Results of impact assessment of resources area of protection shows that compensation of consumptive water use (13,06 MJ) requires more energy than the degraded one (3,06 E-2 MJ). The company should work on water use efficiency to decrease end point resources footprint.

Inventory indicator results are confirmed showing that back up of sunflower consumptive use is the most significant one. ΔR resulted to be 13,09 MJ

3.2.4 Life Cycle Interpretation

In this stage of the study, results are analyzed in order to determine the main environmental hot-spot related to water. Table 3-34 reports on the results of this analysis highlighting the main hotspot and related variables.

Table 3-34 Hot-spot analysis for 1000ml organic oat beverage

Level of analysis	Indicator	Hotspots-process	Variables that influenced results
Inventory	CWU	Sunflower	Use of irrigation water due to local climate conditions
	DWU	Sunflower	Use of fertilizer and leaching due to groundwater caused by volumes of irrigation water
Mid-point Impacts	SCWU	Sunflower	Use of irrigation water due to local climate conditions and local scarcity
	SDWU	Sunflower	Use of fertilizer and leaching due to groundwater caused by volumes of irrigation water
	Eutrophication	Primary packaging materials Sunflower, organic oat	Pollutants release to water of paper processing for primary packaging production, use of fertilizers in sunflower and organic oat cultivation
	Eco-toxicity	Primary packaging materials Sunflower, organic oat	Pollutants release to water of paper processing for primary packaging production, use of fertilizers in sunflower and organic oat cultivation
	Acidification	Organic oat growing, Sunflower growing, primary packaging materials	Use of energy in paper production and agriculture processes.
End-point impacts	Back up of CWU	Sunflower	Use of irrigation water due to local climate conditions
	Back-up of DWU	Sunflower	Use of fertilizer and leaching due to groundwater caused by volumes of irrigation water

Considering all different hotspot it was possible to identify that sunflower cultivation affects 6 out of nine indicators results. Considering the fact that the company owns several ha in different Italian regions, it was decided to study through sensitivity analysis, how the water profile would change in the case of changing in the location to grow sunflower.

Sensitivity analysis: Different location for sunflower production

Sunflower production resulted to be most water intensive process. The company owns land in different regions with different local climate conditions. Table 3-36 reports on the different water requirements performances related to the cultivation of organic oat. These data were assessed using CROPWAT software. Data on climate conditions refers to closest the climate station to the fields understudy; data on crop parameters are the same for the three scenarios.

Table 3-35 Scenario description for 1000ml of organic oat beverage

Scenario	Location	Crop Water requirements (mm)	Effective rainfall	Irrigation requirement
Location business as usual	San Martino in Pensilis (Italy	386,50	105,50	281,00
Location 1	Ferrara (Italy)	429,40	188,80	240,60
Location 2	Rovigo (Italy)	363,60	321,30	96,80

According to climate data, Rovigo resulted to have the best conditions to minimize irrigation requirements. In this case most of the water needed comes from rainwater. Table 3-37 reports the result of quantification of different indicators comparing actual locations with Rovigo.

Table 3-36 Impact assessment results for 1000ml of organic oat beverage in the most favorable climate conditions

	Unit	Business as usual	Location 2	% reduction
CWU	l	18,21	8,02	55,96
DWU	l	2,94	2,74	6,80
SCWU	l_{eq}	16,99	6,80	59,97
SDWU	l_{eq}	4,09	3,94	3,66
Back up of CWU	MJ	13,06	5,20	61,76
Back up of DWU	MJ	0,03	0,02	33,33

No other significant impacts results can be noted: eutrophication, eco-toxicity and acidification impacts in fact resulted to be more influenced by other parameters such as packaging paper production. Based on these result, the company can achieve consistent performance improvement.

It is no interest of the company to change the packaging therefore no sensitivity analysis was conducted on this issue.

3.3. Case study 3: Organic strawberry Jam

The third case study chosen to test the applicability and effectiveness of the developed set of indicators, is related to an organic strawberry jam produced in Asiago (Vicenza Italy) that is made of raw materials produced in different Regions of Bulgaria (Manzardo et al., 2012). The producer has started a specific environmental communication policy and due to the attention on the topic of water footprint, decided to conduct a water footprint study on its most representative products sold in Italy in 2011. This product answers the need of the research for the following reasons:

- It is based on agriculture processes that are recognized to be water intensive;
- Life cycle processes take place in different contests and regions.

3.3.1 Goals and scope definition

The goal of this study is to apply the developed set of indicators to conduct a contribution and hotspot analysis of the potential impacts related to water throughout the life cycle of the strawberry jam understudy. The assessment is intended to assist the company in determining which aspects of the product life cycle contribute the most to the environmental impacts related to water and, therefore, to identify potential opportunities to improve water use and management along the value chain; this study has been performed in accordance with the methodologies and requirements presented in chapter 2.

The Functional Unit (FU) was identified as a 330g organic strawberry Jam produced by the Italian company located in Asiago (Vicenza) and distributed in Italy. The function of the product system is the production of the organic strawberry jam. The formula of the product understudy is presented in table 3-37.

Product system boundaries are based on the cradle to gate approach therefore impacts from the extraction of raw materials and ancillary materials to the production and packaging of the final product are considered. System boundaries are reported in figure 3-16.

Table 3-37 Content of 330g of organic strawberry jam

Material	**Quantity (% in final product)**
Strawberries	**60**
Apple juice concentrated	**38**
Pectin	**2**

For each process unit the following primary/secondary data have been collected: quantity of water use (withdrawal and discharge); type of water resources; data on water quality in and out of the system, when available; location of water use; seasonal changes in water flows; temporal aspects of water use; forms of water use (If not differently specified, all water used was considered to be a liquid). No significant changes in drainage conditions due to land use change were determined.

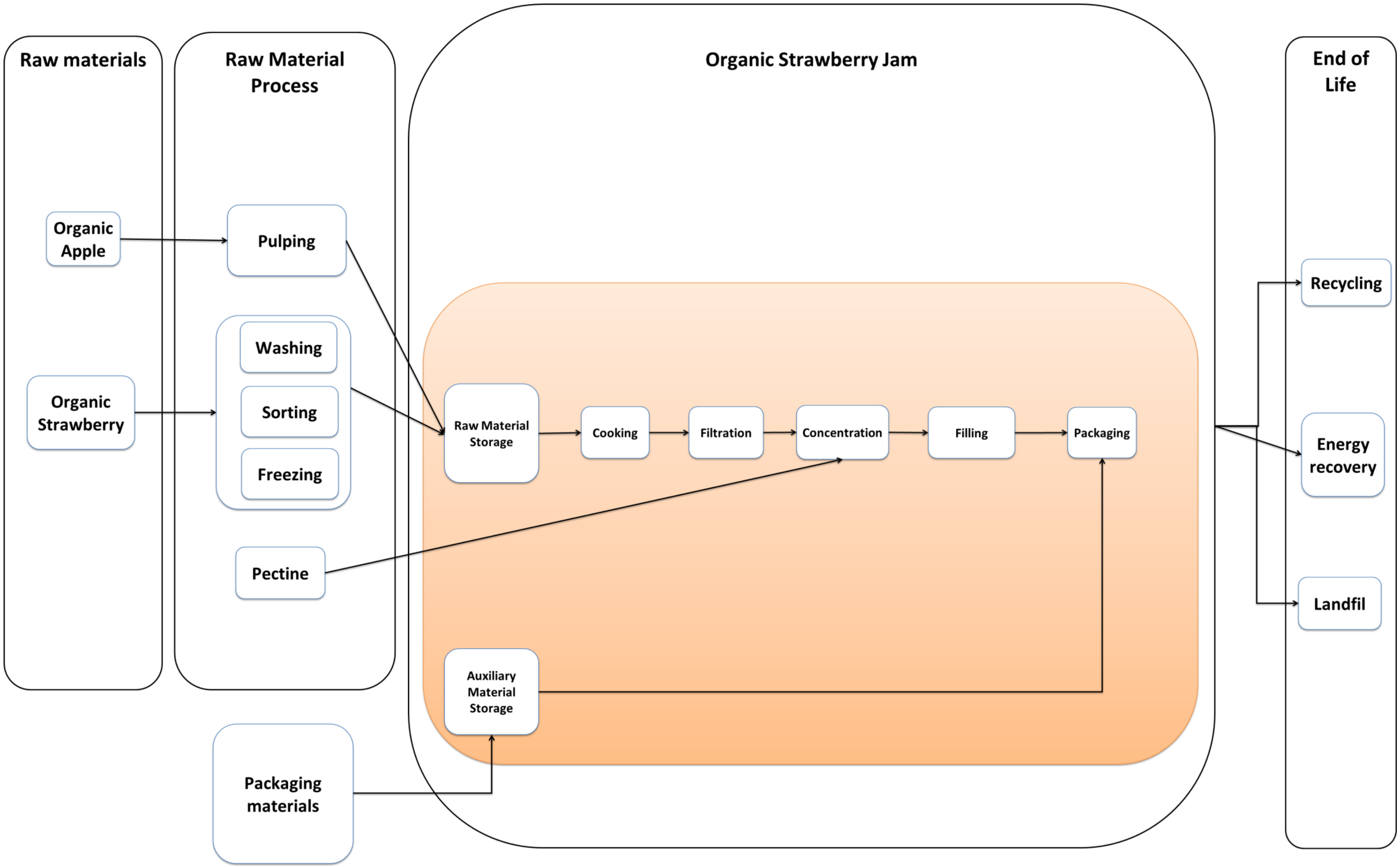

Figure 3-16 System boundaries for the 330g of organic strawberry jam

Criteria used in the selection of data to be used in the study are reported in Table 3-38. In this study, cut off criteria of 1% by mass has been used.

Table 3-38 Data Quality criteria

Topic	Criteria adopted in this study
Time period coverage	Primary data from the most recent representative period (2010-2011 for agriculture processes 2011 for production processes) were used were available. When only secondary data were available, most recent and representative were chosen. (e.g. climate data consolidated over 30 year period for the growth of apple and strawberries).
Geographical coverage	All primary data are site specific. In the case of secondary data, average production from the country of origin is considered where available.
Technology coverage	Primary and secondary data always refers to the technology in use if not differently specified.
Precision and uncertainty	Most of the data collected are primary with limited uncertainty. In the selection of secondary data it was preferred to use Ecoinvent data sets that also present uncertainty information and data.
Completeness, Representativeness	Completeness measures the percent of primary data collected and used for each category in a unit process. Actual manufacturing data for the product life cycles were collected, Where possible, suppliers provided detailed water and energy usage, material usage, and scrap end of life for their operations. When suppliers were not able to provide information, assumptions were made based on industry practice or information provided by other suppliers. Life cycle inventory data is not included in the life cycle if it represents less than 5% by weight of the product materials and the data is not available. Over 95% of the product mass is included in the LCA. It is expected that the remaining mass will have little to no effect on the outcome of the water footprint results.
Consistency	Consistency considers how uniformly the study methodology is applied to the various components of the analysis. The methodology presented in chapter 2 was applied to all components of the product under study consistently, in terms of modeling and assumptions. Consistency in results has been checked with literature reference.
Reproducibility	The modeling has been performed and described such that another water footprint practitioner could reproduce this water footprint.

Unless specified otherwise, secondary inventory data used in this study are from Ecoinvent 2.2 database. Ecoinvent data is maintained by the Ecoinvent Research Centre. Created in 1997, the Ecoinvent Research Centre (Frishknet et al., 2005; Althaus et al., 2007). All emissions data used to address impacts on acidification are taken from Ecoivent. Characterization factors, if not differently specified, are from this version of Ecoinvent.

3.3.2 Life Cycle Inventory

In this chapter, all the data acquired and calculations performed are reported. The paragraph is divided per different process units considered.

Primary data are collected directly from the producer company. In the case of secondary data however not all the information (such as quality in and quantity out) was available. In these cases a conservative approach is adopted considering all withdrawn water used (consumptive use) and the quality entering the system as of the best quality locally available.

3.3.2.1 Strawberries

Strawberry is the most important material used in the production of organic strawberry jam. These are cultivated in Pazardijik, on 47 ha of land. Strawberry plants are trans-planted in July and harvested the next year in June. Due to local climate conditions, strawberries are also irrigated through drip irrigation technology with water coming from surface water body running close to the field. During winter, however, due to rainfall, water irrigation is not needed. Data reported are primary data based on 2010 and 2011. The average yield based on historical company data is 20 tons/ha.

In order to assess the crop water requirements the CROPWAT model (FAO, 2010a) has been used. ET0 (evapotranspiration in standard condition) is determined using the Penman-Montheit equation (FAO, 2010a). Effective rain (the rainfall effectively available to the crop) is assessed through the USDA SCS method (option selected within CROPWAT model). Climatic data are taken from the climatic stations used by the company that are located directly on the field. Such data have been used within CROPWAT software to determine the crop water requirements. Also data on crop coefficients are of primary origin. Specific crop water requirements resulted to be 484,00 mm of water with 329 mm of water coming from rainwater.

To determine irrigation needs, due to the peculiarities of this fruit, the assessment is divided in two periods: from July to September of the first year and from April to July of the second year. This practice follows experience from Chapagain and Hoekstra (2008).

Table 3-39 Precipitation and Effective Rain in strawberry fields

	Pazardjick	
	Rain	Eff rain
	mm	**mm**
January	18,60	18,00
February	56,60	51,50
March	57,60	52,30
April	69,00	61,40
May	2,60	2,40
June	3,40	3,40
July	21,20	20,50
August	34,00	32,20
September	170,00	123,80
October	102,00	85,40
November	12,00	12,20

	Pazardjick	
	Rain	Eff rain
	mm	**mm**
December	100,00	84,00

No chemical fertilizers are used in the growing of strawberries, however a quantity of organic fertilizers containing N is used. Data on fertilizer are reported in Tab 3-41. Following common practice from Hoekstra et al. (2011) the 10%of the quantity of N leaches into the groundwater.

Table 3-40 Data on the use of fertilizers for strawberry tries

Substance considered	N content of applied fertilizer	Reference
P	318 kg/ha	Primary data from supplier, 2010-2011

Other use of water comes from the production of energy used for the first processing of strawberries in the field (Table 3-41).

Table 3-41 Other relevant Inventory data strawberries

Process/material	Inventory data	Reference
Electricity	0,08kWh/kg of strawberry	Electricity, low voltage, at grid/BG S
Diesel	0,024 kg/kg of strawberry	Diesel, at refinery/RER S

3.3.2.3 Apple

Apples are grown directly by the company that produces the jam in Berkovitsa (Bulgaria) in a 20 ha extended field. Apples are grown to produce a sweetener that is one of the main ingredients of the strawberry jam. In order to assess the crop water requirements the same model (CROPWAT) and climate data were used. Specific crop requirements data are of primary origin. Medium soil parameters from CROPWAT are considered. Specific crop water requirements resulted to be 490,00 mm of water with 314,00 mm of water coming from rainwater.

Table 3-42 Precipitation and Effective Rain in the apple fields

	Berkovitsa	
	Rain	Eff rain
	mm	**mm**
January	33,40	26,70
February	57,00	45,60
March	76,60	61,30
April	93,60	74,90
May	95,80	76,60
June	80,80	64,60
July	145,80	116,60
August	60,60	48,50

	Berkovitsa	
	Rain	Eff rain
	mm	**mm**
September	52,40	41,90
October	122,00	97,60
November	33,40	26,70
December	62,60	50,10

No chemical fertilizers are used in the growing of apple, however a quantity of organic fertilizers containing N is used. Data on fertilizer are reported in Tab 3-43. Following common practice from Hoekstra et al. (2011) the 10%of the quantity of P leaches to the groundwater.

Table 3-43 Data on the use of fertilizers for apple trees

Substance considered	P emissions to water	Reference
P	3,18E-5 kg/kg of strawberry	Primary data from supplier, 2011

Other use of water comes from the production of energy used for the first processing of apple in the field (Table 3-44).

Table 3-44 Other relevant Inventory data apples

Process/material	Inventory data	Reference
Apple processing	0,08 kWh/kg of strawberry	Electricity, low voltage, at grid/BG S

3.3.2.4 Frozen strawberry

Once harvested, strawberries are processed in a facility not far from the field where they were grown. In this facility strawberries are selected, washed and finally frozen in order to be sent to the production facility located in Asiago (Italy); in the case of strawberry washing, discharge water resulted to be degraded due to the increased BOD and other nutrients concentration. Other indirect water use come from the electricity needed in the operations. (Table 3-45).

Table 3-45 Other relevant Inventory data freezing strawberry

Process/material	Inventory data	Reference
Freezing strawberry	0,43 kWh/kg of strawberry	Electricity, low voltage, at grid/BG S

3.3.2.5 Apple juice concentrated

Apple is processed in a facility to produce apple juice. This product is then used as sweetener in the production of the strawberry jam. Primary data were acquired from the supplier. In this case water used to wash the apple is considered. Apple is then mashed into apple juice. Inventory data are reported in section 3.3.3.

3.3.2.6 Packaging

In this section primary and secondary packaging is considered. Once produced the organic strawberry jam is packed into glass jar closed by a lid. Label is added and finally the jam is packed into a corrugated carton box containing 6 strawberry jam jars. In this section water use related to the production of primary packaging is considered. Quantity of material used are primary data, environmental elementary flows are secondary data from Ecoinvent v 2.2..

Table 3-46 Inventory data packaging

Process/material	Inventory data	Reference
Lid	73,50 g/Functional unit	Primary data, Steel low alloyed, at plant/RER S, transport lorry >32t, EURO3/RER S; corrugated board, fresh fiber, single wall, at plant/CH S
Label	0,39 g/Functional Unit	Primary data, paper, wood containing LWC, at regional storage/RER S
Glass Jar	204,00 g/Functional Unit	Primary data, packaging glass, white, at plant//RER S; Transport, lorry >32t, EURO3/RER S;
Corrugated carton	300,00 g/Functional Unit	Corrugated board, recycling fiber, double wall, at plant/CH S

3.3.2.7 Transport

In this life cycle stage transportation of raw materials are considered from filed of origin to Asiago facility in Italy. Inventory data are reported in table 3-47

Table 3-47 Inventory data transport

Process/material	Inventory data	Reference
Transport apple	1200,00 kg*km/1 kg of strawberry	Transport lorry >32t, EURO3/RER S;
Transport strawberry	1024,00 kg*km/1 kg of strawberry	Transport lorry >32t, EURO3/RER S;
Corrugated carton	44,00 g/1 kg of strawberry	Corrugated board, recycling fiber, double wall, at plant/CH S

3.3.2.8 Production

Production of strawberry jam takes place in a facility located in Asiago Italy. Raw materials and packaging materials arrive at the production site and are stored before being used in the production of the organic strawberry jam. Strawberries are stored in refrigerated environment. Strawberries are mixed with the sweetener and then cooked consuming natural gas, after a process of filtration the pectin (thickener) is added to jellify the mix. After this process the jelly is packed in the glass jar that is sterilized through the use of vapor before entering the packaging operations. Water use data are reported in chapter 3.3.3. 5kg of strawberry and 132 grams of apple juice are needed in the 330g organic jam production.

Table 3-48 Energy inventory data strawberry jam production

Process/material	Inventory data	Reference
Electricity	0,15 kwh/kg of jam	Electricity, low voltage, at grid/IT S
Natural gas	6,97E-3 m3/kg of jam	Natural gas, at long distance pipeline/RER S

3.3.2.9 End of life

In the end of life stage, the treatment primary packaging materials after use are considered. The following tables report on the destination and treatment of such materials. Information on end of life of packaging discarded by either the retail store or the consumer refers to the national data of municipal waste treatment. Three main treatments are considered, disposal to landfill, energy recovery and recycling.

Material	Recycling rate	Energy Recovery	Disposal to landfill rate
Lid	74%	0,00%	24,00%
Label	59,30%	28,190%	12,60%
Jar	68,30%	0,00%	31,70%
Carton	59,30%	28,190%	12,60%

Table 3-49 End of Life treatment of waste and scraps

3.3.3 Life Cycle Inventory Analysis

Life Cycle inventory analysis is the stage of the study were data collected are aggregated in order to have a first representation of materials and energy flows going in and out of the system. Table 3-50 reports on inventory information to be used according to the inventory method developed and described in chapter 2. Due to the huge amount of data, discharged water quality parameters and air emissions parameters are reported in ANNEX C. Where no information on quantity of discharged water is available (such as from Ecoinvent database) a conservative approach is adopted, considering all the withdrawn water to be consumed. Where no data on quality in and out are available it is assumed that the water going into the system is of the best available quality and the one discharged is of the worst available quality according to the classification from Boulay et al. (2011a). It is reminded that G stands for ground water and S for surface according to the classification from Boulay et al. (2011a) data, if not differently specified, are reported to the functional unit of on product understudy.

Table 3-50 Inventory results for 330g of organic strawberry jam.

Process			Location	Vin (Liters)	Quality class in	αin	Vout (Liters)	Quality Class out	j
Raw Materials	Apple	Apple Growing (l/kg of apple)	Berkovitsa (BG)	176,00	S2a	0,43	41,00	G3b	1,00
		Apple processing (l/kg of Apple)		0,14	S1	1,00	0,00	S3c	1,00
	Strawberry	Strawberry growing (l/kg of strawberry)	Pazardjick (BG)	150,00	S2a	0,43	22,50	G3b	1,00
		Diesel (l/kg of strawberry)		0,59	S1	1,00	0,00	S6	1,00
	Apple Juice concentrated	Electricity (l/kg of strawberry)	Berkovitsa (BG)	0,10	S1	1,00	0,00	S4	1,00
		Water (l/kg of juice)		11,00	S1	0,43	7,00	S4	1,00
	Frozwen strawberry	Water (l/kg of juice)	Pazardjick (BG)	10,37	S1	0,43	7,17	S4	1,00
		Electricity (l/kg of Frozen strawberry)		3,26	S1	1,00	0,00	S4	1,00
Packaging	Glass Jar	White glass	Swtzerland	8,09	G1	1,00	0,00	G6	1,00
		Transport		0,20	G1	1,00	0,00	G6	1,00
	Corrugated carton	Corrugated carton double wall	Switzerland	15,30	G1	1,00	0,00	G6	1,00
	Label	Paper	Italy	41,85	G1	1,00	0,00	G6	1,00
	Lid	Steel	Latina(Italy)	18,62	G1	1,00	0,00	G6	1,00
		Transport		0,70	G1	1,00	0,00	G6	1,00
		Packaging paper		0,02	G1	1,00	0,00	G6	1,00
Transport	Transported froze strawberries	Transport	Pazardjick (BG)	0,40	G1	1,00	0,00	G6	1,00
	Transported apple	Corrugated carton	Berkovitsa (BG)	0,06	G1	1,00	0,00	G6	1,00
		Transport		0,40	G1	1,00	0,00	G6	1,00

Process			Location	Vin (Liters)	Quality class in	αin	Vout (Liters)	Quality Class out	j
Production	Strawberry jam production	Water (l/kg of jam)	Asiago (Italy)	0,14	G1	0,99	0,00	S2	1,00
		Electricity (l/kg of Jam)		0,00	G1	0,99	0,00	S4	1,00
		Natural gas (l/kg of jam)		0,01	G1	0,99	0,00	S2	1,00
End of Life	End of Life Corrugated carton	Italian scenario (l/FU)	Italy	0,06	G1	1,00	0,00	G6	1,00
	End of Life Glass Jar	Italian scenario (l/FU)		0,01	G1	1,00	0,00	G6	1,00
	End of Life Label	Italian scenario (l/FU)		0,00	G1	1,00	0,00	G6	1,00
	End of Life Lid	Italian scenario (l/FU)		0,00	G1	1,00	0,00	G6	1,00

Based on the data collected in the inventory stage it was possible to assess CWU and DWU inventory indicators. Results are reported in Figure 3-17.

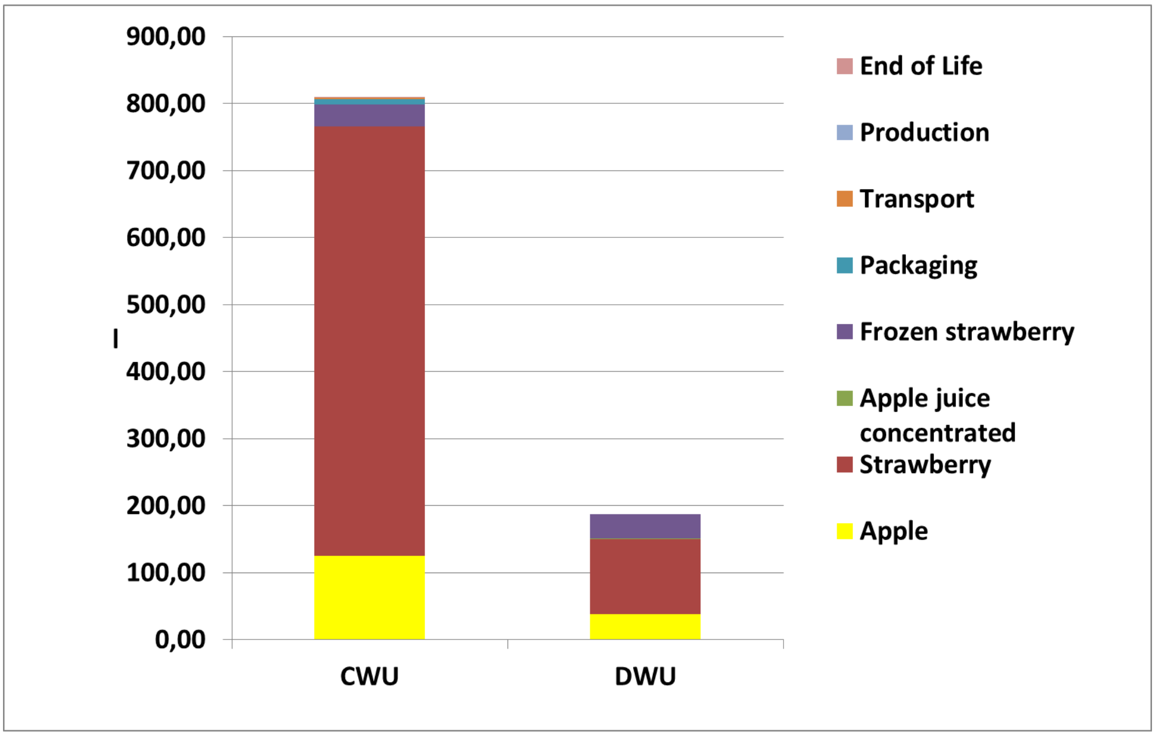

Figure 3-17 Inventory indicator results of 330g of organic strawberry jam

The total CWU of the 330g of organic strawberry jam resulted to be 809,22 liters. This quantity refers to the volume of water that is consumed specifically because of product evaporation or water traded to other water basins. The degradative water use resulted to be 187,15 liters of water. This quantity represents the total volume of discharged water whose quality has been altered if compared to the withdrawn one and quality of destination water body. CWU, in this case, resulted to be more significant than the degradative water use. Going deeper in the analysis of inventory results several processes are responsible of DWU: the production of apple and strawberry contributed the most but also the processing of strawberries resulted to have significant values of degraded discharged water.. Parameter j allowed the comprehension of which water resulted to have altered quality. The biggest contribution to CWU is related to the use of water for irrigation in the growing of strawberries. Final value of CWU resulted to be influenced also by the conversion rate from strawberries to final jam product.

3.3.4 Life Cycle Impact Assessment

In this chapter the results of the water footprint impact assessment are presented. Impact methods developed at mid-point and end-point level were applied. The final water footprint is presented in a form of a profile consisting of the scarcity consumptive water use, scarcity degradative water use, and eutrophication, eco-toxicity, and acidification footprints. Methods described in materials and methods were applied. For the assessment of eutrophication, eco-toxicity and acidification footprint characterization factors from Ecoinvent 2.2 (Weidema and Hischier, 2010) were considered. To model these impacts software Simapro version 7.3 has been used. This software is commonly used in Life Cycle Assessment studies.

3.3.4.1 Water Stress indicator

According to developed method presented in chapter 2, the scarcity cumulative water use method represents the effects of consumptive and degradative water use to local water availability.

The scarcity consumptive water use (SCWU) characterizes the stress (use specific) that the production of one unit of water collection system places on local water resources throughout its entire life cycle. This stress is a result of the consumption of water. Figure 3-18 report the results of the SCWU and related CWU on functional unit.

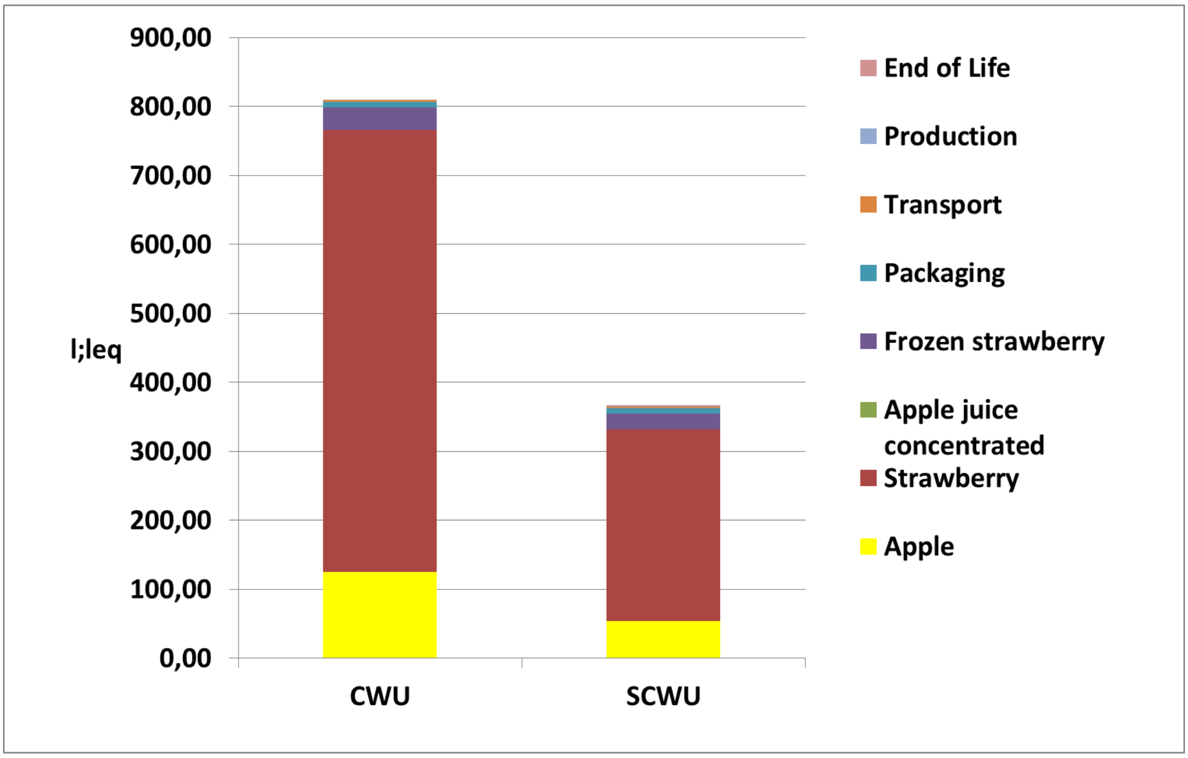

Figure 3-18 SCWU of 330g of organic strawberry jam

The total SCWU of the 330g of organic strawberry jam resulted to be 365,34 l_{eq}. in this case the impacts on water availability from consumptive water use resulted to be smaller than the cumulative water use. The reason of these results is that the most water intensive materials (strawberry and apple) are grown in regions where water is not scarce.

The scarcity degradative water use (SDWU) characterizes the stress (use specific) that the production of one unit of water collection system places on local water resources throughout its entire life cycle. This stress is a result of the degradation of water quality. Figure 3-19 reports the results of the SDWU and related DWU on functional unit.

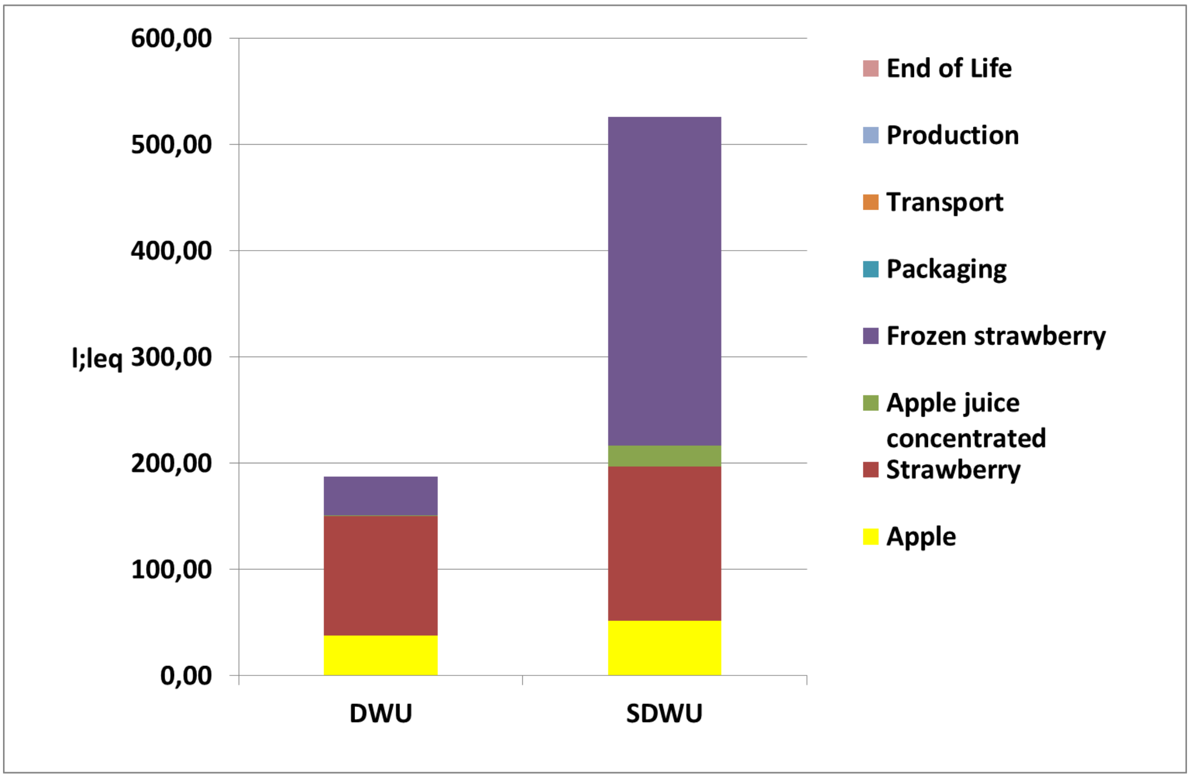

Figure 3-19 SDWU of 330g of organic strawberry jam

The total SDWU of the 330g of organic oat beverage resulted to be 525,94 l_{eq}. These impacts depend on the use of fertilizer for strawberry and apple growing and in particular to the quality of discharged water originated during the processing of strawberries right after before freezing.

In the assessment of water scarcity, SDWU resulted to be more significant than SCWU. The total WSI resulted to be 713,09 l_{eq}.

3.3.4.2 Degradation profile

In this section the results of the mid-point impact assessment for several water quality indicators are presented. The life cycle of the 330g of organic strawberry jam has been modeled through the use of Simapro version 7.3 software. Figure 3-20 reports the result of the impact assessment in eutrophication, eco-toxicity and pacification categories.

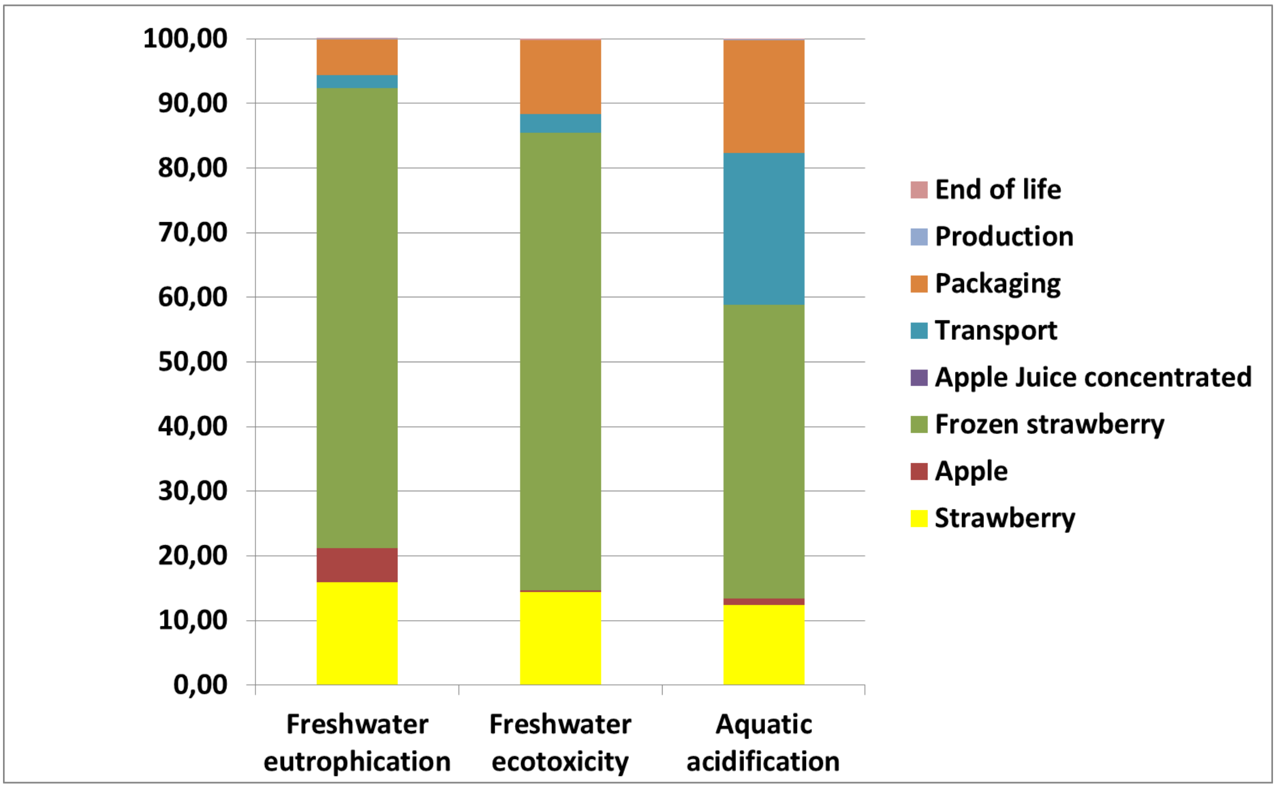

Figure 3-20 Other impacts related to water of 330g of organic strawberry jam

The total water eutrophication footprint of the water collection system resulted to be 3,96E-03 kg of P eq.. The process with biggest contribution to eutrophication is related to the use of energy produced in Bulgaria to freeze the strawberry.

The total water eco-toxicity footprint of the product under study resulted to be 5,99 E-02 kg 1,4-DB eq. Contribution analysis confirm the result already described in the case of eutrophication.

The total water acidification footprint of 1000ml of organic oat beverage resulted to be 1,79E-02 kg SO2 eq once again the energy use and produced in Hungary result in a significant contribution to final eutrophication. Strawberry freezing is the main hotspot related to degradation profile.

3.3.4.3 End-point impacts on Resources

In this paragraph, results of the application of the method related to Resource area of protection presented in chapter 2, are reported. These impacts are related both to degradative and consumptive water use and refer to back-up technology locally applicable.

To compensate the degradative water use, wastewater treatment facilities have been considered as local back – up technology. Values of $E_{local,j}$ are acquired from Ecoinvent v 2.2 database (Weidema and Hischier, 2010) and chosen based on the size of the wastewater treatment facility locally applicable. To determine applicability of the back-up technology the parameter person equivalent has been used. Table 3-51 reports on $E_{local,j}$ values used to back-up degradative water use; these values are determined using CED method. Where no data on specific locations are available a worst case approach has been adopted considering the wastewater treatment plant with the highest surplus energy values (resulting in the smallest one according to Ecoinvent 2.2).

Table 3-51 Elocal,j values of 330g of organic strawberry jam

Process			Location	Person equivalent	$E_{local,j}$ (MJ/l)	Reference
Raw Materials	Apple	Apple Growing	Berkovitsa (BG)	24864	5,76E-03	Waste water treatment plant class 3/CH/I
		Apple processing (				
	Strawberry	Strawberry growing	Pazardjick (BG)			
		Diesel				
	Apple Juice concentrated	Electricity	Berkovitsa (BG)			
		Water				
	Frozwen strawberry	Water	Pazardjick (BG)			
		Electricity (				
Packaging	Glass Jar	White glass	Swtzerland	5231	6,70E-03	Waste water treatment plant class 5/CH/I
		Transport				
	Corrugated carton	Corrugated carton double wall	Switzerland	5231	6,70E-03	Waste water treatment plant class 5/CH/I
	Label	Paper	Italy	5231	6,70E-03	Waste water treatment plant class 5/CH/I
	Lid	Steel	Latina (Italy)	24864	5,76E-03	Waste water treatment plant class 3/CH/I
		Transport				
		Packaging paper mono				
Transport	Transported froze strawberries	Transport	Pazardjick (BG)	24864	5,37E-03	Waste water treatment plant class 3/CH/I
	Transported apple	Corrugated carton	Berkovitsa (BG)			
		Transport				
Production	Strawberry jam	Water	Asiago (Italy)	5231	6,70E-03	Waste water treatment
		Electricity				

Process			Location	Person equivalent	$E_{local,j}$ (MJ/l)	Reference
	production	Natural gas				plant class 5/CH/I
End of Life	End of Life Corrugated carton	Italian scenario	Italy	5231	6,70E-03	Waste water treatment plant class 5/CH/I
	End of Life Glass Jar	Italian scenario				
	End of Life Label	Italian scenario				
	End of Life Lid	Italian scenario				

To compensate the consumptive water use, according to the characteristics of the area understudy where rainwater falls regularly (FAO, 2010b), it was decided to model a water collection system based on the water collection system understudy. The methodology described in chapter 2 has been applied: CED method has been employed to assess the surplus energy cost per liter of the production and installation of the water collection system including the energy to produce other materials and devices (such as pumps and tubes, HDPE geo-membrane) used to install the system and to run a domestic water treatment facility (in this case it is assumed that rainwater quality is the same of surface water).

The collection system is dimensioned on the water requirements of the specific process for the production of 330g of organic strawberry jam and considers the minimum average yearly precipitation based on the 30 years normalized values (FAO, 2010b). It is assumed that the collection system has a lifetime of 30 years according to company specification. When only general information on locations is available a conservative approach is adopted assuming the worst rainwater conditions available in CLIMAWAT Database (2010b) referred to Italy. Only effective rain is used for compensation (% of rainwater that does not evaporate or run-off).

Table 3-52 reports on the dimensioning of the system.

Table 3-52 Water collection system dimensioning for 330g of organic strawberry jam

Process	Rain (local climate conditions [l/m2/yr]	Process cumulative water use [l]	N° of drening elements
Apple	29,50	124,87	4,41
Strawberry	29,50	640,95	22,63
Appel Juice	29,50	0,53	1,00
Frozen Strawberry	29,50	32,30	1,14
Glass Jar	60,60	1,69	1,00

Process	Rain (local climate conditions	Process cumulative water use [l]	N° of drening elements
Corrugated Carton	60,60	4,59	1,00
Label	51,70	0,02	1,00
Lid	51,70	1,42	0,03
Transport	51,70	2,67	0,05
Production	44,30	0,11	1,00
End of Life	51,70	0,07	1,00
Apple	29,50	124,87	4,41
Strawberry	29,50	640,95	22,63

Table 3-53 report the values of $E_{local,I}$.

Table 3-53 Elocal,i values for 330g of organic strawberry jam

Process			Location	$E_{local,i}$ (MJ/l)
Raw Materials	Apple	Apple Growing	Berkovitsa (BG)	0,49
		Apple processing		
	Strawberry	Strawberry growing	Pazardjick (BG)	0,48
		Diesel		
	Apple Juice concentrated	Electricity	Berkovitsa (BG)	0,55
		Water		
	Frozwen strawberry	Water	Pazardjick (BG)	0,51
		Electricity		
	Glass Jar	White glass	Swtzerland	0,27
		Transport		
Packaging	Corrugated carton	Corrugated carton double wall	Switzerland	0,27
	Label	Paper	Italy	0,32
	Lid	Steel	Latina (Italy)	0,32
		Transport		
		Packaging paper mono		
Transport	Transported froze strawberries	Transport	Pazardjick (BG)	0,32

Process			Location	$E_{local,i}$ (MJ/l)
	Transported apple	Corrugated carton	Berkovitsa (BG)	
		Transport		
Production	Strawberry jam production	Water	Asiago (Italy)	0,37233
		Electricity		
		Natural gas		
End of Life	End of Life Corrugated carton	Italian scenario	Italy	0,31983
	End of Life Glass Jar	Italian scenario		
	End of Life Label	Italian scenario		
	End of Life Lid	Italian scenario		

Final values of ΔR are reported in figure 3-21.

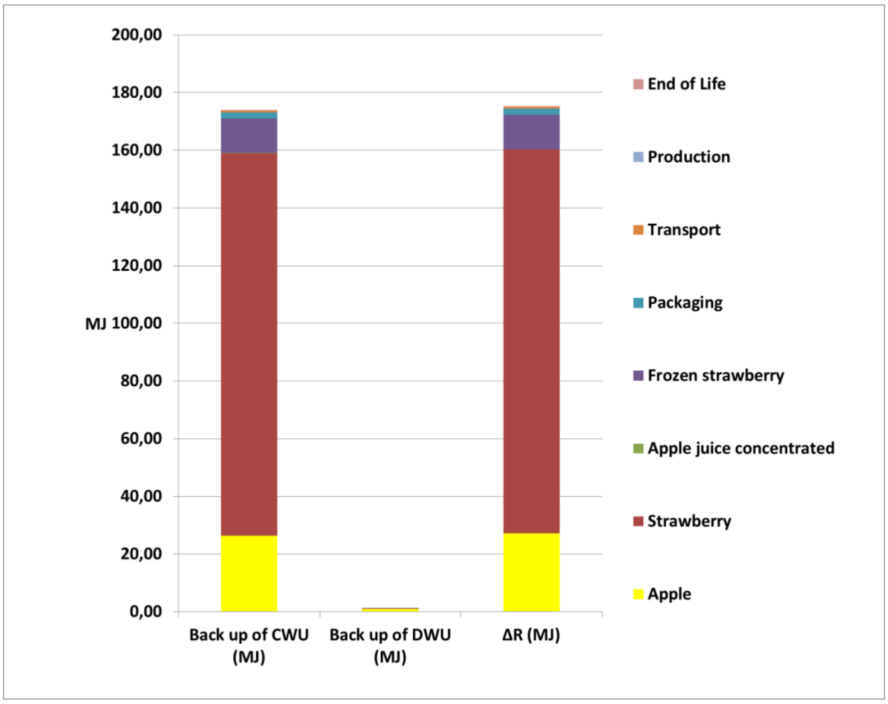

Figure 3-21 Impacts on resources from consumptive and degradative water use of 330g of organic strawberry jam

Back up of CWU with the proposed system resulted in 173,84 MJ of energy per functional unit; back up of DWU resulted in 0,46 MJ of energy per functional unit. Impacts on resources show that compensation of consumptive water use requires more energy than the degraded one. The company should work on water use efficiency to decrease end point resources footprint. Inventory indicator results are confirmed showing that back up of strawberry consumptive use is the most significant one. ΔR resulted to be 174,30 MJ.

3.3.5 Life Cycle Interpretation

In this stage of the study, results are analyzed in order to determine the main environmental hot-spot related to water. Table 3-54 reports on the results of this analysis highlighting the main hotspot and related variables.

Table 3-54 Hot-spot analysis for 1000ml organic oat beverage

Level of analysis	Indicator	Hotspots-process	Variables that influenced results
Inventory	CWU	Strawberry and apple	Use of irrigation water due to local climate conditions
	DWU	Strawberry and apple	Use of fertilizer and leaching due to groundwater caused by irrigation and rain water runoff
Mid-point Impacts	SCWU	Strawberry and apple	Use of irrigation water due to local climate conditions
	SDWU	Strawberry and apple	Use of fertilizer and leaching due to groundwater caused by irrigation and rain water runoff
	Eutrophication Eco-toxicity Acidification	Frozen strawberry	Use of energy produced in BG
End-point impacts	Back up of CWU	Strawberry and apple	Use of irrigation water due to local climate conditions
	Back-up of DWU	Strawberry and apple	Use of fertilizer and leaching due to groundwater caused by irrigation and rain water runoff

Strawberry and apples water requirements are influenced by the climate conditions and irrigation water. However, considering the low scarcity of the regions was fields are located is not recommended to move the production somewhere else. Another strategy would be to change the use of fertilizer rate; however there is no data that suggest changing the actual one, therefore this opportunity was not investigated. Considering the use of surface water, whose scarcity is limited in the region where strawberries and apples are produced, it would be interesting to investigate change in local conditions that force the company to use groundwater.

Considering all different hotspot it decided to work on a potential strategies to reduce impacts related to water; change in the energy mix adopting renewable energies will be investigated throughs sensitivity analysis.

Sensitivity analysis: Change in water withdrawal source

Local scarcity according to Boulay et al. (2011) is studied also according to the origin of resource. In several water basins around the world in fact, relevant differences between scarcity of surface and groundwater resources exist. In the case of the field understudy, if the company had to split from surface to groundwater use, impacts related to water would be much higher. From a 0,43 scarcity factor in fact there would be a 1 scarcity factor value. Table 3-55 reports on result at midpoint and endpoint indicators; these are influenced by local water scarcity.

Table 3-55 Impact assessment results for 1000ml of organic oat beverage in the most favorable climate conditions

	Unit	Surfacewater	Groundwater
SCWU	l_{eq}	365,34	809,22
SDWU	l_{eq}	525,94	1221,35
Back up of CWU	MJ	173,84	387,16
Back up of DWU	MJ	1,08	1,27

Due to the important scarcity of groundwater, the water footprint profile resulted to be in average 2, 25 times higher.

Sensitivity analysis: Change in energy mix

The energy mix used in the freezing of strawberries resulted to have negative impacts in all the degradation indicators profile. As long as the company owns most of the energy consuming facilities of the product life cycle and has direct control on operations in this section the change in the energy mix is investigated. Following a worldwide-established practice, the company could decide to purchase greenhouse gas offsets that finance the generation of renewable energy. From a water footprint perspective (Gerbens-Leenes et al., 2008), the source of renewable energy that presents the best water footprint profile is wind energy. Table 3-56 reports the result of the eutrophication, eco-toxicity and acidification footprints, in the case the company adopts the above mentioned strategy. Results show significant reduction for all the degradation profile indicators.

Table 3-56 Impact assessment results of tomato sauce for different energy mix

	Unit	Business as usual	Use of energy off-set by RECs	% reduction
Eutrophication	kg P eq	3,96 E-03	4,84 E-04	87,78
Eco-toxicity	kg 1,4-DB eq	5,99 E-02	1,10 E-02	81,63
Acidification	kg SO2 eq	1,79 E-02	8,44 E-03	52,84

3.4. Case study 4: Tomato Basil Sauce

In this case study the impact related to water of the production of a tomato sauce are investigated. This product was chosen for several reasons:

- Its production involves several raw materials with different water needs and coming from different regions of the world. It is therefore representative of different local climatic conditions;
- Food products and processes are recognized to be the most water intensive products. The life cycle stages of the tomato sauce allow analysis of water critical processes such as the agricultural ones.

For confidentiality reason, all the reference to the company that delivered the data has been deleted. When specified, particularly at inventory level, sensitive data are qualitatively described but not quantitatively reported.

3.4.1 Goals and scope definition

The goal of this study is to apply the developed set of indicators to conduct a contribution and hotspot analysis of the potential impacts related to water throughout the life cycle of the tomato sauce understudy. The assessment is intended to assist the company in determining which aspects of the product life cycle contribute the most environmental impacts related to water and, therefore, to identify potential opportunities to improve water use and management along the value chain. The company recognize the water footprint to be a strategic tool for their competitiveness because a growing number of their clients demonstrated the need for more environmental friendly products. This study has been performed in accordance with the methodologies and requirements presented in chapter 2.

The Functional Unit (FU) was identified as 680g of tomato sauce packed in a glass jar, produced by an American food company located in the north east of the USA and distributed and consumed in the US (98%) and Canada (2%). The function of the product system is to provide high quality tomato sauce corresponding to a nutritional value of 6 cup equivalents of vegetables (USDA, 2005). If stored according to manufacturer guidelines, the sauce has a recommended shelf life of 2 years if unopened and of one week once opened.

The product system boundary is defined as the product that is distributed and used in the US and spans from extracting materials from the earth to manufacture the product to the end of life of the associated product packaging. A cradle to gate approach has been used in this water footprint study. The impacts of the end of life of the product itself, i.e. the impact of human digestion of the sauce, were excluded. System boundaries are reported in figure 3-22.

The product under study is a food product used as pasta sauce. Its main component is tomato that is produced in California during the summer, processed in California, and then sent to the tomato sauce producer to produce the final 680g sauce packaged in a glass jar. A production-scale formula is made of 2160 kg of raw materials. For privacy reason only the main raw materials used in the production of the tomato sauce are mentioned and reported. These are: tomatoes (processed in paste and diced tomatoes), olive oil, soybean oil and sugar.

For each process unit the following primary/secondary data have been collected: quantity of water use (withdrawal and discharge); type of water resources; data on water quality in and out of the system, when available; location of water use; seasonal changes in water flows; temporal aspects of water use; forms of water use (If not differently specified, all water used was considered to be a liquid). No significant changes in drainage conditions due to land use change were determined.

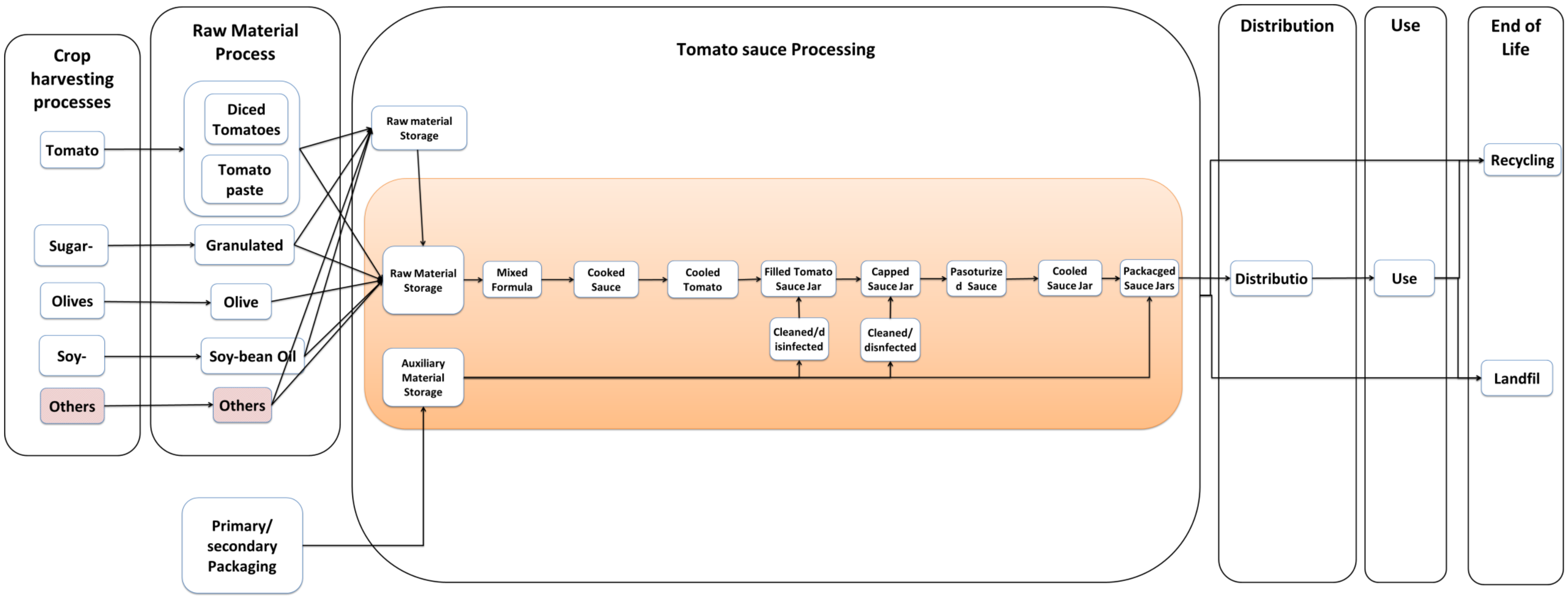

Figure 3-22Tomato sauce system boundaries

Criteria used in the selection of data to be used in the study are reported in Table 3-57. In this study, cut off criteria of 1% by mass has been used.

Table 3-57 Data quality criteria used in the study

Topic	Criteria adopted in this study
Time period coverage	Primary data from the most recent representative period (2011) were used were available. When only secondary data were available, most recent and representative were chosen. (e.g. climate data consolidated over 30 year period).
Geographical coverage	All primary data are site specific. In the case of secondary data, average production from the country of origin is considered where available (e.g. olive oil). If the geographical location is unknown, representative data from the sector under study are considered (e.g. sugar cane)
Technology coverage	Primary and secondary data always refers to the technology in use if not differently specified. In the case where the technology is unknown, representative data for the sector under study is considered (e.g. olive oil production).
Precision and uncertainty	Most of the data collected are primary with limited uncertainty. In the selection of secondary data it was preferred to use Ecoinvent data sets that also present uncertainty information and data.
Completeness, Representativeness	Completeness measures the percent of primary data collected and used for each category in a unit process. Actual manufacturing data for the product life cycles were collected, Where possible, suppliers provided detailed water and energy usage, material usage, and scrap end of life for their operations. When suppliers were not able to provide information, assumptions were made based on industry practice or information provided by other suppliers. Life cycle inventory data is not included in the life cycle if it represents less than 0,5% by weight of the product materials and the data is not available. Over 99% of the product mass is included in the LCA. It is expected that the remaining mass will have little to no effect on the outcome of the water footprint results.
Consistency	Consistency considers how uniformly the study methodology is applied to the various components of the analysis. The water footprint methodology was applied to all components of the product under study consistently, in terms of modeling and assumptions. Consistency in results has been checked with literature reference.
Reproducibility	The water footprint modeling has been performed and described such that another water footprint practitioner could reproduce this water footprint.

Unless specified otherwise, secondary inventory data used in this study are from Ecoinvent 2.2 database. Ecoinvent data is maintained by the Ecoinvent Research Centre. Created in 1997, the Ecoinvent Research Centre (Frishknet et al., 2005; Althaus et al., 2007). All emissions data used to address impacts on acidification are taken from Ecoivent. Characterization factors, if not differently specified, are from this version of Ecoinvent.

3.4.2 Life Cycle Inventory

In this chapter, all the data acquired and calculations performed are reported. The paragraph is divided per different process units considered. For each process unit, all the data used are reported on the reference 680g of tomato sauce.

The inventory is populated with primary data collected directly from companies involved in the study and secondary data from scientific LCA database. In the case of secondary data however not all the information (such as quality in and quantity out) are available. In these cases a worst case approach is adopted considering all withdrawn water as used (consumptive use) and the quality entering the system as of the best quality locally available).

3.4.2.1 Tomato

One of the most important raw materials used in the production of the product under study are tomatoes. Tomatoes are grown in California in different sites located within the Sacramento and the San Joaquin valleys. Following the common practice in California, tomatoes are planted in May and harvested between September and October. The technology used for irrigation is drip irrigation. Data reported are primary data from the supplier and are based on the 2011 production year. The average yield from different production site is 50,43 tons/ha.

In order to assess the crop water requirements the CROPWAT model (FAO, 2010a) has been used. The CROPWAT software developed by FAO is used to model the water requirements of a crop. The model utilizes data on the climatic conditions, the reference evapotranspiration, the soil and the specific crop characteristics to determine the irrigation requirements of the crop under study. ET0 (evapotranspiration in standard condition) is determined using the Penman-Montheit equation (FAO, 2010a). Effective rain (the rainfall effectively available to the crop) is assessed through the USDA SCS method (option selected within CROPWAT model). Climatic data are taken from standardized average data over the last 30 years acquired through the CLIMAWAT 2.0 database (FAO, 2010b); such database offers observed agroclimatic data of over 5000 stations worldwide including the locations under study. The data selected for this study comes from the climatic stations located in Sacramento and Fresno (Tab 3-58 and Tab 3-59). This data was considered to be representative of the climatic conditions of the locations under study. These are primary data collected by the National Climate Data Centre (NOAA) of the USA (http://www.ncdc.noaa.gov/).

Data on the crop modeling are taken from FAO database (FAO, 2010a) accessible within the CROPWAT software and then modified with primary parameters when available. The soil considered in the assessment is black clay soil, which is representative of the locations in California where the tomatoes used in the product under study are grown (primary data from USDA data base: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx). Details on drip irrigation techniques used in California are taken from University of California Division of Agriculture and Natural Resources (USDA, 2005)

Table 3-58 Precipitation and Effective Rain

Sacramento			**Fresno**	
	Rain	Eff rain	Rain	Eff rain
	mm	mm	mm	mm
January	49,80	45,80	49.80	45,80
February	48,00	44,30	45,70	42,40
March	37,40	35,20	48,00	44,30
April	17,30	16,80	24,60	23,60
May	11,90	11,70	7,60	7,50
June	0,20	0,20	2,00	2,00
July	0,10	0,10	0,30	0,30
August	0,10	0,10	0,80	0,80
September	5,90	5,80	6,10	6,00
October	13,80	13,50	13,50	13,20
November	26,70	25,60	34,80	32,90
December	39,90	37,40	36,10	34,00

Table 3-59 Climatic data from Fresno and Sacramento

Month	**Min Temp**	**Max Temp**	**Humidity**	**Wind**	**Sun**	**Rad**	**Eto**
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
Sacramento							
January	3,20	11,50	79,00	251,00	4,70	8,00	1,12
February	5,20	15,60	69,00	285,00	7,20	12,50	2,1
March	6,20	17,80	65,00	328,00	9,00	17,80	3,16
April	7,50	21,70	59,00	346,00	11,00	23,50	4,59
May	10,20	26,80	57,00	363,00	13,10	28,40	6,24
June	12,90	31,00	50,00	380,00	14,00	30,30	7,86
July	14,50	34,00	47,00	346,00	14,20	30,20	8,45
August	14,40	33,40	44,00	337,00	13,10	27,00	7,92
September	13,20	30,70	47,00	294,00	11,60	22,00	6,16
October	10,20	25,50	53,00	242,00	9,60	15,90	3,97
November	6,30	17,30	74,00	233,00	6,50	10,00	1,81
December	3,20	11,50	82,00	251,00	4,50	7,20	1,03
Average	8,90	23,10	60,00	305,00	9,90	19,40	4,53
Fresno							
January	3,00	12,30	79,00	216,00	4,60	8,30	1,17
February	4,70	16,50	72,00	233,00	7,00	12,80	2,03
March	6,30	19,20	64,00	277,00	9,20	18,60	3,26
April	8,50	23,90	52,00	311,00	11,20	24,20	5,2
May	12,10	29,00	43,00	337,00	12,90	28,30	7,25
June	15,80	33,70	38,00	346,00	13,70	30,20	8,85
July	18,40	37,00	36,00	311,00	13,80	29,90	9,31
August	17,70	35,90	41,00	285,00	12,90	27,10	8,19
September	14,90	32,30	45,00	251,00	11,50	22,40	6,28
October	10,40	26,50	53,00	216,00	9,80	16,60	4,04
November	5,80	18,20	68,00	199,00	6,30	10,30	2,04
December	2,80	12,10	80,00	199,00	4,10	7,30	1,09

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	Eto
Average	10,00	24,70	56,00	265,00	9,80	19,70	4,89

The main fertilizers used in the growing of tomatoes are N. Data on fertilizer are reported in Tab 3-54. Following USDA analysis it is assumed that the 15% of the quantity of N and P leach into the groundwater.

Table 3-60 Data on the use of fertilizers

Substance	Application of fertilizer	Reference
N-based	214,18 kg/ha	Primary data from supplier, 2012

3.4.2.2 Olive Oil, Soybean Oil and Sugar

Other relevant raw materials are: olive oil, soybean oil and granulated sugar.

Olive oil is produced in Tunisia and shipped from Tunisia to New York via boat. Tunisia has wide area dedicated to olive growth. The climatic conditions allow growers to use very little water for irrigation. In fact, most of the water needed comes from rainwater. Data on withdrawn and rainwater use comes from Chahed et al. (2009). Data on the use of fertilizer and consequent impact on resources come from Mekonnen and Hoekstra (2010).

Soybean oil is mainly produced in the US, which is one of the biggest producers in the world. In order to model the crop water requirements of this raw material, the CROPWAT model has been used. Statistical information on soybean growing and processing was taken from USDA with reference to 2011 (http://www.ers.usda.gov/topics/crops/soybeans-oil-crops.aspx#.UiGqj7wyHRw). Such data were used to determine the location of production, the climatic conditions and the relevant yield. Withdrawn water were determined using this data. Water quality parameters comes from Mekonnen and Hoekstra 2011.

The granulated sugar used in the product under study comes from several different locations in the world. Thirty percent (30%) of this is produced in the US and the rest in other unspecified countries. Brazil is recognized to be the main granulated sugar producer in the world, as well as one of the top three importers to the US (http://www.ars.usda.gov/News/News.htm?docid=4162&modecode=64-10-05-00&page=5). In this study, it is assumed that all the sugar used comes from Brazil. Inventory data such as withdrawn and quality data are from secondary data published by Mekonnen and Hoekstra, 2011. Such data have been matched with other peer reviewed references, such as Ridoutt et al 2009.

3.4.2.3 Tomato processing

Tomatoes are processed in two facilities located California. At these two sites, tomatoes are used to produce the diced tomatoes and the tomato paste. Tomatoes arrive from several locations presented in the previous chapters.

In the case of diced tomatoes, after a first quality selection that discards almost the 30% of the incoming raw fruit (unripe tomatoes reused within the site in other productions), the tomatoes are diced. The final product, diced tomatoes, is made of tomato juice (resulted from the process of dicing) and diced fruit. The biggest water use in this process is the water used for conveyance and steam produced for heating the tomatoes during processing. Water is reused throughout the process as many times as possible until its quality is no longer suitable for the intended use. In this case, the resultant wastewater is land applied for crop irrigation. Tomato paste is the result of a process that reduces the water content of tomatoes from 95% average water content to a 31% equivalent. Water extracted from the product is reused when possible. The production of cooked and concentrated tomatoes requires a high quantity of energy and steam in order to dry the tomatoes to the desired water content. Tomato paste is made in both of the facilities.

Once prepared, the diced tomatoes and tomato paste are packed in aseptic plastic bags (300 gallon capacity, made of polyethylene with 5% by weight assumed to be aluminum) and placed into a wood crate. The packaged product is placed on a wooden pallet (US standard dimension and capacity) and shipped to the tomato sauce production company by train,

Mots of data comes from direct measure from the two facilities located in California and are related to withdrawn water, discharged water, quantity in and out. This water balance included the water content of the tomatoes. In the case of packaging, secondary data from Ecoinvent v.2.2 was used as primary data was not available.

3.4.2.4 Production

Raw and auxiliary materials are shipped to the tomato sauce producer for the production of the tomato sauce understudy. The production process starts with the mixing of all the different ingredients based on the formula). After the sauce is cooked, it is cooled down. In this process, water is used directly in the product recipe, for cooling, and for the generation of steam (to sterilize the glass jar). Once cooked and cooled, the tomato sauce goes into packaging process. The sauce flows into glass jars that are water-lubed conveyed. Once the jar (glass) is full with the right quantity of product, it is capped (metal lid made of aluminum), pasteurized and cooled. Throughout these processing steps water is also used for cleaning. Once prepared, the sauce is packed using stretch wrap and corrugated carton. Packaged products are placed on a wooden pallet (US standard dimension and capacity) and then distributed to retail stores.

Most of the data of this process are primary data directly supplied by the tomato sauce producer and refers to the entire production of the company in 2012. Due to privacy reason such data cannot be published. In the study mass based allocation is performed because no relevant differences can be noted. This allocation is, therefore, not meant to either lead to relevant discrepancy or affect the quality of the results.

Water withdrawn and discharge and quality in and out of the company are of primary origin. In the case of packaging, volumes of withdrawn water are secondary data from database. It is assumed that all withdrawn water to produce these materials is consumed.

3.4.2.5 Use of Francesco Rinaldi Tomato Basil

Because the tomato sauce is typically consumed on a dish, the water use relevant to the process of cleaning a dish was included as part of the analysis. Data from a report of the US Department of Energy were used (DOE, 2010) to calculate average water and energy use. A standard dishwasher uses 22,334 liters of water and has an annual consumption of 355 kWh for a total of 215 cycles. Following a common practice in literature (Ridoutt et al., 2009), it is assumed that 10% of this annual material and energy use are imputable to the product object of this study. It is also assumed that the quantity of water withdrawn is the same as the quantity of water discharged, and that withdrawal and discharge happen within the same water basin. This study does not take into account the impact of the use of detergent during dishwashing.

3.4.2.6 End of life

In the end of life stage, the treatment of all waste/scrap materials resulting from the processing of the tomato sauce production facility was considered, as well as the end of life of primary packaging after use. The wood cartons received from the tomato supplier are returned to their origin for reuse.

The following tables report on the destination and treatment of such materials. Information on the end-of-life disposition of waste and scrap from company processes are primary data. Information on end of life of packaging discarded by either the retail store or the consumer refers to the EPA 2011 statistics of municipal solid waste in the US (EPA, 2011). Two main treatments are considered, disposal to landfill and recycling.

Table 3-61 End of Life treatment of waste and scraps

Material	Recycling rate	Disposal to landfill rate
From Company production		
Jar	100,00%	0,00%
Lid/metal	100,00%	0,00%
Corrugated Carton	100,00%	0,00%

Plastic/Stretch-wrap	100,00%	0,00%
Organic waste	0,00%	100,00%
End of life data from Environmental Protection Agency (EPA) 2011 facts and figure		
Jar	27,60%	72,40%
Lid/metal	20,70%	79,30%
Corrugated Carton	65,60%	34,40%
Plastic/Stretch-wrap	8,30%	91,70%

3.4.3 Life Cycle Inventory Analysis

Life Cycle inventory analysis is the stage of the study were data collected are aggregated in order to have a first representation of materials and energy flows going in and out of the system. Table 3-62 reports on inventory information to be used according to the inventory method developed and described in chapter 2. Due to huge amount, data on discharged water quality parameters and air emissions parameters are reported in ANNEX D. Where no information on discharged water is available (such as from Ecoinvent database) a conservative approach is adopted, considering all the withdrawn water to be consumed. Where no data on quality in and out are available it is assumed that the water going into the system is for the best available quality and the one discharged is of the worst available quality According to the classification from Boulay et al. (2011a). It is reminded that G stands for ground water and S for surface according to the classification from Boulay et al. (2011a) data are reported on the functional unit of on product understudy.

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Table 3-62 Inventory results for one unit of Tomato sauce

Process			Location	Vin (Liters)	Quality class in	αfin	Vout (Liters)	Quality Class out	j
Diced Tomato Location 1			North of California (USA)	196,29	G1	1,00	185,50	G3c	1,00
Tomato Paste Location 1				1622,65	G1	1,00	1595,87	G3c	1,00
Tomato Paste Location 2			Center of California (USA)	1367,48	G1	1,00	1314,83	G3c	1,00
Olive Oil			Tunisi	0,00	G2	1,00	0	G6	1,00
Soybean Oil			Several locations USA	1,05	G1	0,53	0,01	G2c	1,00
Sugar			Several locations Brazil	5,56	G2	1,00	0,00	G6	1,00
Tomato processing	Processing Diced Location 1		Location 1 (USA)	0,77	G1	1,00	0,70	G3c	1,00
	Water Processing Paste Location 1			0,10	G1	1,00	0,06	G3c	1,00
	Water Processing Paste Location 2			0,86	G1	1,00	0,60	G3c	1,00
	Energy use Diced			0,06	G1	0,39	0,00	G6	1,00
	Energy use Paste Location 1			0,07	G1	0,39	0,00	G6	1,00
	Energy use Paste Location 2			0,22	G1	0,39	0,00	G6	1,00
	Diced	Aseptic Bags	Several locations California (USA)	0,02	G1	0,39	0,00	G6	1,00
		Cardboard boxes		0,31	G1	0,39	0,00	G6	1,00
	Location 1	Aseptic Bags		0,01	G1	0,39	0,00	G6	1,00

Process			Location	Vin (Liters)	Quality class in	αfin	Vout (Liters)	Quality Class out	j
	Location 2	Cardboard boxes		0,16	G1	0,39	0,00	G6	1,00
		Aseptic Bags		0,02	G1	0,39	0,00	G6	1,00
		Cardboard boxes		0,37	G1	0,39	0,00	G6	1,00
	Use of wooden pallet			0,00	G1	0,39	0,00	G6	1,00
Tomato processing	Water use		North-east states of USA	1,52	G1	0,00	1,01	S5	1,00
	Energy use			0,03	G1	0,00	0,00	S5	1,00
	Corrugated Cardboard			0,04	G1	0,39	0,00	G6	1,00
	Jar			1,20	G1	0,39	0,00	G6	1,00
	Lit			0,08	G1	0,39	0,00	G6	1,00
	Stretch wrap			0,06	G1	0,39	0,00	G6	1,00
	Use of wooden pallet			0,00	G1	0,39	0,00	G6	1,00
Use Stage	Water use			2,12	G1	0,39	0,00	G6	1,00
	Energy use			1,42	G1	0,39	0,00	G6	1,00
End of Life	Waste Treatment			0,03	G1	0,39	0,00	G6	1,00

Based on the data collected in the inventory stage it was possible to assess CWU and DWU inventory indicators. Results are reported in Figure 3-23.

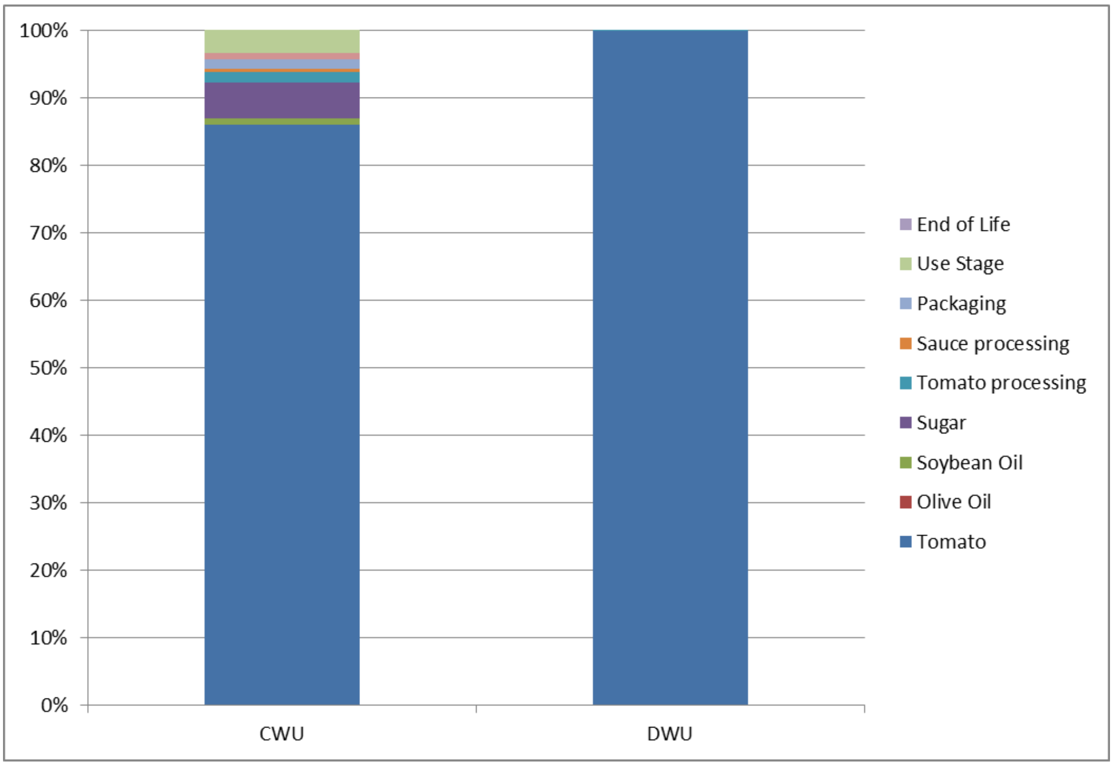

Figure 3-23 Inventory indicator results of the tomato sauce

The total CWU of the tomato sauce resulted to be 103,92 liters. This quantity refers to the volume of water that is consumed because of product incorporation, evaporation or water traded to other water basins. The degradative water use resulted to be 3,098 liters of water. This quantity represent the total volume of discharged water whose quality has been altered if compared to the withdrawn one and quality of destination water body. DWU, in this case, resulted to be more significant than the consumptive use. Going deeper in the analysis of inventory results water used (CWU) was particularly significant from the growth of tomatoes and production of tomato paste in Location2 (43,94%) and tomato growth and production of tomato paste and diced tomato in Location 1 (26,49%). Location 2 produces twice as much tomato paste as is produced in Location 1. The difference between the two sites is a function of the quantity of tomatoes needed to make 1 kg of paste compared to 1 kg of diced tomatoes. Location 2 paste production was more efficient from the water and energy use perspective than Location 1. Several other factors also had a significant influence on the CWU: the yield, the climatic conditions, the use rate of fertilizers and the irrigation technology. Other relevant contributions to the final water footprint came from the other raw materials, respectively olive oil (7,44 l), granulated sugar (3,49 l) and soybean oil (6,71 l).

The biggest contributor to DWU resulted to be the production of tomatoes due to the high rate of fertilizer used in agriculture that is in average 45% higher than the one recommended from Hartz et al. (2008).

3.4.4 Life Cycle Impact Assessment

In this chapter are presented the results of the water footprint impact assessment. Impact methods developed at mid-point and end-point level were applied. The final water footprint is presented in a form of a profile consisting of the scarcity consumptive water use, scarcity degradative water use, eutrophication, eco-toxicity, and acidification footprints. Methods described in materials and methods were applied. For the assessment of eutrophication, eco-toxicity and acidification footprint characterization factors from Ecoinvent 2.2 (Weidema and Hischier, 2010). To model these impacts software Simapro version 7.3 has been used.

3.4.4.1 Water Stress Indicator

According to developed method presented in chapter 3, the scarcity cumulative water use method represents the effect of consumptive and degradative water use to local water availability.

The scarcity consumptive water use (SCWU) characterizes the stress (use specific) that tomato sauce places on local water resources throughout its entire life cycle. This stress is a result of both the consumption of water. Figure 3-24 report the results of the SCWU and related CWU on functional unit.

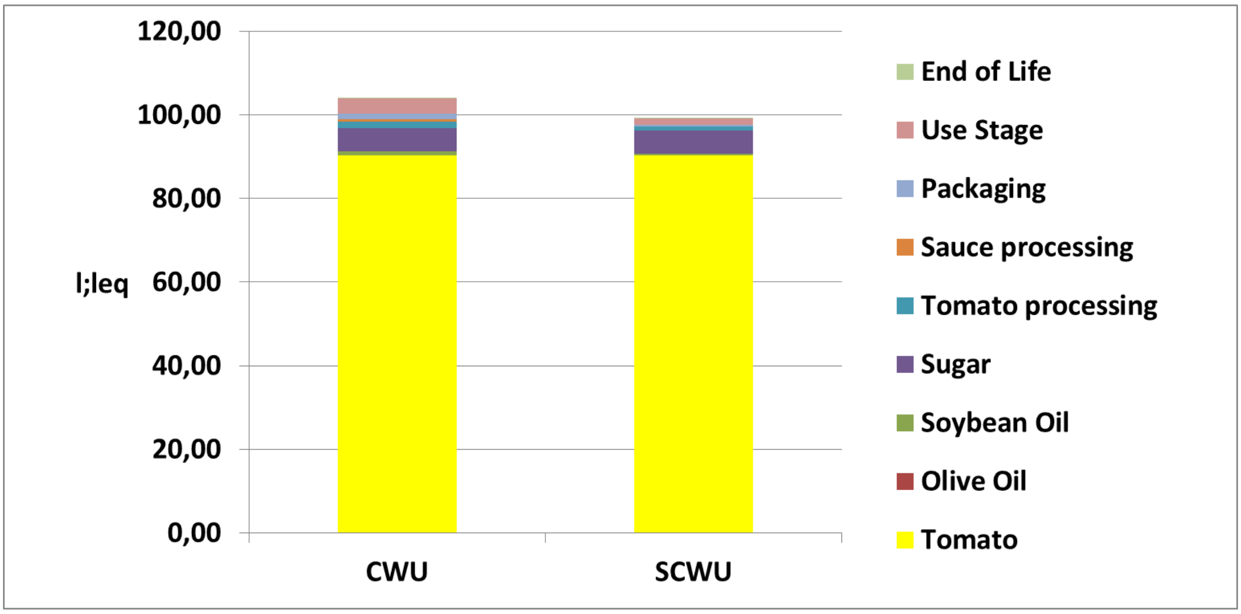

Figure 3-24 SCWU for the of the tomato sauce

The total SCWU of the tomato sauce resulted to be 99,10 liters H2O equivalent. The majority of the SCWU depends on the tomato growing in California (89% contribution to the overall water availability). This is primarily due to the limited availability of water in the Sacramento and San Joaquin water basins where the tomato fields are located.

The contribution of olive oil to the water availability footprint of olive oil was close to zero because in Tunisia olives are mainly rain fed. The second most significant process contribution is granulated sugar (5,49%), followed by the use stage (3,5%).

The scarcity degradative water use (SDWU) characterizes the stress (use specific) that tomato sauce places on local water resources throughout its entire life cycle. This stress is a result of the degradation of water quality. Figure 3-25 reports the results of the SDWU and related DWU on functional unit.

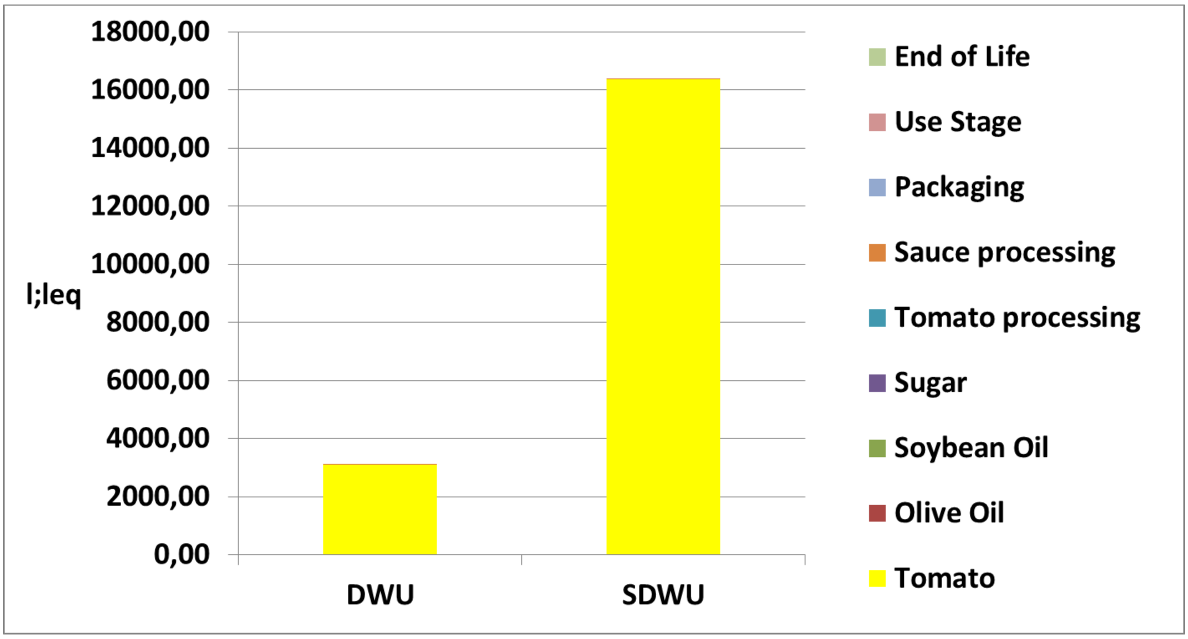

Figure 3-25 SDWU for the of the tomato sauce

The total SDWU of the tomato sauce resulted to be 16.380,30 liters H2O equivalent. The majority of the SDWU depends on the tomato growing in California and related use of fertilizer. This value represents the stress related to the degradation of 3,098 liters of water. Due to the use of distance to target factor it gives the measure of how much water have been potentially degraded due to the emissions of pollutant to water reservoir (in this case groundwater). Assessment of distance to target factor is based on value of N leached, reported to N limit accepted in California for water to be used in agriculture. Another process that resulted to have impacts on SDWU is tomato sauce processing at the produce facility. Due to limited availability of information in Ecoinvent database it was not possible to address values of SDWU for other processes such as Soybean oil or Sugar. The total WSI resulted to be 16.479,40 l_{eq}.

3.4.4.2 Degradation profile

In this section the results of the mid-point impact assessment for several water quality indicators are presented. The life cycle of the tomato sauce has been modeled through the Simapro version 7.3 software. This software is commonly used for Life Cycle Assessments. Figure 3-26 reports the result of the impact assessment in these three categories.

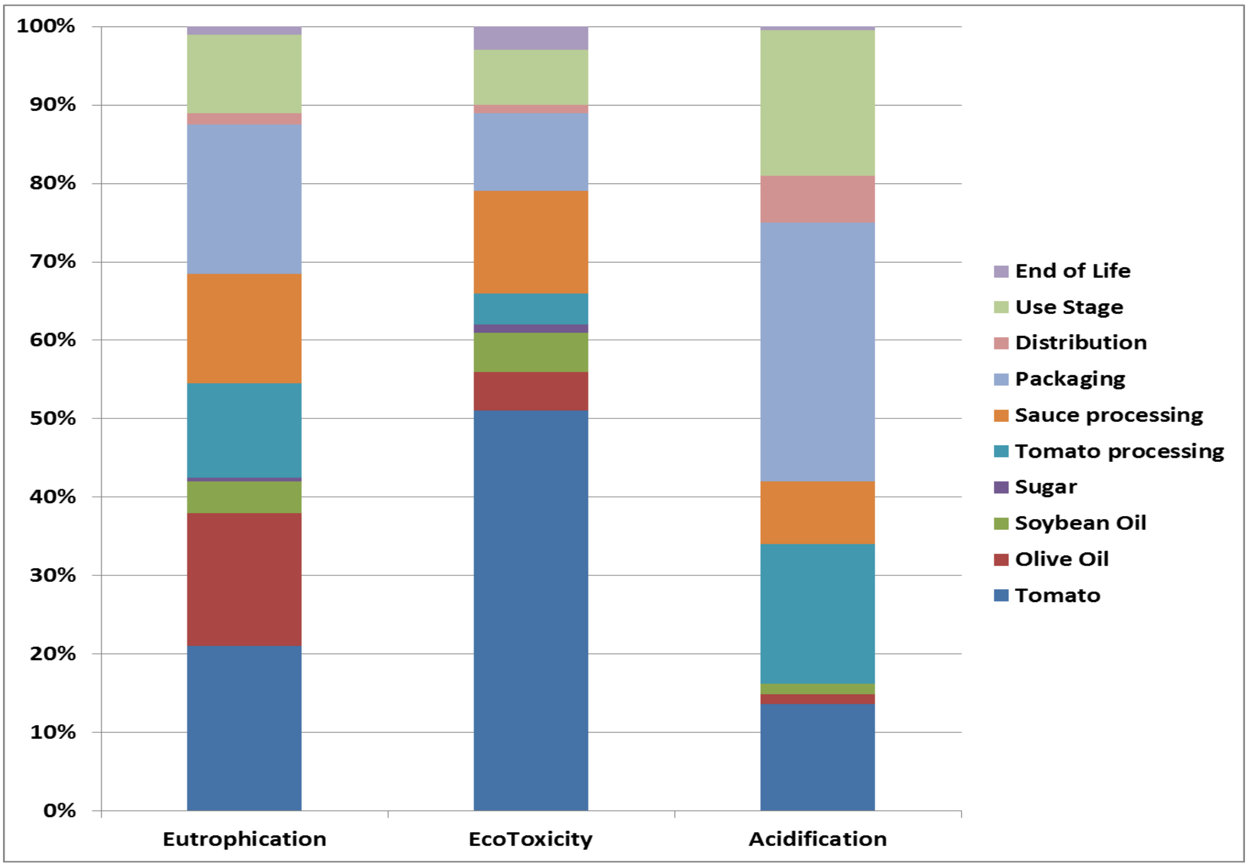

Figure 3-26 Other impacts related to water of the tomato sauce

The total water eutrophication footprint of the tomato sauce resulted to be 3,14E-04 kg of P eq. Once again the major contributor to the footprint of the product is tomato growing in California. In this case, it is the use of fertilizer based on N and P and, in particular, the quantity of these two nutrients that reaches the groundwater that most influences the final impacts. The second highest contributor to eutrophication is olive oil production from olive crop, which is again due primarily to the use of fertilizer. Two other processes also appeared to be relevant—the use of hard coal in the US energy mix and glass used in the primary packaging. The significance of packaging glass, which includes both production and end-of-life, is due to the emission of phosphorus and phosphates to the air and particular to soil.

The total water eco-toxicity footprint of the tomato sauce resulted to be 1,44E-2 kg 1,4-DB eq. These results identify the growing of tomatoes as the main process that contributes to water eco-toxicity. Going deeper in the analysis of this process, it is fertilizer production and use that makes the greatest contribution to impact because of chemical release to water. The second highest contributor to eco-toxicity is production of tomato sauce in the sauce processing. This results primarily from the use of hard coal as primary energy source and from the release of phosphorus to water.

The total water acidification footprint of the tomato sauce resulted to be 5,76E-3 kg SO2 eq. The water acidification footprint was highly influenced by the production of packaging glass and the subsequent emissions of substances like SO2 and Nox to the air.

3.4.4.3 End-point impacts on Resources

According to the method developed and presented in chapter 3, in this section impacts related to Resource area of protection are reported. These impacts are related both to degradative and consumptive water use and refers to back-up technology locally applicable.

To compensate the degradative water use, wastewater treatment facilities have been considered as local back – up technology. Values of $E_{local,j}$ are acquired from Ecoinvent v 2.2 database (Weidema and Hischier, 2010) and chosen based on the size of the wastewater treatment facility locally applicable. To determine applicability of the back-up technology the parameter person equivalent has been used. Table 3-63 reports on $E_{local,j}$ values used to back-up degradative water use; these values are determined using CED method. Where no data on specific locations are available a worst case approach has been adopted considering the wastewater treatment plant with the highest surplus energy values (resulting in the smallest one according to Ecoinvent 2.2).

Table 3-63 Elocal,i values for tomato sauce

Process	Location	Person equivalent	$E_{local,j}$ (MJ/l)
Tomato	California (USA) location 1 and 2	806	6,70E-03
Olive Oil	Tunisi	806	6,70E-03
Soybean Oil	Iowa (USA)	806	6,70E-03
Sugar	Brazil	806	6,70E-03
Tomato processing	California (USA) location 1 and 2	806	6,70E-03
Sauce processing			
Packaging	North –est of the USA	233205	4,74E-03
Use stage			
End of life			

To compensate the consumptive water use, different water back-up technologies were chosen according to their local applicability. In the case of California, which is a water scarce region, desalination plant is used as local back-up technology; the application of this technology in this region is supported by local institutions such as the California Department of Water Resources that recognize it as an alternative to be considered in the water supply portfolio (Bourne et al, 2008). In the case of desalination plant the value of 0,072 MJ per liter is used (Pfister et al., 2009; Meendoza, 2005)

In other regions considered in the study, where rainwater falls regularly (FAO, 2010b), it was decided to model a water collection system based on the system presented in case study 1. The methodology described in chapter 2 has been applied: CED method has been employed to assess the surplus energy cost per liter of the production and installation of the water collection system including the energy used for a domestic water treatment facility (in this case it is assumed that rainwater quality is the same of surface water). The collection system is dimensioned on the water requirements of the specific process and consider the minimum average yearly precipitation based on the 30 years normalized values (FAO, 2010b). It is assumed that the collection system has a lifetime of 30 years according to company specification.

Table 3-64 reports on the dimensioning of the system.

Table 3-64 Water collection system dimensioning for tomato sauce

Process	Rain (local climate conditions) [l/m2]	Process cumulative water use [l]	N° of drening elements
Olive Oil	3,10	0,00	1,00
Soybean Oil	23,40	1,04	1,00
Sugar	36,50	5,56	1,00
Tomato processing	0,30	1,59	6,00
Sauce processing	48,30	0,54	1,00
Packaging	48,30	1,39	1,00
Use stage	48,30	3,54	1,00
End of Life	48,30	0,03	1,00

Table 3-65 report the values of $E_{local,I}$.

Table 3-65 Elocal,i values for tomato sauce

Process	UNIT	Location	back-upTechnology	$E_{local,i}$ (MJ/l)
Diced Tomato Location 1	MJ/l			0,07
Tomato Paste Location 1	MJ/l	California (USA)	Desalination	0,07
Tomato Paste location 2	MJ/l			0,07
Olive Oil	MJ/l	Tunisi	Rainwater collection system	5,25
Soybean Oil	MJ/l	Iowa (USA)		0,69

Process	UNIT	Location	back-upTechnology	$E_{local,i}$ (MJ/l)
Sugar	MJ/l	Brazil		0,45
Tomato processing	MJ/l	California (USA)	Desalination	47,54
Sauce processing	MJ/l			0,34
Packaging	MJ/l	North-east states of USA	Rainwater collection system	0,34
Use stage	MJ/l			0,34
End of Life	MJ/l			0,34

Final values of ΔR are reported in Figure 3-27.

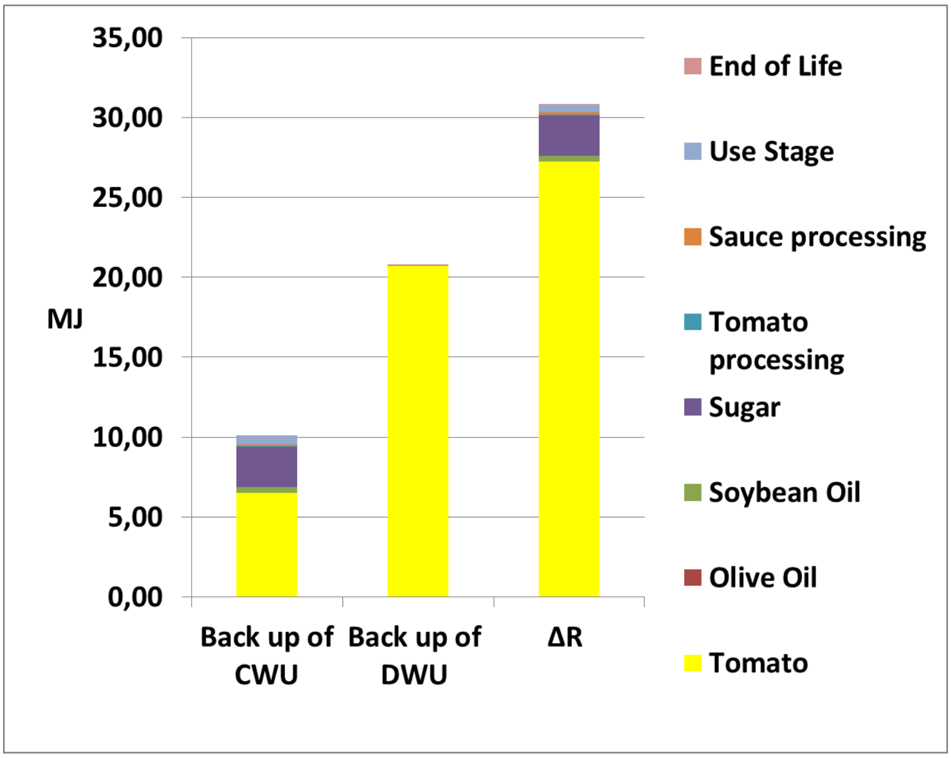

Figure 3-27 Impacts on resources from consumptive and degradative water use of 680g of tomato sauce

Results of impact assessment of resources area of protection shows that compensation of degraded water (20,74 MJ) require more energy than the consumed one (10,21 MJ). Tomato growing is still the main hot-spot that can be recognized also at end point level (88% of total impacts). Sugar production resulted to be the second most significant process (8% of total impacts). ΔR resulted to be 30,95 MJ.

3.4.5 Life Cycle Interpretation

In this stage of the study, results are analyzed in order to determine the main environmental hot-spot related to water. Table 3-66 reports on the results of this analysis highlighting the main hotspot and related variables.

Table 3-66 Hot-spot analysis for tomato sauce

Level of analysis	Indicator	Hotspots-process	Variables that influenced results
Inventory	CWU	Tomato crop	Yield, climatic conditions, irrigation technology
	DWU	Use of Fertilizer in Tomato crop, Wastewater emissions from tomato sauce processing	Quantity of fertilizer, wastewater quality parameters
Mid-point Impacts	SCDW	Tomato crop	Yield, climatic conditions, irrigation technology
	SDWU	Use of Fertilizer in Tomato crop, Wastewater emissions from tomato sauce processing	Quantity of fertilizer, wastewater quality parameters
	Eutrophication	Tomato crop, Energy Use	Quantity of fertilizer, use of hard coal in the energy mix
	Eco-toxicity	Tomato crop, Energy Use	Quantity of fertilizer, use of hard coal in the energy mix
	Acidification	Glass Jar, Energy Use	Emission to air, use of hard coal in the energy mix
End-point Impacts	Back up of CWU	Tomato crop	Yield, climatic conditions, irrigation technology
	Back-up of DWU	Use of Fertilizer in Tomato crop, Wastewater emissions from tomato sauce processing	Quantity of fertilizer, wastewater quality parameters

The hotspots identified, suggest potential water improvement strategies that the company can implement. This strategy can be grouped in two families:

1. Working with the supply chain setting specific requirements on raw materials production;
2. Working within the company and with the supply chain to improve the quality of energy mix used.

Strategy number 1 is focused specifically on tomatoes related processes that resulted to be a main hotspot in 7 out of 9 indicators assessed. In particular, the following actions and their effects on the

Water Footprint Accounting and impact results will be presented performing sensitivity analysis (Table 3-67).

Table 3-67 Potential actions on tomato sauce

Potential Actions
• Minimize use of fertilizer when growing tomatoes
• Different tomato growing locations in California
• Minimize use of hard coal in energy mix

Sensitivity analysis: Minimize use of fertilizer

Tomato growing resulted to be the main hotspot being significant in all the different accounting and impacts indicators results. In this scenario the recommendations from UC DAVIS (2008)on the use of fertilizer are considered.

Actual average use of fertilizers for tomato crop production in the fields under study resulted to be 214,30 kg N/ha. According to UC DAVIS (UC DAVIS, 2008) such value can be easily reduced to a value between 112,00 kg N/ha to 160,00 kg N/ha without affecting the yield of tomatoes. It was, therefore, decided to study how the different water footprint accounting and impact assessment indicators would change under an application rate of 140,00 kg N/ha: this value correspond to the actual minimum fertilizer land application in practice in California (UC DAVIS, 2008).

In particular, the SCDWU, the water eutrophication, eco-toxicity footprint were positively affected by a reduction in fertilizer use (Table 3-68). When fertilizer application rate is minimized, Grey Water can be reduced by 34%, the water eutrophication footprint by 13% and the water eco-toxicity footprint by 28,50%. It is interesting to note that the positive results obtained in terms of eco-toxicity depend both on the reduced impacts relevant to the production of fertilizer and on the quantity of nutrients that leach into the groundwater after land application in agricultural processes. All results are reported relative to the functional unit.

Table 3-68 Impact assessment results of tomato sauce minimizing the use of fertilizer

	Unit	Business as usual	Minimize use of fertilizer	% reduction
Fertilizer Application rate	kg/ha	214,3	140	34,67
SDWU	l_{eq}	16.380,30	10.711,16	34,60
Eutrophication	kg P_{eq}	3,11E-04	2,70E-04	13,18
Eco-toxicity	kg 1,4-DB_{eq}	1,44E-02	1,03E-02	28,47

Sensitivity analysis: Different tomato growing locations in California

The production of tomatoes in the California had a significant impact on the accounting and impact assessment results. In particular, the CWU and the SCWU, which both focus on water consumption, were highly affected. Therefore tomatoes grown in different locations in California were studied:

- Sacramento: Located in the Sacramento water basin, Sacramento is located in the north of the area where tomatoes are generally produced in California; a little percentage of tomatoes supplied the company comes from this area.
- Los Banos: Located in the San Joaquin water basin, Los Banos is in the center of the state. None of the tomatoes supplied to are produced here;
- Fresno: Located in the San Joaquin water basin, Fresno is located in the south of the area where tomatoes are generally produced in California. A percentage of the tomatoes supplied to company are produced in this area.

Using the CROPWAT model and climatic data from CLIMAWAT database for the three locations examined it was possible to determine the crop water requirements and assess the Blue Water footprint for the production of 1 kg of tomato (Table 3-69). All the other parameters used in the assessment, have not been changed. All results are reported to 1 kg of tomatoes.

Table 3-69 Impact assessment results of tomato sauce for different production location

Location	Wiithdrawal (mmH2O)	CWU (l/kg)	α_{in}	SCWU
Los Banos	1.178,60	60,30	1	60,30
Fresno	1.392,90	68,55	1	68,55
Sacramento	1.285,70	64,83	1	64,83

In this case, the SCWU is equal to CWU. The characterization factor, **α**, is the same across all three locations, which implies that the local water availability conditions are similar across the cross-section of California explored in this sensitivity analysis. From the results it can be concluded that significant variation exists from the north to the south region of California (14% higher from north to south).

Sensitivity analysis: Minimize use of hard coal in energy mix

The use of hard coal had a negative impact on the water eutrophication, eco-toxicity and acidification footprints. The company can affect the use of hard coal in two ways:

- Changing its own energy mix to use less hard coal;
- Asking its suppliers to avoid using hard coal in their energy mix;

Following a worldwide-established practice, the company could decide to purchase greenhouse gas offsets that finance the generation of renewable energy. From a water footprint perspective (Gerbens-Leenes et al., 2008), the source of renewable energy that presents the best water footprint profile is wind energy. Table 3-70 reports the result of the eutrophication, eco-toxicity and acidification footprints, in the case the company adopts the above mentioned strategy. An average reduction of 6% can be achieved. All results are reported to functional unit.

Table 3-70 Impact assessment results of tomato sauce for different energy mix

	Unit	Business as usual	Use of hard coal off-set by RECs	% reduction
Eutrophication	kg P eq	3,11 E-04	2,84 E-04	8,68
Eco-toxicity	kg 1,4-DB eq	1,44 E-02	1,39 E-02	3,47
Acidification	kg SO2 eq	5,76 E-03	5,39 E-03	6,42

4. Discussions

To address a comprehensive assessment of impacts related to water following the requirements presented by UNEP-SETAC (Bayart et al., 2010) within the context of LCA and ISO 14046 (ISO 2013), several indicators have been developed and presented in this research.

Focusing at inventory level the CWU and DWU indicators have been introduced; the first one is aimed at determining the quantity of water that leaves the system because of evaporation, product incorporation, or different water basin destination. This indicator represents the mass balance between the water that enters and exit the different unit processes. Following the definitions introduced by Bayart et al. (2020) such indicator represents the consumptive water use contribution of a unit process. DWU represents the volume of water that resulted to be discharged from a unit process with a degraded quality and therefore a limited functionality. It represents the degradative water use of a specific unit process according to Bayart et al. (2010). To see if a change in functionality occurred, the classification by Boulay et al. (2011a) was adopted. Moreover, to allow an easy interpretation, parameter j was introduced in the formulation of DWU. Such parameter in fact represents with a binary value, 0 or 1, if a loss in functionality occurred in the specific unit process understudy. Value of j are assigned considering the different water classification of volumes that enter and exit the system. The use of Boulay et al (2011a) method in the formulation of the inventory structure developed in this research allowed to answer also other criteria reported in chapter 2: resources are classified in function of their origin (surface and groundwater) and it is make possible to understand if a change in water happed with reference to as specific water category. The adoption of CWU and DWU answers the UNEP-SETAC requirement of representing consumptive and degradative water use (Bayart et al., 2010);it also solve the limits of transparency with reference to the framework of ISO 14046 (ISO, 2013) by separately representing consumptive and degradative use.

To make the two indicators fully operative and to answer UNEP-SEATC criteria (Bayart et al., 2010) it was necessary to introduce and collect parameters that are usually not considered in life cycle inventories and international databases. These are: the volume of water leaving the system; information about the location of withdrawn water that allow regionalization; parameters of air emissions (see ANNEXES for detailed data). Another parameter that has been included is the water scarcity index of the water entering the unit process; values of these parameters are regionalized and acquired from Boulay et al. (2011b). The proposed method uses the scarcity of the water type entering the system because this is considered the resource category being affected by consumption and degradation. When compared to the existing method from Hoekstra et al. (2011) or Boulay et al. (2011) the indicators based water footprint method developed in this research resulted more complete in fact none of this methods include a first quantification of consumptive and degradative water use (CWU and DWU indicators), moreover thanks to the additional parameters introduced (such as air emissions), it allowed the quantification of all impacts considered at mid-point and end-point level (ref. chapter 3). The inclusions of these parameters answer the principle of completeness from ISO 14046 (ISO, 2013).

At mid-point level UNEP-SETAC requirements (Bayart et al. 2010) were used to develop a water footprint profile made of 5 indicators named: the Scarcity Consumptive Water Use, SCWU, the Scarcity Degradative Water Use (SDWU), the water eutrophication, the eco-toxicity and the acidification footprint. In this research, SCWU and SDWU were introduced to answer the need of transparently identify the contribution of consumptive and degradative water use to scarcity. SCWU specifically measures the change in water availability resulting in increased competition for freshwater resources; and therefore the contribution that a consumptive water use has on local scarcity; parameter α_{in} is used to represent the scarcity of the water type (considering quality, origin, location and functionality) entering the specific unit process. SDWU is introduced to address the contribution of degradative water use to scarcity; it measures how quality degradation limits the availability of water resources in a specific local context; a distance to target approach is adopted to measure the magnitude of water pollution by using the ratio between $Q_{ou,it}$ and $Q_{ref,I}$; the use of parameter α_{in} allows to weight the results of degradative water use according to local water availability. This approach, focusing on degradative use, differs from Hoekstra et al. (2011) where a dilution factor is used in the quantification of the so-called grey water, and overcome its recognized limits, by fixing specific water quality threshold represented by the maximum acceptable concentration of i-pollutant of the z-water category according to Boulay et al. (2011). This approach differs also from the one presented by Boulay et al. (2011b) that, even if it addresses the scarcity issue from a qualitative and quantitative perspective, is not able to give a clear measure of the consumptive and degradative use; SCWU and SDWU allow to do so. The formulation of these two indicators responds to the other UNEP-SETAC requirements (Bayart et al. 2010): they are expressed in volumes of water equivalent ($m^3_{equivalent}$ or $l_{equivalent}$); they consider seasonal and local difference in water availability using parameter α_{in}. The water eutrophication, the eco-toxicity and the acidification footprint were considered using consolidated methods published in literature based on their acceptance by LCA community (Struijus et al., 2009; Jolliet et al., 2003; Goedkoop et al., 2012). The use of this set of indicators allowed to get a comprehensive view of impacts related to water as introduced by ISO 14046 (ISO 2013) and required by UNEP-SETAC.

At end point level the UNEP-SETAC (Bayart et al. 2010) criteria were adopted to develop two indicators in the specific resource area of protection; these are the back-up of cumulative water use and the back-up of degradative water use indicator; these indicators represent the amount of non-renewable energy that is needed to back up the consumptive and degradative water use. The back-up technology concept has also been adopted introducing a new aspect in literature: the use of local back-up technology; in fact only technologies locally applicable can answer the need to solve local water management issues; results are expressed in term of surplus energy (additional quantity of energy needed to extract non-renewable resources) by using the Cumulative Energy Demand method. Regionalization is guaranteed by two aspects: the use of parameter α_{in} and the use of local back-up technology. Working on this area of protection allowed to answer the need of comprehensiveness and geographical aspects and resolutions required by the principles of ISO 14046 (ISO, 2013). Table 4-1 summarizes the solutions adopted in the set of indicators developed to address ISO 14046 principles.

Table 4-1 Solutions adopted to address 14046 principles

	Solutions
Life Cycle perspective	All stages of the life cycle of products/processes from raw materials to the end of life or all the activities of the organization shall be considered.
Environmental focus	All potentials environmental impacts related to water has be considered
Transparency	At inventory, mid-point and end point (resources) level, the degradative and consumptive freshwater use has been addressed separately with CWU, DWU, SCWU, SDWU, back-up of CWU, back-up of DWU indicators
Completeness	Water inventory has been integrated to fully address quantification of mid-point and end-point indicators
Comprehensiveness	At mid-point level a set of comprehensive indicators was developed: SCWU, SDWU, eutrophication, acidification, and eco-toxicity. To address End point resources area of protection has been investigated and completed considering also back-up of degradative water use through the introduction of Elocal,j.
Geographical aspects and resolutions	Regionalization has been guaranteed at end-point level introducing the concept of local back-up technology and developing ad-hoc characterization factors such as Elocal, I and Elocal,j

Focusing on the results achieved through the application of the inventory method developed, some interesting results emerged. First of all, considering UNEP-SETAC framework and confirming results from recent paper published by Boulay et al. (2013), the use of a set of indicators at inventory level, in our case representing both consumptive and degradative use and the introduction of j parameter, resulted to be useful for water management practices.

In case study number one, for example, where a water collection system production has been studied, it was possible to identify some improvement strategies starting from the analysis of CWU and DWU indicators; in fact the opportunity of reusing the water discharged from the injection molding process emerged. The use of classification and j parameter allowed a straightforward understanding that water discharged from molding could be potentially used for cooling down HDPE granules during recycling. This resulted in 30% potential reduction of DWU and also other indicators such as SDWU and energy costs to back up the water quality expressed through the back-up of DWU indicator. This result would have not been possible without considering j parameter that allowed an effective contribution to the ? hotspot analysis. Another interesting aspect from the application of this inventory method emerged; considering separately the degradative and the consumptive water use, helped the company to understand that: if they want to reduce their water consumption they should start focusing on injection molding process; on the other end, if they want to better manage the degradative use they should focus on HDPE recycling process. Without introducing two different indicators to address consumptive and degradative use, such as CWU and DWU indicators, this would not have been possible.

In case study numbers two, both consumptive and degradative water use suggested the company to focus on sunflower production. In this case the company could adopt a single strategy to reduce both these contributions.

Same considerations are valid in case study number 3 where at inventory level the most significant process resulted to be strawberry production in both CWU and DWU assessment.

In case study number 4 the degraded volume (3098,58 l_{eq}) resulted to be much higher than the consumptive volumes (103,92 l_{eq}). Both of CWU and DWU indicators pointed tomato production as the most water intensive process; however high values of DWU suggested the company to focus more on its degradative footprint working within its facility and also along the supply chain by setting for example raw material specification (lower use of fertilizers).

Another interesting result emerged from the application of the developed inventory structure and method when considering the information on regionalization such as location of withdrawn water and parameter α_{in} .In the case of organic oat, they allowed to perform a sensitivity analysis on production of sunflower in different location, showing that the company can achieve important results both in term of consumptive (reduction of around 55%) and degradative (reduction around 6%) water use reduction. These results depend on the local climate conditions of the locations understudy represented by the introduced parameters. Production of sunflower in Rovigo in fact, allows withdrawing less quantity of water resulting in a smaller consumptive but also degradative water volumes. This sensitivity analysis confirmed the importance of having geographical parameter also in the other impact categories resulting in a consistent reduction of SCWU, SDWU, Back up of CWU Back up of DWU. The same sensitivity analysis approach was adopted in case study number 4. However in this case no-significant difference was noticed due to the high scarcity conditions that characterize California. A different sensitivity analysis permitted by local conditions parameters, is the one presented in case study number 2 were a change in water resource origin is assumed. Introduction of parameter α_{in} allowed making this analysis showing the risk that the company would face in the case that surface water availability would decrease forcing them to use groundwater resources. In this case the impact of the company on water resource would significantly increase in most of the water footprint profile indicators. In case study number 1 such analysis were not performed because all the processes are located in the same region with homogenous scarcity.

From the analysis of the inventory results, in the four case studies emerged that DWU and CWU, except from scarcity conditions, served as screening indicators in the contribution and hotspot analysis of impacts at mid-point and end-point level; in fact CWU almost presented the same hotspot and process with significant contribution of SCWU and back-up of CWU, while DWU presented the same hotspot and process with significant contribution of SDWU and back-up of DWU. Table 4-2 summarizes these results that were already presented in previous paragraphs for the different case studies. This proves the effectiveness of the proposed set of indicators in measuring the performance of life cycle processes related to water at inventory level.

Table 4-2 Screening assessment results

	Indicators	Hotspots-process	Variables that influenced results
Case study 1	CWU SCDW Back up of CWU	Injection molding	Evaporation of withdrawn water to cool down the product in the stamp
	DWU SDWU Back-up of DWU	HDPE Recycling	Water to cool down HDPE recycled granulates
Case study 2	CWU SCDW Back up of CWU	Strawberry and apple	Use of irrigation water due to local climate conditions
	DWU SDWU Back-up of DWU	Strawberry and apple	Use of fertilizer and leaching due to groundwater caused by irrigation and rain water runoff
Case study 3	CWU SCDW Back up of CWU	Sunflower	Use of irrigation water due to local climate conditions
	DWU SDWU Back-up of DWU	Sunflower	Use of fertilizer and leaching due to groundwater caused by volumes of irrigation water
Case study 4	CWU SCDW Back up of CWU	Tomato crop	Yield, climatic conditions, irrigation technology
	DWU SDWU	Use of Fertilizer in Tomato crop, Wastewater emissions from	Quantity of fertilizer, wastewater quality parameters

	Indicators	Hotspots-process	Variables that influenced results
	Back-up of DWU	tomato sauce processing	

Completeness of inventory, according to UNEP-SEATC criteria, was achieved by introducing also emissions to air. No specific water inventory method and approaches consider these parameters. Their use allowed performing a comprehensive water footprint assessment at mid-point level casting the light also on other indicators such as acidification footprint.

From the application of the developed water footprint profile at mid-point level some interesting aspects emerged. First of all, the introduction of different indicators to measure consumptive and degradative aspects resulted to be useful when confronted to other methods published in literature (Boulay et al., 2011b) because they allowed performing a more complete contribution and hotspot analysis. This clearly emerged from case study number 1 and number 3. In the former, as already mentioned, starting from inventory results emerged the need to work both on consumptive and degradative use focusing respectively on injection molding and HDPE recycling. Adopting the most used method in literature from Boulay et al (2011b) this would have not been possible. Figure 4-1 shows the contribution results using the two methods. Result of the method from Boulay et al. (2011b) (Water Scarcity Index WSI) are the same as SCWU in this case study, (this depends on the scarcity parameters values) but is not able to give us the information that SDWU is giving about the significance of HDPE recycling process. In case study number 3 the 330g of organic strawberry jam was studied. Figure 4-2 report on the assessment performed according to Boulay et al (2011b) and the results achieved through the developed set of indicators. In this case emerged that WSI from Boulay et al. (2011b) and SCWU are similar, however from the analysis of SDWU emerged that the process of freezing strawberry is significant. Without considering both consumptive and degradative impacts separately this information would have been lost. This proves the effectiveness in measuring the performance of life cycle processes related to water at mid-point level.

Figure 4-1 Different methods applied to water collection system production

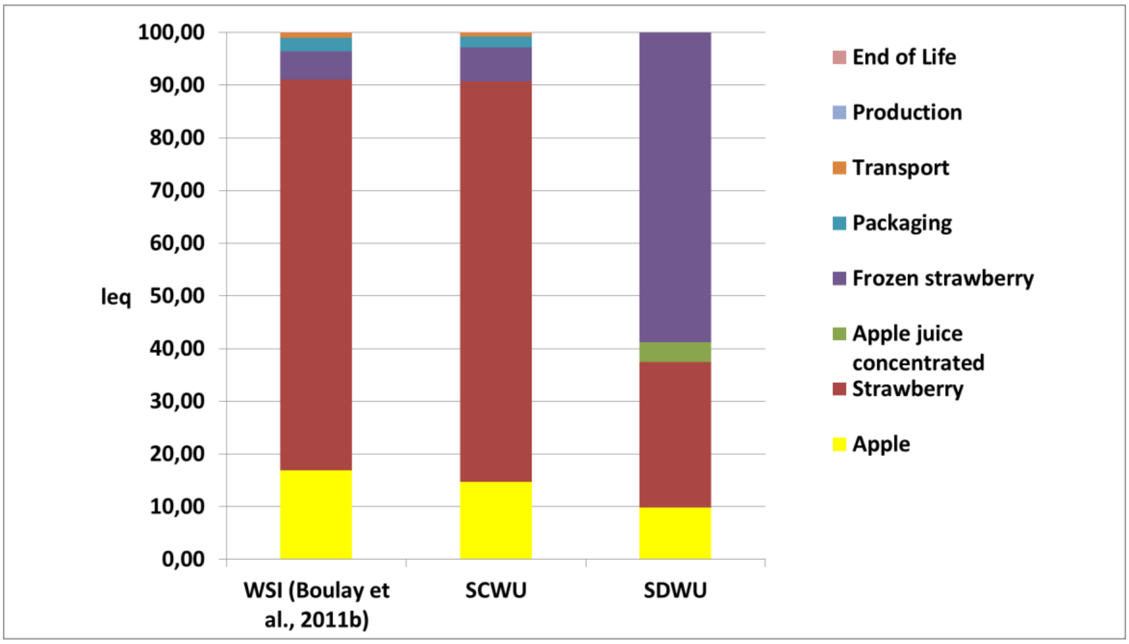

Figure 4-2 Different methods applied to 330g organic oat beverage

SCWU results in the four case studies, was higher in those production with higher water requirements, this is the case of strawberry and tomato production. In the case of SDWU this indicator resulted to be higher in those processes with emissions to water, such as use of fertilizer in tomato production or emissions to water in HDPE recycling.

Contribution and hotspot analysis was effectively supported by the introduction of the degradation profile made of the eutrophication, eco-toxicity and acidification footprints. In case study number 1 and 2, the use of these indicators allowed to better understand the positive contributions of environmental friendly practices active in the product systems understudy: the use of recycling material (HDPE selection) and the reuse of scraps and secondary products (the case of organic oat from which animal fodder is derived). With specific reference to case study number 1 a sensitivity analysis was performed to understand the consequences of using virgin material instead of recycled one; this analysis allowed to understand that the company would partially improve and partially worsen its environmental performances. Without adopting a comprehensive approach this would not have been possible. In case study number 4 the use of these indicators helped to identify another hotspot such as the glass production. Without considering a comprehensive profile it would have not been possible to identify these issues. The use of this profile also effectively helped to determine environmental impact reduction strategies with specific focus on the use of energy sources. This was true in case study 1, 3 and 4 were the change in the energy mix resulted in better performances for all the degradation profile indicators. These results prove the effectiveness of the proposed set of indicators in supporting company performance improvement and therefore industrial process competitiveness.

The method developed at end-point level was successfully applied in all the different case studies. In detail, it was possible to study the application of two technologies to back-up water use: a water collection system dimensioned on specific local back-up needs (based on case study 1, water collection system) and the desalination system that is usually applied in literature (Pfister et al. 2009). Locally back up of degradative water use, was guaranteed in all the different case studies using the parameter person equivalent to decide on the wastewater treatment facility locally applicable. In case study number 1, 2 and 3 back-up of CWU resulted to be bigger than the one of DWU; from the analysis of contribution same considerations made at inventory level are valid. When focusing on characterization factors, it can be noted that values are higher in function of the local climate conditions and the CWU of the specific unit process. Where rainwater volumes are higher, Elocal,i (MJ/l) resulted to be smaller. This is evident in case study number 3 were values to back up water in Switzerland (0,27) resulted to be smaller than the energy needed to back up the water in Italy (0,32) even if in both case the same water collection system dimension has been used (1 water collection system module). In case study n. 3, Elocal,i (MJ/l) resulted to be higher with higher CWU values. This is evident in the case of energy needed in Bulgaria than the one needed in Italy; in fact higher CWU requires bigger water collection system dimensions. Therefore, these results are highly influenced by the specific water technology used to back up CWU. This proves the efficacy of using the proposed model in representing local impacts to back-up local water use. This is also evident in case study number 4. Figure 4-3 reports on the results of back-up of CWU in three different scenarios: when only desalination plants are used (scenario 1), when only water collection is used (scenario 2) and when both of these technologies are used (business as usual). In this case back up of CWU resulted to be smaller than back up of DWU (chapter 3.4..4.3) because of the use of desalination plant.

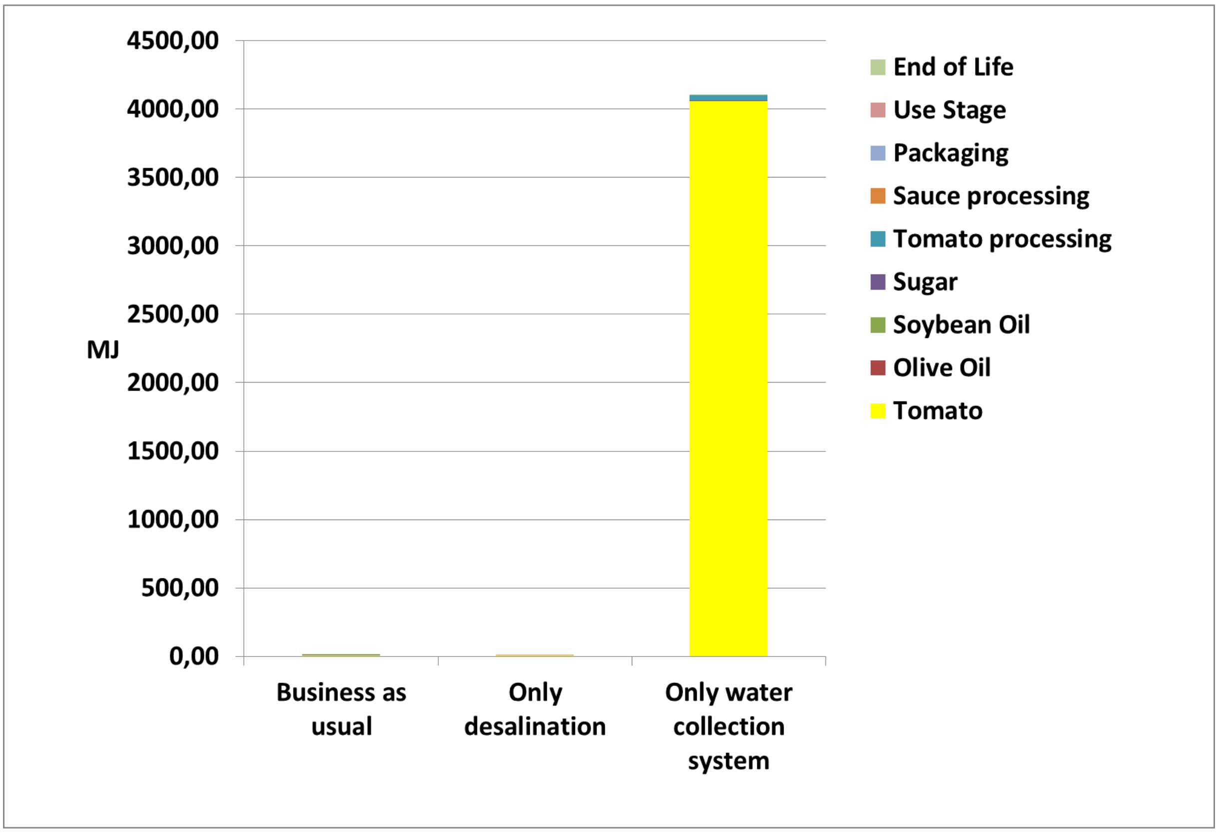

Figure 4-3 back up of CWU in different scenario

The use of only water collection system resulted to be the most energy intensive solution; this is due to local climatic conditions in California where tomato are produced; in those area rainwater is limited therefore a bigger system is needed resulting in bigger energy use. Business as usual result (10,22 MJ) is very similar to only desalination one (7,05 MJ) because most of the impacts are related to tomato production processes that are already assessed through desalination plant. The propose set of indicators allowed to understand process contribution to end-point category resources.

5. Conclusions and future perspectives

The management of scarce resources such as freshwater is a key issue currently being discussed at the international level. Its availability is threatened by climate changes, population growth and industrial processes. In this contest, companies' competitiveness result to be affected by several risks such as freshwater resource accessibility, compliance to local regulation and company market image. Several models have been developed and are available in the literature to support companies in the management of freshwater and related risks; recent developments took place in the context of Life Cycle Assessment methodology (ISO, 2006) and ISO 14046 (ISO 2013a), a tool to quantify the potential environmental impacts of different products, processes and organizations; however, they have some limitations that prevent company to set effective performance improvement strategies (Bayart et al, 2010; Hoekstra et al., 2011; Boulay et al. 2013): at the inventory environmental accounting level, there is lack of completeness and details and lack of indicators to clearly represent consumptive and degradative freshwater use; at mid-point environmental impact assessment level, there are no indicators to separately and clearly address how consumptive and degradative freshwater use affect freshwater availability, therefore a lack of comprehensiveness; at end-point environmental impact assessment level, within resource area of protection, regionalization and effects of degradative use are not considered. These limitations do not allow companies to understand the contribution that life cycle processes have on freshwater related impacts and therefore limit the opportunity to develop strategies to reduce environmental impacts.

This is the framework were the research activity of this PhD took place. It focused on the development and application of a new model to achieve the water management as a competitive tool for industrial processes. The specific objectives of the research were:

1. the definition of a set of indicators to integrate the framework of LCA and ISO 14046 and solve identified limits at inventory, mid-point, end-point level;
2. Verification of the applicability of the developed set of indicators in real case studies and their effectiveness in measuring the performance of life cycle processes related to freshwater.

To determine the set of indicators, the criteria suggested by UNEP-SETAC (Bayart et al., 2010) and the principles of ISO 14046 (ISO 2013a) were adopted. At inventory level two new indicators have been presented and common practice of freshwater inventory has been integrated with new parameters. The first indicator to be developed is the Consumptive Water Use (CWU) that measure the quantity of volume leaving the system and therefore contributing to freshwater scarcity. The second indicator is the Degradative Water Use (DWU) indicator that assesses the quantity of volumes degraded, thanks to the use of a j parameter that indicates if a loss in functionality of the water entering the system occurred and therefore contribute to limit freshwater availability. No method published in literature address both consumptive and degradative freshwater use at inventory level. To guarantee completeness and comprehensiveness the following parameters have been added to traditional and recent published water inventories: quality parameters of freshwater entering the system, air emissions and parameter j.

At mid-point level a water footprint profile of 5 indicators has been proposed. It is composed of the Scarcity Consumptive Water Use (SCWU), Scarcity Degradative Water Use (SDWU), Eutrophication, Eco-toxicity and Acidification. Considering all these impact indicators, it was possible to guarantee comprehensiveness of assessment according to ISO 14046 framework (ISO 2013a). No specific current water method takes into considerations all these aspects. In particular SCWU and SDWU indicators have been developed to address separately the contribution that consumptive water use and degradative water use have on local freshwater scarcity. This approach overcomes the limit of transparency of current methods that do not distinguish between degradative and consumptive water use (Hoekstra et al., 2011; Boulay et al., 2011b). SCWU and SDWU are reported in the same unit (l equivalent or m3 equivalent) and can be summed into the Water Scarcity Indicator (WSI).

At end point level the focus has been on resource area of protection and a new approach has been developed, to consider effects of both degradative (back-up of DWU) and consumptive water use (back-up of CWU) and to fully address regionalization. The first issue is solved introducing the back-up of water use concept defined as the surplus energy needed to back-up the quality of water when degraded; the second issue has been solved by studying local back-up technologies and weighing water use with α_{in} scarcity parameters from Boulay et al. (2011b). Results of back-up of DWU and back-up of CWU can be summed into ΔR representing the total amount of energy needed to back up comprehensive water use. No model presented in literature considers local back-up technologies and effects of degradative use on resources (Pfister et al., 2009).

To verify the applicability and effectiveness of the proposed set of indicators 4 case studies have been investigated adopting the methodological framework of LCA (ISO, 2006) and ISO 14046 (ISO, 2013a). Products with critical water processes and with life cycle stages potentially located in different regions were selected. The 4 case studies dealt with: a water collection system; an organic oat beverage; an organic oat strawberry jam; a tomato sauce. Applicability of the developed set of indicators has been confirmed in all the case studies investigated. A summary of results is reported in table 5-1. In all these case studies the proposed set of indicators allowed to define comprehensive strategy to reduce the impacts of water use in term of volumes and quality degradation. This allowed the companies to identify potential actions to improve performances and therefore competitiveness. At inventory level CWU and DWU resulted to be reliable screening indicators in all the case studies, giving a first idea of potential hotspots related to water and with specific reference to SCWU, SDWU, back-up of CWU, Back up of DWU. In case study on water collection system in fact, they allowed to identify injection molding and HDPE recycling hotspots; in the case of organic oat beverage casted the light on sunflower agriculture processes; in the case of organic strawberry jam identified apple and strawberry growing as potential hot-spot; in the tomato sauce production highlighted the importance of tomato growing and agriculture practices. This is an interesting result because the use of screening indicators is warmly welcomed in literature as it allows an easy comprehension of environmental related issues with less time and money than conducting a full analysis (Scipioni et al., 2012). Therefore it facilitates the adoption of water footprint analysis at the company level.

Another important result of the application of the inventory indicators is their potential support to water management in response to recent literature needs (Boulay et al., 2011). In fact, for example in water collection system production, they allowed understanding potential water saving, coming from the reuse of injection molding discharged water.

The proposed set of inventory indicators supported transparency and comprehension of different process contribution by giving a measure also of the degraded volume in all the different case studies (see DWU from Table 5-1).

The inclusion of inventory parameters such as quality in, air emissions and j, allowed to complete current water inventories (Hoekstra et al; 2011 Boulay et al 2011a) and to apply all the selected indicators at mid-point and end-point level in all the 4 case studies; in fact without considering quality in and j, it would not have been possible to quantify SCWU, SDWU, back up of CWU and back up of SDWU and without considering air emissions it would have not been possible to quantify acidification.

Results at mid-point level proved the importance of being comprehensive and therefore to consider more than one impact indicator related to water. These aspects resulted to be central to impact reduction strategy definition. In the water collection system study, being comprehensive, allowed to understand the positive contribution of HDPE selection process in acidification and eutrophication and also to identify several hot-spot (energy use and lubricant oil consumption) that allowed the definition of water related impact reduction strategies such as the change in the energy-mix. Similar results are confirmed by the application of the proposed set of indicators also to the other case studies: in the oat beverage production it allowed to identify avoided impacts coming from the reuse of oat scraps as fodder and allowed to determine the importance to work on the use of fertilizer and innovative packaging solutions; in the analysis of organic strawberry jam it suggested to work on the energy mix and also to consider the negative consequences of changing the resource use for irrigation therefore suggesting to put particular attention on local water availability; in the case of tomato sauce allowed to set a comprehensive strategy focused on the company processes and the supply chain one, setting strategies on product specification and energy-mix. Considering only one or part of the proposed indicators this result would have not been achievable. The development of water specific indicators support also LCA practice that missed a comprehensive perspective related to water. Being comprehensive avoid the burden shifting issue as recommended by LCA standards (ISO, 2006)

The proposed end-point set of indicators allowed to understand the impacts of back-up consumptive and degradative water use on non-renewable resources. In three out of four case studies the energy needed to back-up consumptive water use resulted to be higher than the degradative one and depended on the technology used. These results suggest the importance of regionalization also in this method in order to allow a better understanding of consequences of local water use.

Results at mid-point and end-point level confirmed the importance of regionalization. In particular this emerged in the analysis of impacts related to scarcity. In the case of sunflower and tomato production sensitivity analysis based on these parameters allowed the companies to better focus on specific issue to set effective water management strategies. Considering regionalization allowed understanding the contribution of local climate conditions to final water footprint profile: water degradation and consumption should be avoided in water scarce regions. Regionalization resulted to be a key issue also at end-point level: it is more expensive in term of energy to back up water where it is scarce (e.g. in the case of organic oat beverage where a change in location to produce sunflower could result from 30 to 60% reduction in terms of energy to back-up degradative water use).

Table 5-1 Set of indicators results in the 4 case studies

		INVENTORY		MID-POINT						END-POINT		
Product	**Sector**	**CWU (l)**	**DWU (l)**	**SCWU (l_{eq})**	**SDWU (l_{eq})**	**WSI (leq)**	**Eutrophication (kgP_{eq})**	**Eco-toxicity (kg 1,4-DB $_{eq}$)**	**Acidification ($kgSO_{2\ eq}$)**	**Back up of CWU (MJ)**	**Back-up of DWU (MJ)**	**ΔR (MJ)**
Water harvesting system	**Water recovery**	10,79	31,80	10,79	1.272,00	1.282,79	6,19E-03	9,25E-02	3,99E-02	3,46	0,20	3,66
Organic Oat Beverage	**Beverage**	18,21	2,94	16,99	4,23	21,22	6,01E-05	3,28E-03	1,26E-03	13,06	3,01E-02	13,09
Organic Strawberry Jam	**Food**	809,22	365,34	187,15	525,94	713,09	3,96E-03	5,99E-02	1,79E-02	173,84	0,46	174,30
Tomato Sauce	**Food**	103,92	3.098,58	99,10	16.380,30	16.479,40	3,14E-04	1,44E-02	5,76E-03	10,21	20,74	30,95

Definition of the set of indicators allowed developing a new model to address impacts related to water. It is presented in figure 5-1. Yellow squares represent the additional information required and made available thanks to the set of developed indicators. At inventory level the proposed model include additional quality parameters that make the entire different impact assessment model applicable; moreover a set of indicators is added giving preliminary information on the water footprint profile of the products understudy. At mid and end point level it is possible to address separately the full environmental chain related to consumptive and degradative water use. Moreover it allows a comprehensive assessment at mid-point but also at end point level fully considering the resource area of protection.

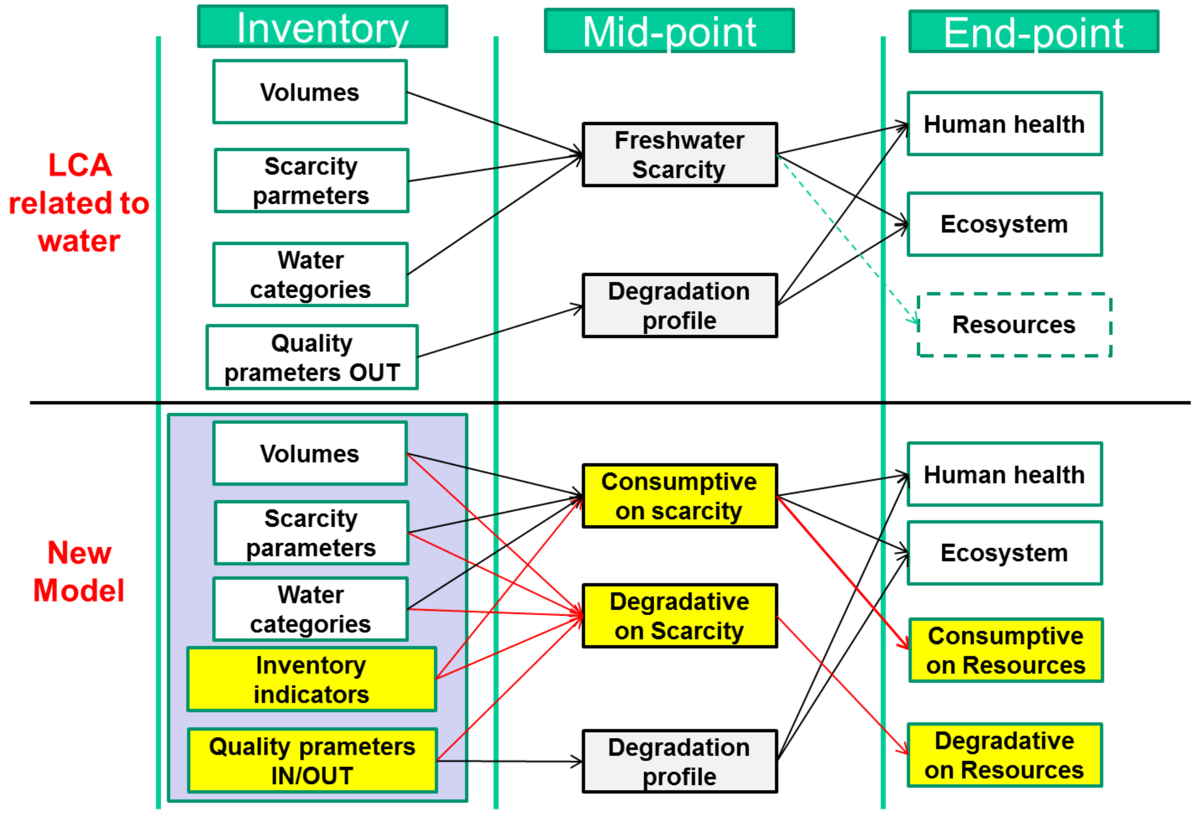

Figure 5-1 New model developed vs LCA Related to water model

Results of this research open to new research perspectives. At inventory level future research could focus on the application of CWU and DWU inventory indicators in other case studies representing different sectors; this would prove its general validity. In this direction it would also be interesting to investigate if it is possible to make available an inventory indicator to be used as screening for the other degradation indicators such as acidification. From the conduction of the case studies, some limits of actual database emerged: they do not have quality in parameters or discharged water volume. Future research should work on the development of such databases. With reference to the mid-point level two future perspectives can be identified. The first one is related to the α_{in}: it would be interesting to develop dynamic indicators allowing determining how present water use will affect future scarcity. The second aspect is related to another environmental issue that is central to international debates such as climate change (Scipioni et al., 2011). No model currently addresses how climate change is affecting local water scarcity. Research in this field is warmed welcome also by the diffusion of another environmental indicator such as Carbon Footprint (Scipioni et al., 2011). With specific reference to the end-point resource category, future development can be identified; in this study it was possible to consider a water collection system and desalination plants, however other water recovery technologies are available on the market and should be considered when assessing local impacts. It would therefore be interesting to investigate several potential back-up solutions in order to allow a more effective water impact reduction strategy definition. To do this the same CED method proposed in this research can be easily applied. Another need emerged in this research with reference to back-up technology: it would be useful to develop a set of indicators specifically designed to support the analysis of optimal back-up of local solutions; for instance, following the wide experience on another limited resource such as energy, it would be interesting to develop an indicator similar to the Energy Pay-Back time, that is recognized to support decisions on the best technology to be locally applied. These future perspectives could also contribute to make LCA database more complete and support a better water management to guarantee local water availability. Another possible future research line should focus on expressing the surplus energy at end-point level in economic term as suggest by the European platform on LCA (EC-JRC, 2011).

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Student	Type	Thesis title	A.A.
Luca Rettore	Research Master	Il calcolo del Water Footprint di prodotti industriali: il problema della Grey Water in relazione all'inquinamento della risorsa idrica	2010/2011
Matteo Ciesa	Research Master	La gestione dell'energia a livello territoriale: sviluppo e applicazione di un modello nel Comune di Teolo	2010/2011
Filippo Longo	Bachelor	Il contributo dei progetti CDM nella lotta i cambiamenti climatici: dal Protocollo di Kyoto ai futuri accordi globali	2011/2012
Alessandra Vangelista	Bachelor	Gestione dei fanghi conciari e cambiamento climatico: analisi comparativa di Carbon Footprint	2011/2012
Maria Diletta Marotti	Research Master	Water Footprint di prodotto per la gestione delle performance di processo: il caso studio Abafoods Srl	2011/2012
Matteo Simonetto	Research Master	Water footprint: assessment of impact on water resources through the adoption of local endpoint characterization factors	2012/2013
Luca Righetto	Bachelor	L'evoluzione del concetto di Water Footprint: revisione critica degli scenari di sviluppo	2012/2013

ANNEX A: water collection system quality parameters inventory

Project WF_Drening

Product: 1 p Ciclo di Vita Modulo Drening (of project WF_Drening)

Substance	Compartment	Sub-compartment	Unit	Total	Substance	Compartment	Sub-compartment	Unit	Total
Chloride	Water	river, long-term	kg	4,1E-10	Sulfur dioxide	Air	low. pop.	kg	0,041564
Benzene, chloro-	Water	river, long-term	kg	3,19E-12	Sulfate	Air	low. pop.	kg	1,36E-06
Zirconium-95	Water	river	Bq	0,000981	Styrene	Air	low. pop.	kg	1,17E-09
Zinc, ion	Water	river	kg	2,39E-06	Strontium	Air	low. pop.	kg	1,57E-06
Zinc-65	Water	river	Bq	0,084708	Sodium	Air	low. pop.	kg	5,98E-08
Xylene	Water	river	kg	6,4E-06	Silver-110	Air	low. pop.	Bq	1,78E-06
Water	Water	river	kg	31,79688	Silver	Air	low. pop.	kg	3,93E-12
VOC, volatile organic compounds, unspecified origin	Water	river	kg	2,45E-05	Silicon tetrafluoride	Air	low. pop.	kg	2,9E-10
Vanadium, ion	Water	river	kg	2,36E-06	Silicon	Air	low. pop.	kg	1,06E-06
Urea	Water	river	kg	3,08E-12	Selenium	Air	low. pop.	kg	9,63E-07
Uranium alpha	Water	river	Bq	19,14311	Scandium	Air	low. pop.	kg	5,28E-10
Uranium-238	Water	river	Bq	1,392897	Ruthenium-103	Air	low. pop.	Bq	1,79E-07
Uranium-235	Water	river	Bq	0,657859	Radon-222	Air	low. pop.	Bq	55566,89
Uranium-234	Water	river	Bq	0,398693	Radon-220	Air	low. pop.	Bq	15,17088
Tungsten	Water	river	kg	9,61E-08	Radium-228	Air	low. pop.	Bq	0,158064
Trimethylamine	Water	river	kg	4,07E-14	Radium-226	Air	low. pop.	Bq	0,92288
Toluene, 2-chloro-	Water	river	kg	3,57E-12	Radioactive species, other beta emitters	Air	low. pop.	Bq	0,000102
Toluene	Water	river	kg	7,71E-06	Protactinium-234	Air	low. pop.	Bq	0,017998
TOC, Total Organic Carbon	Water	river	kg	0,005415	Propene	Air	low. pop.	kg	1,04E-06
Titanium, ion	Water	river	kg	2,2E-07	Propane	Air	low. pop.	kg	0,000243
Tin, ion	Water	river	kg	5,16E-08	Potassium-40	Air	low. pop.	Bq	0,566551
Thorium-234	Water	river	Bq	0,332269	Potassium	Air	low. pop.	kg	6,81E-08
Thorium-232	Water	river	Bq	0,186288	Polonium-210	Air	low. pop.	Bq	2,410612
Thorium-230	Water	river	Bq	45,33183	Plutonium-alpha	Air	low. pop.	Bq	3,93E-08
Thorium-228	Water	river	Bq	13,53342	Plutonium-238	Air	low. pop.	Bq	1,71E-08
Thallium	Water	river	kg	1,96E-07	Platinum	Air	low. pop.	kg	1E-11
Tellurium-132	Water	river	Bq	4,78E-05	Phosphorus	Air	low. pop.	kg	1,01E-08
Tellurium-123m	Water	river	Bq	0,003768	Phenol,	Air	low. pop.	kg	9,08E-08

					pentachloro-				
Technetium-99m	Water	river	Bq	0,018973	Phenol	Air	low. pop.	kg	4,11E-08
t-Butylamine	Water	river	kg	6,71E-13	Pentane	Air	low. pop.	kg	8,54E-06
t-Butyl methyl ether	Water	river	kg	2,41E-11	Particulates, > 2.5 um, and < 10um	Air	low. pop.	kg	0,000844
Suspended solids, unspecified	Water	river	kg	-0,00189	Particulates, > 10 um	Air	low. pop.	kg	0,008921
Sulfur	Water	river	kg	1,95E-05	Particulates, < 2.5 um	Air	low. pop.	kg	0,002148
Sulfite	Water	river	kg	9,7E-05	PAH, polycyclic aromatic hydrocarbons	Air	low. pop.	kg	2,81E-07
Sulfide	Water	river	kg	2,88E-06	Ozone	Air	low. pop.	kg	7,72E-11
Sulfate	Water	river	kg	-0,00119	Noble gases, radioactive, unspecified	Air	low. pop.	Bq	1207374
Strontium-90	Water	river	Bq	12,42624	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	low. pop.	kg	0,005627
Strontium-89	Water	river	Bq	0,014462	Nitrogen oxides	Air	low. pop.	kg	0,017732
Strontium	Water	river	kg	0,000123	Nitrate	Air	low. pop.	kg	1,79E-07
Solved solids	Water	river	kg	-0,00019	Niobium-95	Air	low. pop.	Bq	8,16E-07
Solids, inorganic	Water	river	kg	4,5E-05	Nickel	Air	low. pop.	kg	8,85E-06
Sodium, ion	Water	river	kg	0,018998	Molybdenum	Air	low. pop.	kg	3,76E-08
Sodium formate	Water	river	kg	3,39E-10	Methanol	Air	low. pop.	kg	3,46E-07
Sodium-24	Water	river	Bq	0,006248	Methane, monochloro-, R-40	Air	low. pop.	kg	2,41E-10
Silver, ion	Water	river	kg	6,07E-08	Methane, fossil	Air	low. pop.	kg	0,033208
Silver-110	Water	river	Bq	0,701006	Methane, dichlorodifluoro-, CFC-12	Air	low. pop.	kg	2,93E-10
Silicon	Water	river	kg	-2E-05	Methane, dichloro-, HCC-30	Air	low. pop.	kg	1,32E-10
Selenium	Water	river	kg	-4E-07	Methane, chlorodifluoro-, HCFC-22	Air	low. pop.	kg	7,99E-07
Scandium	Water	river	kg	9,15E-08	Methane, bromotrifluoro-, Halon 1301	Air	low. pop.	kg	5,45E-08

Ruthenium-103	Water	river	Bq	0,000174	Methane, bromochlorodifluoro-, Halon 1211	Air	low. pop.	kg	2,21E-07
Rubidium	Water	river	kg	6,77E-07	Methane, biogenic	Air	low. pop.	kg	0,000147
Radium-228	Water	river	Bq	6,766709	Mercury	Air	low. pop.	kg	2,19E-07
Radium-226	Water	river	Bq	212,5597	Manganese-54	Air	low. pop.	Bq	6,88E-06
Radium-224	Water	river	Bq	3,383327	Manganese	Air	low. pop.	kg	1,84E-06
Radioactive species, Nuclides, unspecified	Water	river	Bq	0,40805	Magnesium	Air	low. pop.	kg	2,03E-07
Radioactive species, alpha emitters	Water	river	Bq	0,000371	Lead-210	Air	low. pop.	Bq	1,342612
Protactinium-234	Water	river	Bq	0,332244	Lead	Air	low. pop.	kg	1,05E-05
Propylene oxide	Water	river	kg	1,55E-08	Lanthanum-140	Air	low. pop.	Bq	7,39E-05
Propylamine	Water	river	kg	1,07E-12	Krypton-89	Air	low. pop.	Bq	1,559302
Propionic acid	Water	river	kg	7,98E-13	Krypton-88	Air	low. pop.	Bq	3,686242
Propene	Water	river	kg	2,02E-07	Krypton-87	Air	low. pop.	Bq	2,8037
Propanal	Water	river	kg	2,67E-12	Krypton-85m	Air	low. pop.	Bq	12,49234
Potassium, ion	Water	river	kg	-0,00119	Krypton-85	Air	low. pop.	Bq	5,764139
Potassium-40	Water	river	Bq	0,999193	Isoprene	Air	low. pop.	kg	2,07E-10
Polonium-210	Water	river	Bq	0,795954	Iron	Air	low. pop.	kg	2,41E-07
Phosphorus	Water	river	kg	-5,6E-07	Iodine-135	Air	low. pop.	Bq	0,000249
Phosphate	Water	river	kg	-6,1E-06	Iodine-133	Air	low. pop.	Bq	0,001148
Phenol	Water	river	kg	-1,5E-05	Iodine-131	Air	low. pop.	Bq	0,487817
PAH, polycyclic aromatic hydrocarbons	Water	river	kg	3,29E-07	Iodine-129	Air	low. pop.	Bq	0,125646
Oils, unspecified	Water	river	kg	0,005759	Iodine	Air	low. pop.	kg	4,44E-06
Nitrogen, organic bound	Water	river	kg	2,32E-05	Hydrogen sulfide	Air	low. pop.	kg	9,56E-05
Nitrogen	Water	river	kg	0,000426	Hydrogen fluoride	Air	low. pop.	kg	0,000148
Nitrobenzene	Water	river	kg	2,27E-11	Hydrogen chloride	Air	low. pop.	kg	0,000391
Nitrite	Water	river	kg	3,66E-08	Hydrogen-3, Tritium	Air	low. pop.	Bq	682,4431
Nitrate	Water	river	kg	6,94E-05	Hydrocarbons, chlorinated	Air	low. pop.	kg	9,23E-11
Niobium-95	Water	river	Bq	0,003632	Hydrocarbons, aromatic	Air	low. pop.	kg	8,56E-06
Nickel, ion	Water	river	kg	-3,1E-07	Hydrocarbons, aliphatic, unsaturated	Air	low. pop.	kg	1,26E-05

Molybdenum-99	Water	river	Bq	0,000826	Hydrocarbons, aliphatic, alkanes, unspecified	Air	low. pop.	kg	2,91E-05
Molybdenum	Water	river	kg	-8,9E-07	Hydrocarbons, aliphatic, alkanes, cyclic	Air	low. pop.	kg	2,63E-10
Methyl formate	Water	river	kg	2,54E-13	Hexane	Air	low. pop.	kg	1,26E-06
Methyl amine	Water	river	kg	1,1E-12	Helium	Air	low. pop.	kg	3,87E-06
Methyl acrylate	Water	river	kg	1,34E-09	Heat, waste	Air	low. pop.	MJ	64,559
Methyl acetate	Water	river	kg	2,3E-14	Furan	Air	low. pop.	kg	4,46E-09
Methanol	Water	river	kg	3,91E-09	Formic acid	Air	low. pop.	kg	1,57E-08
Methane, dichloro-, HCC-30	Water	river	kg	1,93E-06	Formaldehyde	Air	low. pop.	kg	3,42E-06
Mercury	Water	river	kg	8,19E-09	Fluorine	Air	low. pop.	kg	3,67E-07
Manganese-54	Water	river	Bq	0,049654	Ethyne	Air	low. pop.	kg	5,36E-08
Manganese	Water	river	kg	6,33E-06	Ethylene oxide	Air	low. pop.	kg	6,49E-13
Magnesium	Water	river	kg	0,000529	Ethene, tetrachloro-	Air	low. pop.	kg	1,95E-11
m-Xylene	Water	river	kg	3,62E-12	Ethene	Air	low. pop.	kg	1,54E-06
Lithium, ion	Water	river	kg	6,42E-11	Ethanol	Air	low. pop.	kg	1,18E-08
Lead-210	Water	river	Bq	0,795954	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	low. pop.	kg	4,01E-08
Lead	Water	river	kg	1,56E-06	Ethane, 1,2-dichloro-	Air	low. pop.	kg	1,82E-11
Lanthanum-140	Water	river	Bq	0,002395	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	low. pop.	kg	2,08E-09
Lactic acid	Water	river	kg	2,24E-12	Ethane, 1,1,1-trichloro-, HCFC-140	Air	low. pop.	kg	9,09E-12
Isopropylamine	Water	river	kg	2,75E-13	Ethane	Air	low. pop.	kg	0,000993
Iron, ion	Water	river	kg	2,94E-05	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	low. pop.	kg	7,77E-13
Iron-59	Water	river	Bq	0,000388	Dinitrogen monoxide	Air	low. pop.	kg	0,000134
Iodine-133	Water	river	Bq	0,001412	Cyanide	Air	low. pop.	kg	1,17E-07
Iodine-131	Water	river	Bq	0,010384	Cumene	Air	low. pop.	kg	2,48E-12
Iodide	Water	river	kg	6,82E-06	Copper	Air	low. pop.	kg	1,16E-05
Hypochlorite	Water	river	kg	1,69E-05	Cobalt-60	Air	low. pop.	Bq	0,000165
Hydroxide	Water	river	kg	6,22E-09	Cobalt-	Air	low. pop.	Bq	1,87E-05

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Hydrogen sulfide	Water	river	kg	1,55E-07	Cobalt	Air	low. pop.	kg	1,2E-07
Hydrogen peroxide	Water	river	kg	-1,4E-09	Chromium VI	Air	low. pop.	kg	7,71E-08
Hydrogen-3, Tritium	Water	river	Bq	5107,424	Chromium-51	Air	low. pop.	Bq	1,34E-05
Hydrocarbons, unspecified	Water	river	kg	-0,00015	Chromium	Air	low. pop.	kg	2,49E-06
Hydrocarbons, aromatic	Water	river	kg	3,56E-05	Chloroform	Air	low. pop.	kg	4,46E-11
Hydrocarbons, aliphatic, unsaturated	Water	river	kg	8,12E-07	Chlorine	Air	low. pop.	kg	1,73E-08
Hydrocarbons, aliphatic, alkanes, unspecified	Water	river	kg	8,8E-06	Cesium-137	Air	low. pop.	Bq	0,000178
Heat, waste	Water	river	MJ	23,26309	Cesium-134	Air	low. pop.	Bq	1E-05
Formic acid	Water	river	kg	9,77E-13	Cerium-141	Air	low. pop.	Bq	0,00021
Formate	Water	river	kg	8,61E-11	Carbon monoxide, fossil	Air	low. pop.	kg	0,002923
Formamide	Water	river	kg	3,37E-12	Carbon monoxide, biogenic	Air	low. pop.	kg	7,05E-05
Formaldehyde	Water	river	kg	1,57E-09	Carbon disulfide	Air	low. pop.	kg	8,13E-05
Fluosilicic acid	Water	river	kg	1,25E-07	Carbon dioxide, land transformation	Air	low. pop.	kg	6,86E-05
Fluoride	Water	river	kg	-0,00019	Carbon dioxide, fossil	Air	low. pop.	kg	6,36252
Ethylene oxide	Water	river	kg	1,01E-10	Carbon dioxide, biogenic	Air	low. pop.	kg	0,119723
Ethylene diamine	Water	river	kg	4,5E-11	Carbon-14	Air	low. pop.	Bq	147,1805
Ethylamine	Water	river	kg	2,39E-12	Calcium	Air	low. pop.	kg	8,76E-08
Ethyl acetate	Water	river	kg	4,87E-12	Cadmium	Air	low. pop.	kg	1,21E-06
Ethene, chloro-	Water	river	kg	9,46E-09	Butane	Air	low. pop.	kg	3,79E-05
Ethene	Water	river	kg	1,81E-07	Butadiene	Air	low. pop.	kg	6,72E-14
Ethanol	Water	river	kg	1,02E-09	Bromine	Air	low. pop.	kg	8,9E-06
Ethane, 1,2-dichloro-	Water	river	kg	1,11E-08	Boron	Air	low. pop.	kg	4,4E-05
DOC, Dissolved Organic Carbon	Water	river	kg	0,005473	Beryllium	Air	low. pop.	kg	1,14E-09
Dipropylamine	Water	river	kg	2,85E-12	Benzo(a)pyrene	Air	low. pop.	kg	2,08E-07
Dimethylamine	Water	river	kg	3,69E-12	Benzene, ethyl-	Air	low. pop.	kg	4,28E-11
Diethylamine	Water	river	kg	4,53E-12	Benzene	Air	low. pop.	kg	4,48E-05
Dichromate	Water	river	kg	1,13E-06	Barium-140	Air	low. pop.	Bq	0,000864
Cyanide	Water	river	kg	3,37E-06	Barium	Air	low. pop.	kg	1,8E-06
Cumene	Water	river	kg	4,92E-07	Arsenic	Air	low. pop.	kg	3,69E-06
Copper, ion	Water	river	kg	-2,1E-06	Argon-41	Air	low. pop.	Bq	1,645646
COD, Chemical Oxygen	Water	river	kg	0,01661	Antimony-125	Air	low. pop.	Bq	1,33E-05

Demand									
Cobalt-60	Water	river	Bq	0,713642	Antimony -124	Air	low. pop.	Bq	1,27E-06
Cobalt-58	Water	river	Bq	0,825361	Antimony	Air	low. pop.	kg	4,86E-07
Cobalt-57	Water	river	Bq	0,005065	Ammonia	Air	low. pop.	kg	8,71E-05
Cobalt	Water	river	kg	-4E-06	Aluminium	Air	low. pop.	kg	5,48E-07
Chromium, ion	Water	river	kg	4,76E-07	Aldehydes, unspecified	Air	low. pop.	kg	5,89E-08
Chromium VI	Water	river	kg	-1,1E-05	Aerosols, radioactive, unspecified	Air	low. pop.	Bq	0,028213
Chromium-51	Water	river	Bq	0,173268	Actinides, radioactive, unspecified	Air	low. pop.	Bq	0,000942
Chlorosulfonic acid	Water	river	kg	7,18E-13	Acrolein	Air	low. pop.	kg	1,51E-09
Chloroform	Water	river	kg	8,8E-12	Acetonitrile	Air	low. pop.	kg	2,35E-09
Chloroacetyl chloride	Water	river	kg	9,29E-14	Acetone	Air	low. pop.	kg	1,13E-06
Chloroacetic acid	Water	river	kg	4,24E-09	Acetic acid	Air	low. pop.	kg	5,62E-08
Chlorine	Water	river	kg	8,58E-08	Acetaldehyde	Air	low. pop.	kg	8,55E-09
Chlorinated solvents, unspecified	Water	river	kg	-5E-08	Acenaphthene	Air	low. pop.	kg	2,32E-13
Chloride	Water	river	kg	0,03501	Zinc	Air	high. pop.	kg	1,67E-06
Chlorate	Water	river	kg	-6,1E-06	Xylene	Air	high. pop.	kg	8,49E-06
Chloramine	Water	river	kg	2,45E-11	Water	Air	high. pop.	kg	2,3E-08
Cesium-137	Water	river	Bq	0,308592	Vanadium	Air	high. pop.	kg	5,68E-05
Cesium-136	Water	river	Bq	0,00016	Uranium-238	Air	high. pop.	Bq	0,002581
Cesium-134	Water	river	Bq	0,025409	Uranium	Air	high. pop.	kg	6,52E-10
Cesium	Water	river	kg	6,77E-08	Trimethylamine	Air	high. pop.	kg	1,7E-14
Cerium-144	Water	river	Bq	0,000274	Toluene, 2-chloro-	Air	high. pop.	kg	1,72E-12
Cerium-141	Water	river	Bq	0,000899	Toluene	Air	high. pop.	kg	1,39E-05
Carboxylic acids, unspecified	Water	river	kg	0,000249	Titanium	Air	high. pop.	kg	9,95E-08
Carbonate	Water	river	kg	-0,00032	Tin	Air	high. pop.	kg	1,16E-09
Carbon disulfide	Water	river	kg	8,8E-11	Thorium-232	Air	high. pop.	Bq	0,000903
Calcium, ion	Water	river	kg	0,003431	Thorium-228	Air	high. pop.	Bq	0,001419
Cadmium, ion	Water	river	kg	3,94E-08	Thorium	Air	high. pop.	kg	4,9E-10
Butyrolactone	Water	river	kg	9,66E-13	Thallium	Air	high. pop.	kg	4,12E-10
Butyl acetate	Water	river	kg	5,36E-10	t-Butylamine	Air	high. pop.	kg	2,79E-13
Butene	Water	river	kg	1,21E-09	t-Butyl methyl ether	Air	high. pop.	kg	1,47E-09
Bromine	Water	river	kg	-3,1E-05	Sulfuric acid	Air	high. pop.	kg	1,3E-10

Bromide	Water	river	kg	8,21E-09	Sulfur trioxide	Air	high. pop.	kg	4,57E-11
Bromate	Water	river	kg	-7,3E-07	Sulfur dioxide	Air	high. pop.	kg	-0,0107
Boron	Water	river	kg	5,94E-06	Sulfate	Air	high. pop.	kg	2,82E-05
Borate	Water	river	kg	1,42E-10	Styrene	Air	high. pop.	kg	2,38E-09
BOD5, Biological Oxygen Demand	Water	river	kg	0,018325	Strontium	Air	high. pop.	kg	4,9E-08
Beryllium	Water	river	kg	1,06E-09	Sodium hydroxide	Air	high. pop.	kg	6,1E-10
Benzene, ethyl-	Water	river	kg	1,62E-06	Sodium formate	Air	high. pop.	kg	1,41E-10
Benzene, chloro-	Water	river	kg	4,03E-09	Sodium dichromate	Air	high. pop.	kg	3,03E-07
Benzene, 1,2-dichloro-	Water	river	kg	2E-10	Sodium chlorate	Air	high. pop.	kg	4,65E-09
Benzene	Water	river	kg	4,55E-06	Sodium	Air	high. pop.	kg	1,84E-05
Barium-140	Water	river	Bq	0,002249	Silver	Air	high. pop.	kg	2,92E-10
Barium	Water	river	kg	5,92E-05	Silicon	Air	high. pop.	kg	-7,1E-06
Arsenic, ion	Water	river	kg	-1,5E-06	Selenium	Air	high. pop.	kg	2,99E-07
AOX, Adsorbable Organic Halogen as Cl	Water	river	kg	3,99E-07	Scandium	Air	high. pop.	kg	3,25E-10
Antimony-125	Water	river	Bq	0,044672	Radon-222	Air	high. pop.	Bq	0,000259
Antimony-124	Water	river	Bq	0,049227	Radon-220	Air	high. pop.	Bq	0,000259
Antimony-122	Water	river	Bq	0,000513	Radium-228	Air	high. pop.	Bq	0,016772
Antimony	Water	river	kg	-4E-05	Radium-226	Air	high. pop.	Bq	0,003097
Aniline	Water	river	kg	1,01E-11	Radioactive species, other beta emitters	Air	high. pop.	Bq	0,298223
Ammonium, ion	Water	river	kg	-2E-05	Propylene oxide	Air	high. pop.	kg	6,46E-09
Aluminium	Water	river	kg	1,66E-05	Propylamine	Air	high. pop.	kg	4,44E-13
Acrylate, ion	Water	river	kg	1,43E-10	Propionic acid	Air	high. pop.	kg	2,59E-06
Acidity, unspecified	Water	river	kg	-2,1E-05	Propene	Air	high. pop.	kg	-8,7E-06
Acetyl chloride	Water	river	kg	1,45E-12	Propane	Air	high. pop.	kg	0,000205
Acetonitrile	Water	river	kg	1,97E-13	Propanal	Air	high. pop.	kg	-1,8E-09
Acetone	Water	river	kg	2,14E-11	Potassium-40	Air	high. pop.	Bq	0,003484
Acetic acid	Water	river	kg	5,07E-08	Potassium	Air	high. pop.	kg	2,39E-05
Acetaldehyde	Water	river	kg	8,72E-10	Polychlorinated biphenyls	Air	high. pop.	kg	2,19E-15
Acenaphthylene	Water	river	kg	2,63E-11	Polonium-210	Air	high. pop.	Bq	0,021938
Acenaphthene	Water	river	kg	4,21E-10	Platinum	Air	high. pop.	kg	4,34E-13
2-Propanol	Water	river	kg	6,36E-13	Phosphorus	Air	high. pop.	kg	2,18E-07
2-Methyl-2-butene	Water	river	kg	3,09E-16	Phosphine	Air	high. pop.	kg	5,21E-14

2-Methyl-1-propanol	Water	river	kg	3,35E-12	Phenol, pentachloro-	Air	high. pop.	kg	4,41E-12
2-Aminopropanol	Water	river	kg	6,97E-14	Phenol, 2,4-dichloro-	Air	high. pop.	kg	2,67E-13
1,4-Butanediol	Water	river	kg	7,52E-13	Phenol	Air	high. pop.	kg	8,6E-09
1-Propanol	Water	river	kg	2,74E-12	Pentane	Air	high. pop.	kg	0,0003
1-Pentene	Water	river	kg	1,39E-12	Particulates, > 2.5 um, and < 10um	Air	high. pop.	kg	-0,00267
1-Pentanol	Water	river	kg	1,84E-12	Particulates, > 10 um	Air	high. pop.	kg	-0,00192
1-Butanol	Water	river	kg	4,12E-10	Particulates, < 2.5 um	Air	high. pop.	kg	-0,001
Zinc, ion	Water	lake	kg	7,73E-15	PAH, polycyclic aromatic hydrocarbons	Air	high. pop.	kg	1,4E-06
Nickel, ion	Water	lake	kg	1,07E-14	Ozone	Air	high. pop.	kg	5,48E-09
Mercury	Water	lake	kg	6,79E-17	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	high. pop.	kg	-0,04657
Lead	Water	lake	kg	7,85E-15	Nitrogen oxides	Air	high. pop.	kg	-0,00923
DOC, Dissolved Organic Carbon	Water	lake	kg	7,78E-09	Nitrobenzene	Air	high. pop.	kg	5,67E-12
Copper, ion	Water	lake	kg	1,2E-13	Nitrate	Air	high. pop.	kg	3,76E-08
Calcium, ion	Water	lake	kg	2,9E-07	Nickel	Air	high. pop.	kg	1,58E-05
Cadmium, ion	Water	lake	kg	2,65E-15	Monoethanolamine	Air	high. pop.	kg	1,75E-08
Arsenic, ion	Water	lake	kg	3,12E-15	Molybdenum	Air	high. pop.	kg	4,46E-07
Zinc, ion	Water	groundwater, long-term	kg	0,001202	Methyl lactate	Air	high. pop.	kg	1,02E-12
Vanadium, ion	Water	groundwater, long-term	kg	3,36E-05	Methyl formate	Air	high. pop.	kg	6,35E-13
Tungsten	Water	groundwater, long-term	kg	2,13E-05	Methyl ethyl ketone	Air	high. pop.	kg	1,14E-07
TOC, Total Organic Carbon	Water	groundwater, long-term	kg	-0,00583	Methyl borate	Air	high. pop.	kg	2,86E-13
Titanium, ion	Water	groundwater, long-term	kg	0,000202	Methyl amine	Air	high. pop.	kg	4,59E-13
Tin, ion	Water	groundwater, long-term	kg	1,02E-05	Methyl acrylate	Air	high. pop.	kg	6,84E-11
Thallium	Water	groundwater, long-term	kg	1,81E-06	Methyl acetate	Air	high. pop.	kg	9,56E-15
Sulfate	Water	groundwater, long-	kg	0,443213	Methanol	Air	high. pop.	kg	2,89E-05

		term							
Strontium	Water	groundwater, long-term	kg	0,001856	Methane sulfonic acid	Air	high. pop.	kg	2,38E-13
Sodium, ion	Water	groundwater, long-term	kg	0,049889	Methane, trifluoro-, HFC-23	Air	high. pop.	kg	1,4E-11
Silver, ion	Water	groundwater, long-term	kg	8,91E-07	Methane, trichlorofluoro-, CFC-11	Air	high. pop.	kg	7,12E-14
Silicon	Water	groundwater, long-term	kg	0,043775	Methane, tetrafluoro-, CFC-14	Air	high. pop.	kg	9,37E-11
Selenium	Water	groundwater, long-term	kg	2,52E-05	Methane, tetrachloro-, CFC-10	Air	high. pop.	kg	2,99E-09
Scandium	Water	groundwater, long-term	kg	1,64E-05	Methane, monochloro-, R-40	Air	high. pop.	kg	2,93E-12
Potassium, ion	Water	groundwater, long-term	kg	0,035577	Methane, fossil	Air	high. pop.	kg	-0,15436
Phosphate	Water	groundwater, long-term	kg	0,015586	Methane, dichlorofluoro-, HCFC-21	Air	high. pop.	kg	4,39E-14
Nitrogen, organic bound	Water	groundwater, long-term	kg	1,98E-06	Methane, dichlorodifluoro-, CFC-12	Air	high. pop.	kg	7,25E-11
Nitrite	Water	groundwater, long-term	kg	6,6E-08	Methane, dichloro-, HCC-30	Air	high. pop.	kg	4,5E-10
Nitrate	Water	groundwater, long-term	kg	0,004954	Methane, chlorodifluoro-, HCFC-22	Air	high. pop.	kg	2,62E-10
Nickel, ion	Water	groundwater, long-term	kg	0,000455	Methane, bromotrifluoro-, Halon 1301	Air	high. pop.	kg	8,84E-15
Molybdenum	Water	groundwater, long-term	kg	3,66E-05	Methane, biogenic	Air	high. pop.	kg	-0,00108
Mercury	Water	groundwater, long-term	kg	9,21E-07	Mercury	Air	high. pop.	kg	-8,6E-09
Manganese	Water	groundwater, long-term	kg	0,005445	Manganese	Air	high. pop.	kg	7,83E-07
Magnesium	Water	groundwater, long-term	kg	0,061977	Magnesium	Air	high. pop.	kg	1,25E-06
Lead	Water	groundwater, long-term	kg	2,82E-06	m-Xylene	Air	high. pop.	kg	1,22E-07
Iron, ion	Water	groundwater, long-term	kg	0,014904	Lead-210	Air	high. pop.	Bq	0,012001
Iodide	Water	groundwater, long-term	kg	4,54E-12	Lead	Air	high. pop.	kg	2E-06
Hydrogen	Water	groundwat	kg	7,62E-06	Lactic	Air	high. pop.	kg	9,32E-13

sulfide		er, long-term			acid				
Heat, waste	Water	groundwater, long-term	MJ	0,023248	Isopropyl amine	Air	high. pop.	kg	1,15E-13
Fluoride	Water	groundwater, long-term	kg	0,001219	Isocyanic acid	Air	high. pop.	kg	4,18E-08
DOC, Dissolved Organic Carbon	Water	groundwater, long-term	kg	-0,00583	Iron	Air	high. pop.	kg	5,12E-06
Copper, ion	Water	groundwater, long-term	kg	0,000115	Iodine	Air	high. pop.	kg	2,94E-09
COD, Chemical Oxygen Demand	Water	groundwater, long-term	kg	-0,01492	Hydrogen sulfide	Air	high. pop.	kg	-5,5E-08
Cobalt	Water	groundwater, long-term	kg	0,00014	Hydrogen peroxide	Air	high. pop.	kg	1,66E-10
Chromium VI	Water	groundwater, long-term	kg	7,03E-06	Hydrogen fluoride	Air	high. pop.	kg	-1,8E-05
Chloride	Water	groundwater, long-term	kg	0,010856	Hydrogen chloride	Air	high. pop.	kg	-0,00067
Calcium, ion	Water	groundwater, long-term	kg	0,111485	Hydrogen	Air	high. pop.	kg	-0,00045
Cadmium, ion	Water	groundwater, long-term	kg	1,77E-05	Hydrocarbons, chlorinated	Air	high. pop.	kg	-8,8E-09
Bromine	Water	groundwater, long-term	kg	-1,9E-05	Hydrocarbons, aromatic	Air	high. pop.	kg	-0,00094
Boron	Water	groundwater, long-term	kg	0,000619	Hydrocarbons, aliphatic, unsaturated	Air	high. pop.	kg	6,09E-06
BOD5, Biological Oxygen Demand	Water	groundwater, long-term	kg	-0,00508	Hydrocarbons, aliphatic, alkanes, unspecified	Air	high. pop.	kg	5,97E-05
Beryllium	Water	groundwater, long-term	kg	1,03E-05	Hydrocarbons, aliphatic, alkanes, cyclic	Air	high. pop.	kg	4,28E-09
Barium	Water	groundwater, long-term	kg	0,000164	Hexane	Air	high. pop.	kg	0,000172
Arsenic, ion	Water	groundwater, long-term	kg	4,4E-05	Heptane	Air	high. pop.	kg	2,1E-05
Antimony	Water	groundwater, long-term	kg	-6,3E-05	Heat, waste	Air	high. pop.	MJ	-85,485
Ammonium, ion	Water	groundwater, long-term	kg	1,21E-06	Formic acid	Air	high. pop.	kg	1,35E-10
Aluminium	Water	groundwater, long-term	kg	0,003793	Formamide	Air	high. pop.	kg	1,4E-12
Zinc, ion	Water	groundwater	kg	2,6E-06	Formaldehyde	Air	high. pop.	kg	4,8E-05

Vanadium, ion	Water	groundwater	kg	1,43E-07	Fluosilicic acid	Air	high. pop.	kg	6,94E-08
Uranium-238	Water	groundwater	Bq	4,75E-05	Fluorine	Air	high. pop.	kg	5,08E-08
Tungsten	Water	groundwater	kg	4,13E-07	Ethyne	Air	high. pop.	kg	1,26E-07
Titanium, ion	Water	groundwater	kg	1,25E-07	Ethylene oxide	Air	high. pop.	kg	2,83E-09
Tin, ion	Water	groundwater	kg	2,45E-08	Ethylene diamine	Air	high. pop.	kg	1,87E-11
Thorium-228	Water	groundwater	Bq	1,13E-06	Ethylamine	Air	high. pop.	kg	9,95E-13
Thallium	Water	groundwater	kg	3,04E-09	Ethyl cellulose	Air	high. pop.	kg	2,19E-10
Sulfate	Water	groundwater	kg	0,025423	Ethyl acetate	Air	high. pop.	kg	1,14E-07
Strontium	Water	groundwater	kg	2,81E-05	Ethene, tetrachloro-	Air	high. pop.	kg	1,54E-12
Solved solids	Water	groundwater	kg	0,000508	Ethene, chloro-	Air	high. pop.	kg	7,04E-07
Solids, inorganic	Water	groundwater	kg	0,002416	Ethene	Air	high. pop.	kg	-1,2E-05
Sodium, ion	Water	groundwater	kg	0,00045	Ethanol	Air	high. pop.	kg	2,82E-05
Silver, ion	Water	groundwater	kg	1,54E-08	Ethane, hexafluoro-, HFC-116	Air	high. pop.	kg	2,42E-10
Silicon	Water	groundwater	kg	0,000155	Ethane, 1,2-dichloro-	Air	high. pop.	kg	1,01E-06
Selenium	Water	groundwater	kg	2,71E-07	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	Air	high. pop.	kg	2,86E-12
Scandium	Water	groundwater	kg	9,37E-08	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	high. pop.	kg	1,54E-11
Radium-226	Water	groundwater	Bq	0,000104	Ethane, 1,1-difluoro-, HFC-152a	Air	high. pop.	kg	1,82E-09
Potassium, ion	Water	groundwater	kg	0,000186	Ethane	Air	high. pop.	kg	0,000242
Potassium-40	Water	groundwater	Bq	1,12E-05	Dipropylamine	Air	high. pop.	kg	1,19E-12
Polonium-210	Water	groundwater	Bq	0,000141	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	high. pop.	kg	3,25E-13
Phosphorus	Water	groundwater	kg	3,78E-10	Dinitrogen monoxide	Air	high. pop.	kg	0,00041
Phosphate	Water	groundwater	kg	0,003181	Dimethyl malonate	Air	high. pop.	kg	2,96E-13
Nitrate	Water	groundwater	kg	0,000115	Diethylamine	Air	high. pop.	kg	1,89E-12
Nickel, ion	Water	groundwater	kg	1,38E-06	Cyanoacetic acid	Air	high. pop.	kg	2,36E-13
Molybdenum	Water	groundwater	kg	2,38E-06	Cyanide	Air	high. pop.	kg	-4,2E-07

Mercury	Water	groundwater	kg	3,42E-09	Cumene	Air	high. pop.	kg	2,05E-07
Manganese	Water	groundwater	kg	3,51E-05	Copper	Air	high. pop.	kg	2,76E-06
Magnesium	Water	groundwater	kg	0,000669	Cobalt	Air	high. pop.	kg	1,97E-06
Lead-210	Water	groundwater	Bq	9,26E-05	Chromium VI	Air	high. pop.	kg	1,75E-08
Lead	Water	groundwater	kg	2,38E-08	Chromium	Air	high. pop.	kg	6,58E-07
Iron, ion	Water	groundwater	kg	0,001055	Chlorosulfonic acid	Air	high. pop.	kg	2,88E-13
Iodide	Water	groundwater	kg	6,04E-08	Chlorosilane, trimethyl-	Air	high. pop.	kg	1,37E-10
Fluoride	Water	groundwater	kg	1,48E-05	Chloroform	Air	high. pop.	kg	1,83E-09
Copper, ion	Water	groundwater	kg	3,04E-07	Chloroacetic acid	Air	high. pop.	kg	8,06E-11
COD, Chemical Oxygen Demand	Water	groundwater	kg	4,73E-07	Chlorine	Air	high. pop.	kg	1,08E-06
Cobalt	Water	groundwater	kg	2,75E-07	Chloramine	Air	high. pop.	kg	2,74E-12
Chromium, ion	Water	groundwater	kg	1,24E-09	Carbon monoxide, fossil	Air	high. pop.	kg	-0,13309
Chromium VI	Water	groundwater	kg	7,04E-07	Carbon monoxide, biogenic	Air	high. pop.	kg	-0,00093
Chloride	Water	groundwater	kg	0,019855	Carbon disulfide	Air	high. pop.	kg	-1,2E-10
Calcium, ion	Water	groundwater	kg	0,001762	Carbon dioxide, fossil	Air	high. pop.	kg	-1,86343
Cadmium, ion	Water	groundwater	kg	5,05E-08	Carbon dioxide, biogenic	Air	high. pop.	kg	-0,02027
Bromine	Water	groundwater	kg	4,8E-07	Calcium	Air	high. pop.	kg	7,65E-06
Boron	Water	groundwater	kg	5,76E-05	Cadmium	Air	high. pop.	kg	2,3E-07
BOD5, Biological Oxygen Demand	Water	groundwater	kg	4,73E-07	Butyrolactone	Air	high. pop.	kg	4,02E-13
Beryllium	Water	groundwater	kg	2,94E-08	Butene	Air	high. pop.	kg	2,1E-06
Barium	Water	groundwater	kg	2,19E-07	Butane	Air	high. pop.	kg	0,00024
Arsenic, ion	Water	groundwater	kg	1,51E-06	Butadiene	Air	high. pop.	kg	4,94E-13
Antimony	Water	groundwater	kg	4,39E-07	Bromine	Air	high. pop.	kg	6,3E-08
Ammonium, ion	Water	groundwater	kg	2,36E-06	Boron trifluoride	Air	high. pop.	kg	9,62E-18
Aluminium	Water	groundwater	kg	1,13E-05	Boron	Air	high. pop.	kg	1,33E-07
Zinc, ion	Water		kg	2,36E-07	Beryllium	Air	high. pop.	kg	3,27E-09
Xylene	Water		kg	1,01E-10	Benzo(a)pyrene	Air	high. pop.	kg	1,42E-09
Vanadium, ion	Water		kg	3,42E-12	Benzene, pentachloro-	Air	high. pop.	kg	-3,5E-11
Toluene	Water		kg	1,99E-10	Benzene, hexachloro-	Air	high. pop	kg	-1,4E-11

TOC, Total Organic Carbon	Water	kg	1,7E-06	Benzene, ethyl-	Air	high. pop.	kg	2,14E-06
Titanium, ion	Water	kg	2,17E-11	Benzene, 1,2-dichloro-	Air	high. pop.	kg	2E-12
Tin, ion	Water	kg	1,38E-11	Benzene, 1-methyl-2-nitro-	Air	high. pop.	kg	3,57E-14
Thallium	Water	kg	2,99E-13	Benzene	Air	high. pop.	kg	1,39E-05
Suspended solids, unspecified	Water	kg	1,51E-05	Benzaldehyde	Air	high. pop.	kg	-1,8E-09
Sulfur	Water	kg	3,33E-10	Barium	Air	high. pop.	kg	3,17E-08
Sulfate	Water	kg	1,57E-07	Arsine	Air	high. pop.	kg	7,03E-16
Strontium	Water	kg	6,86E-09	Arsenic	Air	high. pop.	kg	3,91E-07
Solved solids	Water	kg	5,59E-06	Antimony	Air	high. pop.	kg	3,21E-10
Sodium, ion	Water	kg	3,14E-05	Anthranilic acid	Air	high. pop.	kg	3,01E-14
Silver, ion	Water	kg	2,64E-10	Aniline	Air	high. pop.	kg	4,22E-12
Selenium	Water	kg	2,79E-13	Ammonium carbonate	Air	high. pop.	kg	5,32E-08
Radium-228	Water	Bq	0,000234	Ammonia	Air	high. pop.	kg	1,38E-05
Radium-226	Water	Bq	0,000166	Aluminium	Air	high. pop.	kg	2,43E-06
Phosphorus	Water	kg	3,22E-09	Aldehydes, unspecified	Air	high. pop.	kg	6,1E-08
Phenol	Water	kg	3,27E-09	Acrylic acid	Air	high. pop.	kg	6,03E-11
Oils, unspecified	Water	kg	4,67E-06	Acrolein	Air	high. pop.	kg	-3,4E-09
o-Xylene	Water	kg	2,77E-12	Acetone	Air	high. pop.	kg	1,38E-05
Nickel, ion	Water	kg	1,08E-07	Acetic acid	Air	high. pop.	kg	7,61E-05
Molybdenum	Water	kg	2,89E-12	Acetaldehyde	Air	high. pop.	kg	1,4E-05
Methanol	Water	kg	9,65E-09	Acenaphthene	Air	high. pop.	kg	1,27E-10
Mercury	Water	kg	3,3E-09	2-Propanol	Air	high. pop.	kg	2,32E-08
Manganese	Water	kg	5,38E-08	2-Nitrobenzoic acid	Air	high. pop.	kg	4,13E-14
Magnesium	Water	kg	7,89E-08	2-Methyl-1-propanol	Air	high. pop.	kg	1,4E-12
m-Xylene	Water	kg	3,81E-12	2-Butene, 2-methyl-	Air	high. pop.	kg	1,29E-16
Lithium, ion	Water	kg	1,35E-07	2-Aminopropanol	Air	high. pop.	kg	2,79E-14
Lead-210	Water	Bq	3,64E-05	1,4-Butanediol	Air	high. pop.	kg	1,88E-12
Lead	Water	kg	4,09E-08	1-Propanol	Air	high. pop.	kg	7,03E-11
Iron, ion	Water	kg	1,12E-05	1-Pentene	Air	high. pop.	kg	5,8E-13
Hydrocarbons, unspecified	Water	kg	1,66E-07	1-Pentanol	Air	high. pop.	kg	7,67E-13
Heat, waste	Water	MJ	0,000607	1-Butanol	Air	high. pop.	kg	9,2E-14
Formaldehyde	Water	kg	3,22E-08	Zinc	Air		kg	7,09E-07

Fluoride	Water		kg	1,68E-07	Xylene	Air		kg	1,65E-07
DOC, Dissolved Organic Carbon	Water		kg	1,7E-06	Water	Air		kg	0,001259
Cyanide	Water		kg	6,66E-08	Vanadium	Air		kg	3,18E-09
Copper, ion	Water		kg	6,07E-08	Uranium-238	Air		Bq	1,38E-10
COD, Chemical Oxygen Demand	Water		kg	1,41E-05	Toluene	Air		kg	1,78E-07
Cobalt	Water		kg	2,79E-12	Titanium	Air		kg	1,14E-09
Chromium, ion	Water		kg	4,76E-08	Tin	Air		kg	3,61E-09
Chromium VI	Water		kg	9,29E-09	Thorium-232	Air		Bq	4,15E-11
Chloride	Water		kg	2,77E-05	Thorium-228	Air		Bq	2,64E-11
Calcium, ion	Water		kg	4,04E-07	Thallium	Air		kg	1,24E-10
Cadmium, ion	Water		kg	1,98E-08	Sulfur hexafluoride	Air		kg	3,45E-06
Bromine	Water		kg	2,7E-08	Sulfur dioxide	Air		kg	0,000146
Boron	Water		kg	3,95E-10	Sulfate	Air		kg	1,48E-09
BOD5, Biological Oxygen Demand	Water		kg	1,4E-05	Styrene	Air		kg	3,17E-18
Beryllium	Water		kg	1,26E-12	Strontium	Air		kg	5,85E-16
Benzene, ethyl-	Water		kg	1,19E-11	Sodium	Air		kg	1,54E-11
Benzene	Water		kg	2,11E-10	Silicon	Air		kg	2,7E-13
Barium	Water		kg	3,58E-08	Selenium	Air		kg	2,25E-10
Arsenic, ion	Water		kg	6,69E-09	Radon-222	Air		Bq	1,93E-09
AOX, Adsorbable Organic Halogen as Cl	Water		kg	3,22E-10	Radon-220	Air		Bq	3,45E-09
Antimony	Water		kg	1,42E-12	Radium-228	Air		Bq	4,91E-11
Ammonium, ion	Water		kg	1,55E-09	Radium-226	Air		Bq	1,66E-10
Aluminium	Water		kg	4,54E-08	Propionic acid	Air		kg	2,2E-11
Acidity, unspecified	Water		kg	2,64E-11	Propene	Air		kg	1,14E-12
Acetone	Water		kg	1,26E-12	Propane	Air		kg	9,68E-10
4-Methyl-2-pentanone	Water		kg	5,27E-13	Propanal	Air		kg	4,82E-17
Zinc	Air	stratosphere + troposphere	kg	2,16E-14	Potassium-40	Air		Bq	1,58E-10
Water	Air	stratosphere + troposphere	kg	2,68E-08	Polychlorinated biphenyls	Air		kg	1,07E-09
Sulfur dioxide	Air	stratosphere + troposphere	kg	2,16E-11	Polonium-210	Air		Bq	1,17E-09
Selenium	Air	stratosphere + troposphere	kg	2,16E-16	Phosphorus	Air		kg	1,7E-10
Particulates, < 2.5 um	Air	stratosphere +	kg	8,21E-13	Phenol	Air		kg	1,2E-09

		troposphere							
NMVOC, non-methane volatile organic compounds, unspecified origin	Air	stratosphere + troposphere	kg	1,45E-11	Pentane	Air		kg	1,58E-09
Nitrogen oxides	Air	stratosphere + troposphere	kg	3,02E-10	Particulates, > 2.5 um, and < 10um	Air		kg	2,47E-05
Nickel	Air	stratosphere + troposphere	kg	1,51E-15	Particulates, > 10 um	Air		kg	3,54E-05
Methane, fossil	Air	stratosphere + troposphere	kg	1,08E-12	Particulates, < 2.5 um	Air		kg	0,000124
Mercury	Air	stratosphere + troposphere	kg	1,51E-18	PAH, polycyclic aromatic hydrocarbons	Air		kg	2,75E-07
Lead	Air	stratosphere + troposphere	kg	4,32E-16	Ozone	Air		kg	0,000192
Hydrogen chloride	Air	stratosphere + troposphere	kg	1,86E-14	NMVOC, non-methane volatile organic compounds, unspecified origin	Air		kg	0,000446
Heat, waste	Air	stratosphere + troposphere	MJ	9,85E-07	Nitrogen oxides	Air		kg	0,002768
Formaldehyde	Air	stratosphere + troposphere	kg	3,4E-12	Nickel	Air		kg	4,01E-08
Ethylene oxide	Air	stratosphere + troposphere	kg	3,95E-12	Molybdenum	Air		kg	5,55E-12
Dinitrogen monoxide	Air	stratosphere + troposphere	kg	6,48E-13	Methanol	Air		kg	2,82E-07
Copper	Air	stratosphere + troposphere	kg	3,67E-14	Methane, tetrafluoro-, CFC-14	Air		kg	5,35E-07
Chromium	Air	stratosphere + troposphere	kg	1,08E-15	Methane, tetrachloro-, CFC-10	Air		kg	6,04E-15
Carbon monoxide, fossil	Air	stratosphere + troposphere	kg	7,99E-11	Methane, fossil	Air		kg	4,59E-06
Carbon dioxide, fossil	Air	stratosphere + tropospher	kg	6,8E-08	Methane, dichlorodifluoro-,	Air		kg	1,35E-17

		e			CFC-12				
Cadmium	Air	stratosphere + troposphere	kg	2,16E-16	Methane, bromo-, Halon 1001	Air		kg	2,03E-17
Butadiene	Air	stratosphere + troposphere	kg	4,08E-13	Methane, biogenic	Air		kg	0,000905
Benzene	Air	stratosphere + troposphere	kg	4,31E-13	Mercury	Air		kg	6,48E-08
Water	Air	stratosphere	kg	21,41374	Manganese	Air		kg	8,01E-08
Zinc	Air	low. pop., long-term	kg	3,9E-07	Magnesium	Air		kg	2,61E-12
Vanadium	Air	low. pop., long-term	kg	3,77E-07	Lead-210	Air		Bq	6,42E-10
Tungsten	Air	low. pop., long-term	kg	2,46E-08	Lead	Air		kg	3,26E-07
Titanium	Air	low. pop., long-term	kg	3,97E-06	Isoprene	Air		kg	1,44E-17
Tin	Air	low. pop., long-term	kg	1,27E-08	Iron	Air		kg	4,23E-07
Sulfate	Air	low. pop., long-term	kg	5,6E-05	Iodine	Air		kg	1,55E-15
Strontium	Air	low. pop., long-term	kg	2,21E-07	Hydrogen sulfide	Air		kg	2,36E-05
Sodium	Air	low. pop., long-term	kg	3,57E-06	Hydrogen fluoride	Air		kg	2,14E-06
Silver	Air	low. pop., long-term	kg	9,1E-09	Hydrogen chloride	Air		kg	5,53E-06
Silicon	Air	low. pop., long-term	kg	1,35E-05	Hydrogen	Air		kg	3,32E-08
Selenium	Air	low. pop., long-term	kg	3,04E-08	Hydrocarbons, chlorinated	Air		kg	2,38E-08
Scandium	Air	low. pop., long-term	kg	2,18E-07	Hydrocarbons, aromatic	Air		kg	2,04E-06
Radon-222	Air	low. pop., long-term	Bq	2325706	Hydrocarbons, aliphatic, unsaturated	Air		kg	1,14E-15
Potassium	Air	low. pop., long-term	kg	1,04E-05	Hydrocarbons, aliphatic, alkanes, unspecified	Air		kg	1,06E-05
Phosphorus	Air	low. pop., long-term	kg	1,02E-07	Hexane	Air		kg	1,09E-09
Particulates, > 2.5 um, and < 10um	Air	low. pop., long-term	kg	7,28E-05	Helium	Air		kg	6,84E-14
Particulates, > 10 um	Air	low. pop., long-term	kg	0,000121	Heat, waste	Air		MJ	10,73625
Particulates, < 2.5 um	Air	low. pop., long-term	kg	4,85E-05	Furan	Air		kg	1,08E-18
Nitrate	Air	low. pop., long-term	kg	5,22E-07	Formaldehyde	Air		kg	2,88E-07
Nickel	Air	low. pop., long-term	kg	1,12E-07	Fluorine	Air		kg	1,19E-11
Molybdenum	Air	low. pop.,	kg	1,06E-07	Ethyne	Air		kg	2,27E-09

		long-term							
Mercury	Air	low. pop., long-term	kg	4,19E-09	Ethylene oxide	Air		kg	9,21E-12
Manganese	Air	low. pop., long-term	kg	1,37E-06	Ethene, tetrachloro-	Air		kg	1,1E-14
Magnesium	Air	low. pop., long-term	kg	6,06E-06	Ethene, chloro-	Air		kg	5,08E-18
Lead	Air	low. pop., long-term	kg	5,45E-07	Ethane, hexafluoro-, HFC-116	Air		kg	5,94E-08
Iron	Air	low. pop., long-term	kg	6,61E-05	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air		kg	3,57E-08
Fluorine	Air	low. pop., long-term	kg	3,7E-06	Ethane, 1,1,1-trichloro-, HCFC-140	Air		kg	1,39E-17
Copper	Air	low. pop., long-term	kg	5,15E-07	Ethane	Air		kg	1,88E-09
Cobalt	Air	low. pop., long-term	kg	4,88E-08	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air		kg	6,3E-13
Chromium VI	Air	low. pop., long-term	kg	3,92E-08	Dinitrogen monoxide	Air		kg	0,000225
Chlorine	Air	low. pop., long-term	kg	7,54E-07	Cyanide	Air		kg	3,17E-16
Calcium	Air	low. pop., long-term	kg	1,98E-05	Cumene	Air		kg	6,73E-19
Cadmium	Air	low. pop., long-term	kg	8,31E-09	Copper	Air		kg	7,52E-08
Boron	Air	low. pop., long-term	kg	1,02E-07	Cobalt	Air		kg	3,84E-11
Beryllium	Air	low. pop., long-term	kg	7,67E-09	Chromium VI	Air		kg	5,76E-12
Barium	Air	low. pop., long-term	kg	3,52E-07	Chromium	Air		kg	7,63E-08
Arsenic	Air	low. pop., long-term	kg	3,22E-07	Chloroform	Air		kg	7,5E-18
Antimony	Air	low. pop., long-term	kg	5,48E-09	Chlorine	Air		kg	1,6E-10
Aluminium	Air	low. pop., long-term	kg	6,08E-05	Carbon monoxide, fossil	Air		kg	0,003194
Zirconium-95	Air	low. pop.	Bq	3,36E-05	Carbon disulfide	Air		kg	1,65E-17
Zirconium	Air	low. pop.	kg	1,55E-09	Carbon dioxide, fossil	Air		kg	0,189411
Zinc-65	Air	low. pop.	Bq	3,43E-05	Carbon dioxide, biogenic	Air		kg	0,041395
Zinc	Air	low. pop.	kg	6,86E-06	Cadmium	Air		kg	2,62E-09
Xylene	Air	low. pop.	kg	5,5E-05	Butane	Air		kg	1,27E-09
Xenon-138	Air	low. pop.	Bq	31,85707	Butadiene	Air		kg	9,52E-13
Xenon-137	Air	low. pop.	Bq	4,268432	Bromine	Air		kg	3,03E-15
Xenon-135m	Air	low. pop.	Bq	135,4823	Boron	Air		kg	3,7E-15
Xenon-135	Air	low. pop.	Bq	214,9312	Beryllium	Air		kg	2,87E-11

Xenon-133m	Air	low. pop.	Bq	0,536105	Benzo(a) pyrene	Air	kg	6,5E-09
Xenon-133	Air	low. pop.	Bq	537,3146	Benzene, hexachloro-	Air	kg	5,28E-10
Xenon-131m	Air	low. pop.	Bq	14,68081	Benzene	Air	kg	4,61E-07
Water	Air	low. pop.	kg	4,41E-09	Benzal chloride	Air	kg	8,88E-17
Vanadium	Air	low. pop.	kg	3,42E-07	Barium	Air	kg	6,42E-16
Uranium alpha	Air	low. pop.	Bq	0,980792	Arsenic	Air	kg	1,15E-10
Uranium-238	Air	low. pop.	Bq	0,471002	Antimony	Air	kg	1,91E-11
Uranium-235	Air	low. pop.	Bq	0,010167	Ammonia	Air	kg	0,000346
Uranium-234	Air	low. pop.	Bq	0,209956	Aluminium	Air	kg	0,000819
Uranium	Air	low. pop.	kg	6,4E-11	Aldehydes, unspecified	Air	kg	5,15E-12
Tungsten	Air	low. pop.	kg	5,38E-11	Acrolein	Air	kg	7E-13
Toluene	Air	low. pop.	kg	7,9E-06	Acetic acid	Air	kg	5,6E-07
Titanium	Air	low. pop.	kg	1,94E-08	Acetaldehyde	Air	kg	6,91E-08
Tin	Air	low. pop.	kg	4,72E-07	Acenaphthene	Air	kg	1,21E-15
Thorium-234	Air	low. pop.	Bq	0,018001				
Thorium-232	Air	low. pop.	Bq	0,133424				
Thorium-230	Air	low. pop.	Bq	0,067054				
Thorium-228	Air	low. pop.	Bq	0,085196				
Thorium	Air	low. pop.	kg	1,26E-10				
Thallium	Air	low. pop.	kg	7,2E-11				
Terpenes	Air	low. pop.	kg	1,96E-09				
Sulfuric acid	Air	low. pop.	kg	1,81E-12				
Sulfur hexafluoride	Air	low. pop.	kg	1,36E-10				

ANNEX B: organic oat beverage quality parameters inventory

Project	WF_organic oat								
Product:	1 p 1000 ml Organic Oat Beverage (of project WF_Abafoods)								
Substance	Compartment	Sub-compartment	Unit	Total	Substance	Compartment	Sub-compartment	Unit	Total
Chloride	Water	river, long-term	kg	2,32E-08	Vanadium	Air	low. pop.	kg	1,26E-09
Benzene, chloro-	Water	river, long-term	kg	3,04E-10	Uranium alpha	Air	low. pop.	Bq	6,21E-03
Zirconium-95	Water	river	Bq	2,28E-06	Uranium -238	Air	low. pop.	Bq	4,56E-03
Zinc, ion	Water	river	kg	1,03E-07	Uranium -235	Air	low. pop.	Bq	6,45E-05
Zinc-65	Water	river	Bq	1,97E-04	Uranium -234	Air	low. pop.	Bq	3,77E-03
Xylene	Water	river	kg	6,75E-08	Uranium	Air	low. pop.	kg	2,54E-12
Waste water/m3	Water	river	m3	2,20E-04	Tungsten	Air	low. pop.	kg	3,42E-13
VOC, volatile organic compounds, unspecified origin	Water	river	kg	2,55E-07	Toluene	Air	low. pop.	kg	4,82E-06
Vanadium, ion	Water	river	kg	2,22E-08	Titanium	Air	low. pop.	kg	7,74E-10
Urea	Water	river	kg	1,94E-10	Tin	Air	low. pop.	kg	4,52E-09
Uranium alpha	Water	river	Bq	1,21E-01	Thorium-234	Air	low. pop.	Bq	1,15E-04
Uranium-238	Water	river	Bq	7,65E-03	Thorium-232	Air	low. pop.	Bq	3,50E-04
Uranium-235	Water	river	Bq	4,18E-03	Thorium-230	Air	low. pop.	Bq	2,86E-03
Uranium-234	Water	river	Bq	2,53E-03	Thorium-228	Air	low. pop.	Bq	2,09E-04
Tungsten	Water	river	kg	8,56E-10	Thorium	Air	low. pop.	kg	5,00E-12
Trimethylamine	Water	river	kg	1,04E-10	Thallium	Air	low. pop.	kg	1,35E-12
Toluene, 2-chloro-	Water	river	kg	3,81E-10	Terpenes	Air	low. pop.	kg	2,89E-06
Toluene	Water	river	kg	8,93E-08	Sulfuric acid	Air	low. pop.	kg	1,26E-14
TOC, Total Organic Carbon	Water	river	kg	2,09E-04	Sulfur hexafluoride	Air	low. pop.	kg	1,39E-11
Titanium, ion	Water	river	kg	7,46E-08	Sulfur dioxide	Air	low. pop.	kg	1,92E-04
Tin, ion	Water	river	kg	3,01E-	Sulfate	Air	low. pop.	kg	8,61E-09

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Thorium-234	Water	river	Bq	2,11E-03	Styrene	Air	low. pop.	kg	1,87E-12
Thorium-232	Water	river	Bq	6,13E-04	Strontium	Air	low. pop.	kg	4,23E-09
Thorium-230	Water	river	Bq	2,88E-01	Sodium	Air	low. pop.	kg	3,44E-09
Thorium-228	Water	river	Bq	1,42E-01	Silver-110	Air	low. pop.	Bq	4,13E-09
Thallium	Water	river	kg	2,01E-10	Silver	Air	low. pop.	kg	1,08E-14
Tellurium-132	Water	river	Bq	1,11E-07	Silicon tetrafluoride	Air	low. pop.	kg	3,95E-11
Tellurium-123m	Water	river	Bq	3,06E-05	Silicon	Air	low. pop.	kg	3,26E-07
Technetium-99m	Water	river	Bq	4,41E-05	Selenium	Air	low. pop.	kg	4,19E-09
t-Butylamine	Water	river	kg	1,53E-09	Scandium	Air	low. pop.	kg	7,56E-12
t-Butyl methyl ether	Water	river	kg	1,26E-11	Ruthenium-103	Air	low. pop.	Bq	4,17E-10
Suspended solids, unspecified	Water	river	kg	1,98E-05	Radon-222	Air	low. pop.	Bq	3,54E+02
Sulfur	Water	river	kg	6,41E-06	Radon-220	Air	low. pop.	Bq	5,00E-02
Sulfite	Water	river	kg	7,66E-08	Radium-228	Air	low. pop.	Bq	3,83E-04
Sulfide	Water	river	kg	5,73E-08	Radium-226	Air	low. pop.	Bq	7,53E-03
Sulfate	Water	river	kg	1,09E-04	Radioactive species, other beta emitters	Air	low. pop.	Bq	2,17E-06
Strontium-90	Water	river	Bq	4,84E-01	Protactinium-234	Air	low. pop.	Bq	1,15E-04
Strontium-89	Water	river	Bq	5,80E-05	Propene	Air	low. pop.	kg	2,62E-05
Strontium	Water	river	kg	1,29E-06	Propane	Air	low. pop.	kg	2,47E-05
Solved solids	Water	river	kg	4,07E-06	Potassium-40	Air	low. pop.	Bq	1,12E-03
Solids, inorganic	Water	river	kg	7,00E-06	Potassium	Air	low. pop.	kg	5,95E-09
Sodium, ion	Water	river	kg	6,24E-04	Polonium-210	Air	low. pop.	Bq	9,53E-03
Sodium formate	Water	river	kg	9,23E-12	Plutonium-alpha	Air	low. pop.	Bq	2,47E-10
Sodium-24	Water	river	Bq	1,45E-05	Plutonium-238	Air	low. pop.	Bq	1,08E-10
Silver, ion	Water	river	kg	7,10E-10	Platinum	Air	low. pop.	kg	9,16E-15
Silver-110	Water	river	Bq	2,26E-03	Phosphorus	Air	low. pop.	kg	1,65E-10

Silicon	Water	river	kg	2,17E-06	Phenol, pentachloro-	Air	low. pop.	kg	1,36E-10
Selenium	Water	river	kg	1,88E-08	Phenol	Air	low. pop.	kg	1,10E-07
Scandium	Water	river	kg	8,65E-10	Pentane	Air	low. pop.	kg	3,01E-08
Ruthenium-103	Water	river	Bq	4,05E-07	Particulates, > 2.5 um, and < 10um	Air	low. pop.	kg	4,36E-05
Rubidium	Water	river	kg	7,12E-09	Particulates, > 10 um	Air	low. pop.	kg	5,88E-05
Radium-228	Water	river	Bq	7,12E-02	Particulates, < 2.5 um	Air	low. pop.	kg	2,10E-04
Radium-226	Water	river	Bq	1,37E+00	PAH, polycyclic aromatic hydrocarbons	Air	low. pop.	kg	1,92E-08
Radium-224	Water	river	Bq	3,56E-02	Ozone	Air	low. pop.	kg	7,75E-12
Radioactive species, Nuclides, unspecified	Water	river	Bq	2,07E-03	Noble gases, radioactive, unspecified	Air	low. pop.	Bq	7,60E+03
Radioactive species, alpha emitters	Water	river	Bq	8,70E-04	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	low. pop.	kg	7,63E-05
Protactinium-234	Water	river	Bq	2,11E-03	Nitrogen oxides	Air	low. pop.	kg	3,79E-04
Propylene oxide	Water	river	kg	5,98E-08	Nitrate	Air	low. pop.	kg	1,14E-09
Propylamine	Water	river	kg	4,84E-11	Niobium-95	Air	low. pop.	Bq	1,90E-09
Propionic acid	Water	river	kg	8,69E-09	Nickel	Air	low. pop.	kg	5,27E-08
Propene	Water	river	kg	1,63E-07	Molybdenum	Air	low. pop.	kg	1,90E-10
Propanal	Water	river	kg	1,21E-10	Methanol	Air	low. pop.	kg	4,06E-05
Potassium, ion	Water	river	kg	1,64E-05	Methane, monochloro-, R-40	Air	low. pop.	kg	2,90E-12

Potassium-40	Water	river	Bq	3,29E-03	Methane, fossil	Air	low. pop.	kg	6,08E-04
Polonium-210	Water	river	Bq	2,62E-03	Methane, dichlorodifluoro-, CFC-12	Air	low. pop.	kg	7,77E-12
Phosphorus	Water	river	kg	1,35E-05	Methane, dichloro-, HCC-30	Air	low. pop.	kg	1,59E-12
Phosphate	Water	river	kg	1,49E-06	Methane, chlorodifluoro-, HCFC-22	Air	low. pop.	kg	7,84E-09
Phenol	Water	river	kg	1,09E-07	Methane, bromotrifluoro-, Halon 1301	Air	low. pop.	kg	6,86E-10
PAH, polycyclic aromatic hydrocarbons	Water	river	kg	3,78E-09	Methane, bromochlorodifluoro-, Halon 1211	Air	low. pop.	kg	2,25E-09
Oils, unspecified	Water	river	kg	4,54E-05	Methane, biogenic	Air	low. pop.	kg	2,12E-04
Nitrogen, organic bound	Water	river	kg	1,79E-07	Mercury	Air	low. pop.	kg	1,30E-09
Nitrogen	Water	river	kg	4,92E-06	Manganese-54	Air	low. pop.	Bq	1,60E-08
Nitrobenzene	Water	river	kg	1,96E-09	Manganese	Air	low. pop.	kg	1,08E-08
Nitrite	Water	river	kg	1,57E-07	Magnesium	Air	low. pop.	kg	9,00E-09
Nitrate	Water	river	kg	2,98E-05	Lead-210	Air	low. pop.	Bq	6,03E-03
Niobium-95	Water	river	Bq	3,93E-05	Lead	Air	low. pop.	kg	7,61E-08
Nickel, ion	Water	river	kg	1,92E-08	Lanthanum-140	Air	low. pop.	Bq	1,72E-07
Molybdenum-99	Water	river	Bq	1,92E-06	Krypton-89	Air	low. pop.	Bq	3,73E-03
Molybdenum	Water	river	kg	1,97E-08	Krypton-88	Air	low. pop.	Bq	9,82E-03
Methyl formate	Water	river	kg	6,76E-12	Krypton-87	Air	low. pop.	Bq	8,12E-03
Methyl amine	Water	river	kg	6,91E-10	Krypton-85m	Air	low. pop.	Bq	3,11E-02
Methyl acrylate	Water	river	kg	4,52E-10	Krypton-85	Air	low. pop.	Bq	1,45E-01

Methyl acetate	Water	river	kg	5,63E-11	Isoprene	Air	low. pop.	kg	3,05E-07
Methanol	Water	river	kg	2,05E-08	Iron	Air	low. pop.	kg	1,09E-08
Methane, dichloro-, HCC-30	Water	river	kg	1,79E-08	Iodine-135	Air	low. pop.	Bq	2,45E-06
Mercury	Water	river	kg	2,12E-09	Iodine-133	Air	low. pop.	Bq	3,53E-06
Manganese-54	Water	river	Bq	1,98E-04	Iodine-131	Air	low. pop.	Bq	1,78E-02
Manganese	Water	river	kg	5,01E-07	Iodine-129	Air	low. pop.	Bq	7,90E-04
Magnesium	Water	river	kg	1,49E-05	Iodine	Air	low. pop.	kg	1,42E-08
m-Xylene	Water	river	kg	1,37E-10	Hydrogen sulfide	Air	low. pop.	kg	1,09E-06
Lithium, ion	Water	river	kg	2,92E-09	Hydrogen fluoride	Air	low. pop.	kg	5,26E-07
Lead-210	Water	river	Bq	2,62E-03	Hydrogen chloride	Air	low. pop.	kg	1,84E-06
Lead	Water	river	kg	2,19E-08	Hydrogen-3, Tritium	Air	low. pop.	Bq	4,58E+00
Lanthanum-140	Water	river	Bq	5,57E-06	Hydrocarbons, chlorinated	Air	low. pop.	kg	1,11E-12
Lactic acid	Water	river	kg	1,35E-10	Hydrocarbons, aromatic	Air	low. pop.	kg	2,27E-07
Isopropylamine	Water	river	kg	1,73E-10	Hydrocarbons, aliphatic, unsaturated	Air	low. pop.	kg	4,61E-08
Iron, ion	Water	river	kg	3,17E-07	Hydrocarbons, aliphatic, alkanes, unspecified	Air	low. pop.	kg	4,80E-07
Iron-59	Water	river	Bq	9,02E-07	Hydrocarbons, aliphatic, alkanes, cyclic	Air	low. pop.	kg	3,17E-12
Iodine-133	Water	river	Bq	3,28E-06	Hexane	Air	low. pop.	kg	8,01E-09
Iodine-131	Water	river	Bq	5,49E-05	Helium	Air	low. pop.	kg	7,57E-08
Iodide	Water	river	kg	1,65E-07	Heat, waste	Air	low. pop.	MJ	6,25E-01
Hypochlorite	Water	river	kg	1,30E-08	Furan	Air	low. pop.	kg	6,58E-06

Hydroxide	Water	river	kg	1,75E-09	Formic acid	Air	low. pop.	kg	2,32E-05
Hydrogen sulfide	Water	river	kg	3,20E-09	Formaldehyde	Air	low. pop.	kg	2,06E-05
Hydrogen peroxide	Water	river	kg	1,56E-09	Fluorine	Air	low. pop.	kg	3,22E-09
Hydrogen-3, Tritium	Water	river	Bq	3,48E+01	Ethyne	Air	low. pop.	kg	7,74E-06
Hydrocarbons, unspecified	Water	river	kg	3,82E-06	Ethylene oxide	Air	low. pop.	kg	1,26E-13
Hydrocarbons, aromatic	Water	river	kg	3,75E-07	Ethene, tetrachloro-	Air	low. pop.	kg	2,35E-13
Hydrocarbons, aliphatic, unsaturated	Water	river	kg	1,06E-08	Ethene	Air	low. pop.	kg	3,74E-05
Hydrocarbons, aliphatic, alkanes, unspecified	Water	river	kg	9,26E-08	Ethanol	Air	low. pop.	kg	3,28E-07
Heat, waste	Water	river	MJ	9,78E-02	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	low. pop.	kg	3,79E-10
Formic acid	Water	river	kg	4,44E-11	Ethane, 1,2-dichloro-	Air	low. pop.	kg	2,19E-13
Formate	Water	river	kg	1,97E-07	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	low. pop.	kg	2,35E-11
Formamide	Water	river	kg	1,53E-10	Ethane, 1,1,1-trichloro-, HCFC-140	Air	low. pop.	kg	1,10E-13
Formaldehyde	Water	river	kg	1,94E-09	Ethane	Air	low. pop.	kg	3,61E-05
Fluosilicic acid	Water	river	kg	1,41E-07	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	low. pop.	kg	7,24E-15
Fluoride	Water	river	kg	1,28E-06	Dinitrogen monoxide	Air	low. pop.	kg	4,35E-05
Ethylene oxide	Water	river	kg	3,81E-09	Cyanide	Air	low. pop.	kg	5,78E-06
Ethylene diamine	Water	river	kg	7,73E-11	Cumene	Air	low. pop.	kg	2,98E-14
Ethylamine	Water	river	kg	3,50E-10	Copper	Air	low. pop.	kg	8,53E-08

Ethyl acetate	Water	river	kg	2,70E-10	Cobalt-60	Air	low. pop.	Bq	3,84E-07
Ethene, chloro-	Water	river	kg	3,12E-11	Cobalt-58	Air	low. pop.	Bq	4,34E-08
Ethene	Water	river	kg	1,53E-08	Cobalt	Air	low. pop.	kg	4,12E-09
Ethanol	Water	river	kg	1,80E-07	Chromium VI	Air	low. pop.	kg	7,24E-09
Ethane, 1,2-dichloro-	Water	river	kg	5,46E-09	Chromium-51	Air	low. pop.	Bq	3,12E-08
DOC, Dissolved Organic Carbon	Water	river	kg	5,29E-05	Chromium	Air	low. pop.	kg	2,89E-07
Dipropylamine	Water	river	kg	1,72E-10	Chloroform	Air	low. pop.	kg	5,37E-13
Dimethylamine	Water	river	kg	6,42E-09	Chlorine	Air	low. pop.	kg	1,13E-10
Diethylamine	Water	river	kg	3,59E-10	Cesium-137	Air	low. pop.	Bq	4,13E-07
Dichromate	Water	river	kg	1,84E-09	Cesium-134	Air	low. pop.	Bq	2,33E-08
Cyanide	Water	river	kg	2,63E-08	Cerium-141	Air	low. pop.	Bq	4,87E-07
Cumene	Water	river	kg	8,75E-08	Carbon monoxide, fossil	Air	low. pop.	kg	2,07E-03
Copper, ion	Water	river	kg	2,00E-08	Carbon monoxide, biogenic	Air	low. pop.	kg	1,45E-06
COD, Chemical Oxygen Demand	Water	river	kg	4,63E-04	Carbon disulfide	Air	low. pop.	kg	5,12E-07
Cobalt-60	Water	river	Bq	2,57E-03	Carbon dioxide, land transformation	Air	low. pop.	kg	4,19E-02
Cobalt-58	Water	river	Bq	3,13E-03	Carbon dioxide, fossil	Air	low. pop.	kg	4,47E-02
Cobalt-57	Water	river	Bq	1,18E-05	Carbon dioxide, biogenic	Air	low. pop.	kg	1,56E-03
Cobalt	Water	river	kg	6,16E-09	Carbon-14	Air	low. pop.	Bq	8,22E-01
Chromium, ion	Water	river	kg	1,46E-08	Calcium	Air	low. pop.	kg	3,52E-09
Chromium VI	Water	river	kg	2,79E-07	Cadmium	Air	low. pop.	kg	6,83E-09
Chromium-51	Water	river	Bq	5,49E-04	Butane	Air	low. pop.	kg	1,54E-06
Chlorosulfonic acid	Water	river	kg	2,63E-09	Butadiene	Air	low. pop.	kg	1,30E-14
Chloroform	Water	river	kg	1,31E-10	Bromine	Air	low. pop.	kg	2,86E-08

Chloroacetyl chloride	Water	river	kg	1,35E-10	Boron	Air	low. pop.	kg	2,30E-07
Chloroacetic acid	Water	river	kg	3,26E-08	Beryllium	Air	low. pop.	kg	1,37E-11
Chlorine	Water	river	kg	2,42E-09	Benzo(a) pyrene	Air	low. pop.	kg	5,38E-10
Chlorinated solvents, unspecified	Water	river	kg	9,05E-10	Benzene, ethyl-	Air	low. pop.	kg	5,15E-13
Chloride	Water	river	kg	8,96E-04	Benzene	Air	low. pop.	kg	7,89E-06
Chlorate	Water	river	kg	9,07E-07	Barium-140	Air	low. pop.	Bq	2,01E-06
Chloramine	Water	river	kg	2,05E-09	Barium	Air	low. pop.	kg	4,38E-09
Cesium-137	Water	river	Bq	1,17E-03	Arsenic	Air	low. pop.	kg	2,27E-08
Cesium-136	Water	river	Bq	3,71E-07	Argon-41	Air	low. pop.	Bq	4,59E-02
Cesium-134	Water	river	Bq	2,60E-04	Antimony-125	Air	low. pop.	Bq	3,09E-08
Cesium	Water	river	kg	7,12E-10	Antimony-124	Air	low. pop.	Bq	2,96E-09
Cerium-144	Water	river	Bq	6,36E-07	Antimony	Air	low. pop.	kg	2,80E-09
Cerium-141	Water	river	Bq	2,09E-06	Ammonia	Air	low. pop.	kg	6,40E-05
Carboxylic acids, unspecified	Water	river	kg	2,62E-06	Aluminium	Air	low. pop.	kg	3,04E-08
Carbonate	Water	river	kg	2,29E-06	Aldehydes, unspecified	Air	low. pop.	kg	3,76E-10
Carbon disulfide	Water	river	kg	1,95E-10	Aerosols, radioactive, unspecified	Air	low. pop.	Bq	2,01E-04
Calcium, ion	Water	river	kg	3,70E-05	Actinides, radioactive, unspecified	Air	low. pop.	Bq	1,13E-05
Cadmium, ion	Water	river	kg	3,60E-09	Acrolein	Air	low. pop.	kg	3,65E-12
Butyrolactone	Water	river	kg	2,93E-13	Acetonitrile	Air	low. pop.	kg	3,46E-06
Butyl acetate	Water	river	kg	1,85E-10	Acetone	Air	low. pop.	kg	1,34E-05
Butene	Water	river	kg	1,76E-08	Acetic acid	Air	low. pop.	kg	8,28E-05
Bromine	Water	river	kg	7,01E-07	Acetaldehyde	Air	low. pop.	kg	1,26E-05
Bromide	Water	river	kg	7,38E-07	Acenaphthene	Air	low. pop.	kg	2,79E-15
Bromate	Water	river	kg	9,32E-	Zinc	Air	high. pop.	kg	7,51E-08

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Boron	Water	river	kg	1,01E-07	Xylene	Air	high. pop.	kg	1,00E-07
Borate	Water	river	kg	1,20E-08	Water	Air	high. pop.	kg	2,04E-10
BOD5, Biological Oxygen Demand	Water	river	kg	2,01E-04	Vanadium	Air	high. pop.	kg	1,89E-07
Beryllium	Water	river	kg	4,07E-11	Uranium-238	Air	high. pop.	Bq	1,84E-04
Benzene, ethyl-	Water	river	kg	1,71E-08	Uranium	Air	high. pop.	kg	4,65E-11
Benzene, chloro-	Water	river	kg	1,47E-07	Trimethylamine	Air	high. pop.	kg	4,32E-11
Benzene, 1,2-dichloro-	Water	river	kg	1,32E-08	Toluene, 2-chloro-	Air	high. pop.	kg	2,40E-10
Benzene	Water	river	kg	2,89E-07	Toluene	Air	high. pop.	kg	2,33E-07
Barium-140	Water	river	Bq	5,23E-06	Titanium	Air	high. pop.	kg	1,26E-08
Barium	Water	river	kg	6,33E-07	Tin	Air	high. pop.	kg	5,43E-11
Arsenic, ion	Water	river	kg	1,37E-07	Thorium-232	Air	high. pop.	Bq	6,43E-05
AOX, Adsorbable Organic Halogen as Cl	Water	river	kg	8,65E-07	Thorium-228	Air	high. pop.	Bq	1,01E-04
Antimony-125	Water	river	Bq	3,03E-04	Thorium	Air	high. pop.	kg	3,49E-11
Antimony-124	Water	river	Bq	2,69E-04	Thallium	Air	high. pop.	kg	4,67E-11
Antimony-122	Water	river	Bq	1,19E-06	t-Butylamine	Air	high. pop.	kg	6,39E-10
Antimony	Water	river	kg	8,07E-08	t-Butyl methyl ether	Air	high. pop.	kg	7,32E-10
Aniline	Water	river	kg	7,61E-10	Sulfuric acid	Air	high. pop.	kg	4,29E-11
Ammonium, ion	Water	river	kg	7,93E-06	Sulfur trioxide	Air	high. pop.	kg	5,19E-09
Aluminium	Water	river	kg	2,50E-06	Sulfur dioxide	Air	high. pop.	kg	1,38E-04
Acrylate, ion	Water	river	kg	4,83E-11	Sulfate	Air	high. pop.	kg	5,73E-06
Acidity, unspecified	Water	river	kg	3,09E-08	Styrene	Air	high. pop.	kg	2,58E-10
Acetyl chloride	Water	river	kg	6,56E-11	Strontium	Air	high. pop.	kg	3,58E-09
Acetonitrile	Water	river	kg	7,23E-10	Sodium hydroxide	Air	high. pop.	kg	2,05E-10
Acetone	Water	river	kg	2,50E-10	Sodium formate	Air	high. pop.	kg	3,84E-12

Acetic acid	Water	river	kg	2,68E-07	Sodium dichromate	Air	high. pop.	kg	5,01E-10
Acetaldehyde	Water	river	kg	2,11E-08	Sodium chlorate	Air	high. pop.	kg	3,93E-09
Acenaphthylene	Water	river	kg	2,77E-13	Sodium	Air	high. pop.	kg	3,66E-07
Acenaphthene	Water	river	kg	4,43E-12	Silver	Air	high. pop.	kg	2,04E-12
2-Propanol	Water	river	kg	3,98E-10	Silicon	Air	high. pop.	kg	7,26E-07
2-Methyl-2-butene	Water	river	kg	1,40E-14	Selenium	Air	high. pop.	kg	1,21E-09
2-Methyl-1-propanol	Water	river	kg	2,81E-10	Scandium	Air	high. pop.	kg	2,31E-11
2-Aminopropanol	Water	river	kg	1,01E-10	Radon-222	Air	high. pop.	Bq	1,84E-05
1,4-Butanediol	Water	river	kg	2,58E-09	Radon-220	Air	high. pop.	Bq	1,84E-05
1-Propanol	Water	river	kg	1,15E-09	Radium-228	Air	high. pop.	Bq	1,19E-03
1-Pentene	Water	river	kg	6,31E-11	Radium-226	Air	high. pop.	Bq	2,21E-04
1-Pentanol	Water	river	kg	8,36E-11	Radioactive species, other beta emitters	Air	high. pop.	Bq	6,77E-02
1-Butanol	Water	river	kg	2,48E-09	Propylene oxide	Air	high. pop.	kg	2,49E-08
Zinc, ion	Water	lake	kg	2,34E-15	Propylamine	Air	high. pop.	kg	2,02E-11
Nickel, ion	Water	lake	kg	3,23E-15	Propionic acid	Air	high. pop.	kg	7,99E-09
Mercury	Water	lake	kg	2,06E-17	Propene	Air	high. pop.	kg	1,27E-07
Lead	Water	lake	kg	2,38E-15	Propane	Air	high. pop.	kg	1,08E-06
DOC, Dissolved Organic Carbon	Water	lake	kg	1,77E-07	Propanal	Air	high. pop.	kg	2,50E-09
Copper, ion	Water	lake	kg	3,64E-14	Potassium-40	Air	high. pop.	Bq	2,48E-04
Calcium, ion	Water	lake	kg	3,35E-09	Potassium	Air	high. pop.	kg	2,93E-06
Cadmium, ion	Water	lake	kg	8,03E-16	Polychlorinated biphenyls	Air	high. pop.	kg	7,44E-16
Arsenic, ion	Water	lake	kg	9,45E-16	Polonium-210	Air	high. pop.	Bq	1,56E-03
Zinc, ion	Water	groundwater, long-term	kg	1,58E-05	Platinum	Air	high. pop.	kg	2,04E-15

Vanadium, ion	Water	groundwater, long-term	kg	7,00E-06	Phosphorus	Air	high. pop.	kg	3,95E-08
Tungsten	Water	groundwater, long-term	kg	1,33E-07	Phosphine	Air	high. pop.	kg	1,76E-14
TOC, Total Organic Carbon	Water	groundwater, long-term	kg	1,90E-03	Phenol, pentachloro-	Air	high. pop.	kg	4,69E-12
Titanium, ion	Water	groundwater, long-term	kg	5,05E-05	Phenol, 2,4-dichloro-	Air	high. pop.	kg	3,54E-09
Tin, ion	Water	groundwater, long-term	kg	4,63E-07	Phenol	Air	high. pop.	kg	2,18E-08
Thallium	Water	groundwater, long-term	kg	2,89E-08	Pentane	Air	high. pop.	kg	1,58E-06
Sulfate	Water	groundwater, long-term	kg	2,75E-03	Particulates, > 2.5 um, and < 10um	Air	high. pop.	kg	5,71E-06
Strontium	Water	groundwater, long-term	kg	1,11E-05	Particulates, > 10 um	Air	high. pop.	kg	5,01E-06
Sodium, ion	Water	groundwater, long-term	kg	8,38E-04	Particulates, < 2.5 um	Air	high. pop.	kg	8,41E-06
Silver, ion	Water	groundwater, long-term	kg	9,36E-09	PAH, polycyclic aromatic hydrocarbons	Air	high. pop.	kg	3,80E-09
Silicon	Water	groundwater, long-term	kg	1,11E-03	Ozone	Air	high. pop.	kg	1,45E-10
Selenium	Water	groundwater, long-term	kg	1,82E-07	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	high. pop.	kg	9,94E-05
Scandium	Water	groundwater, long-term	kg	9,03E-08	Nitrogen oxides	Air	high. pop.	kg	1,46E-04

Potassium, ion	Water	groundwater, long-term	kg	2,66E-04	Nitrobenzene	Air	high. pop.	kg	4,90E-10
Phosphate	Water	groundwater, long-term	kg	8,87E-05	Nitrate	Air	high. pop.	kg	1,50E-10
Nitrogen, organic bound	Water	groundwater, long-term	kg	1,37E-05	Nickel	Air	high. pop.	kg	9,66E-08
Nitrite	Water	groundwater, long-term	kg	4,56E-07	Monoethanolamine	Air	high. pop.	kg	2,15E-08
Nitrate	Water	groundwater, long-term	kg	2,68E-05	Molybdenum	Air	high. pop.	kg	1,56E-09
Nickel, ion	Water	groundwater, long-term	kg	4,17E-06	Methyl lactate	Air	high. pop.	kg	6,16E-11
Molybdenum	Water	groundwater, long-term	kg	2,35E-07	Methyl formate	Air	high. pop.	kg	1,69E-11
Mercury	Water	groundwater, long-term	kg	1,50E-08	Methyl ethyl ketone	Air	high. pop.	kg	3,66E-08
Manganese	Water	groundwater, long-term	kg	4,43E-05	Methyl borate	Air	high. pop.	kg	1,69E-11
Magnesium	Water	groundwater, long-term	kg	4,26E-04	Methyl amine	Air	high. pop.	kg	2,88E-10
Lead	Water	groundwater, long-term	kg	2,89E-06	Methyl acrylate	Air	high. pop.	kg	2,32E-11
Iron, ion	Water	groundwater, long-term	kg	1,16E-04	Methyl acetate	Air	high. pop.	kg	2,35E-11
Iodide	Water	groundwater, long-term	kg	1,66E-11	Methanol	Air	high. pop.	kg	5,87E-08
Hydrogen sulfide	Water	groundwater, long-term	kg	1,31E-06	Methane sulfonic acid	Air	high. pop.	kg	8,72E-10
Heat, waste	Water	groundwater, long-term	MJ	3,39E-01	Methane, trifluoro-, HFC-23	Air	high. pop.	kg	2,07E-12

Fluoride	Water	groundwater, long-term	kg	2,21E-05	Methane, trichlorofluoro-, CFC-11	Air	high. pop.	kg	1,15E-08
DOC, Dissolved Organic Carbon	Water	groundwater, long-term	kg	1,90E-03	Methane, tetrafluoro-, CFC-14	Air	high. pop.	kg	6,50E-13
Copper, ion	Water	groundwater, long-term	kg	7,78E-06	Methane, tetrachloro-, CFC-10	Air	high. pop.	kg	3,06E-10
COD, Chemical Oxygen Demand	Water	groundwater, long-term	kg	2,22E-03	Methane, monochloro-, R-40	Air	high. pop.	kg	7,98E-12
Cobalt	Water	groundwater, long-term	kg	1,10E-06	Methane, fossil	Air	high. pop.	kg	2,46E-04
Chromium VI	Water	groundwater, long-term	kg	1,07E-06	Methane, dichlorofluoro-, HCFC-21	Air	high. pop.	kg	6,49E-15
Chloride	Water	groundwater, long-term	kg	9,11E-04	Methane, dichlorodifluoro-, CFC-12	Air	high. pop.	kg	8,47E-10
Calcium, ion	Water	groundwater, long-term	kg	9,99E-04	Methane, dichloro-, HCC-30	Air	high. pop.	kg	1,46E-09
Cadmium, ion	Water	groundwater, long-term	kg	3,82E-07	Methane, chlorodifluoro-, HCFC-22	Air	high. pop.	kg	3,79E-11
Bromine	Water	groundwater, long-term	kg	1,80E-07	Methane, bromotrifluoro-, Halon 1301	Air	high. pop.	kg	1,15E-08
Boron	Water	groundwater, long-term	kg	4,35E-06	Methane, biogenic	Air	high. pop.	kg	1,14E-06
BOD5, Biological Oxygen Demand	Water	groundwater, long-term	kg	5,52E-04	Mercury	Air	high. pop.	kg	6,57E-10

Beryllium	Water	groundwater, long-term	kg	6,89E-08	Manganese	Air	high. pop.	kg	2,18E-08
Barium	Water	groundwater, long-term	kg	5,15E-06	Magnesium	Air	high. pop.	kg	1,70E-07
Arsenic, ion	Water	groundwater, long-term	kg	2,83E-07	m-Xylene	Air	high. pop.	kg	1,48E-08
Antimony	Water	groundwater, long-term	kg	2,28E-07	Lead-210	Air	high. pop.	Bq	8,55E-04
Ammonium, ion	Water	groundwater, long-term	kg	8,37E-06	Lead	Air	high. pop.	kg	1,01E-08
Aluminium	Water	groundwater, long-term	kg	2,30E-03	Lactic acid	Air	high. pop.	kg	5,61E-11
Zinc, ion	Water	groundwater	kg	2,19E-08	Isopropylamine	Air	high. pop.	kg	7,19E-11
Zinc	Water	groundwater	kg	1,43E-11	Isocyanic acid	Air	high. pop.	kg	3,86E-10
Xylene	Water	groundwater	kg	2,69E-11	Iron	Air	high. pop.	kg	9,65E-08
VOC, volatile organic compounds, unspecified origin	Water	groundwater	kg	1,71E-12	Iodine	Air	high. pop.	kg	2,10E-10
Vanadium, ion	Water	groundwater	kg	8,73E-10	Hydrogen sulfide	Air	high. pop.	kg	1,32E-06
Vanadium	Water	groundwater	kg	2,73E-12	Hydrogen peroxide	Air	high. pop.	kg	5,49E-11
Uranium-238	Water	groundwater	Bq	1,13E-04	Hydrogen fluoride	Air	high. pop.	kg	8,96E-08
Tungsten	Water	groundwater	kg	3,18E-09	Hydrogen chloride	Air	high. pop.	kg	1,59E-06
Toluene	Water	groundwater	kg	5,24E-12	Hydrogen	Air	high. pop.	kg	9,56E-06
TOC, Total Organic Carbon	Water	groundwater	kg	1,42E-09	Hydrocarbons, chlorinated	Air	high. pop.	kg	2,39E-08
Titanium, ion	Water	groundwater	kg	8,53E-10	Hydrocarbons, aromatic	Air	high. pop.	kg	3,35E-06

Titanium	Water	groundwater	kg	2,17E-12	Hydrocarbons, aliphatic, unsaturated	Air	high. pop.	kg	3,97E-07
Tin, ion	Water	groundwater	kg	1,48E-10	Hydrocarbons, aliphatic, alkanes, unspecified	Air	high. pop.	kg	2,92E-07
Tin	Water	groundwater	kg	5,97E-16	Hydrocarbons, aliphatic, alkanes, cyclic	Air	high. pop.	kg	6,23E-07
Thorium-228	Water	groundwater	Bq	1,55E-07	Hexane	Air	high. pop.	kg	5,52E-05
Thallium	Water	groundwater	kg	1,78E-11	Heptane	Air	high. pop.	kg	3,38E-07
Sulfur	Water	groundwater	kg	9,13E-15	Heat, waste	Air	high. pop.	MJ	2,34E+00
Sulfite	Water	groundwater	kg	1,24E-11	Formic acid	Air	high. pop.	kg	6,43E-11
Sulfide	Water	groundwater	kg	1,00E-10	Formamide	Air	high. pop.	kg	6,37E-11
Sulfate	Water	groundwater	kg	1,59E-04	Formaldehyde	Air	high. pop.	kg	1,33E-07
Strontium-90	Water	groundwater	Bq	1,78E-05	Fluosilicic acid	Air	high. pop.	kg	7,81E-08
Strontium	Water	groundwater	kg	1,19E-07	Fluorine	Air	high. pop.	kg	6,29E-09
Solved solids	Water	groundwater	kg	1,86E-06	Ethyne	Air	high. pop.	kg	9,46E-09
Solids, inorganic	Water	groundwater	kg	2,68E-05	Ethylene oxide	Air	high. pop.	kg	3,47E-08
Sodium, ion	Water	groundwater	kg	3,72E-06	Ethylene diamine	Air	high. pop.	kg	3,22E-11
Silver, ion	Water	groundwater	kg	7,09E-11	Ethylamine	Air	high. pop.	kg	1,46E-10
Silver-110	Water	groundwater	Bq	5,51E-10	Ethyl cellulose	Air	high. pop.	kg	7,41E-11
Silicon	Water	groundwater	kg	1,27E-06	Ethyl acetate	Air	high. pop.	kg	3,68E-08
Selenium	Water	groundwater	kg	1,97E-09	Ethene, tetrachloro-	Air	high. pop.	kg	1,37E-14
Scandium	Water	groundwater	kg	9,20E-10	Ethene, chloro-	Air	high. pop.	kg	1,24E-08
Ruthenium-106	Water	groundwater	Bq	3,63E-07	Ethene	Air	high. pop.	kg	5,40E-07
Radium-226	Water	groundwater	Bq	6,00E-03	Ethanol	Air	high. pop.	kg	3,73E-08

Propane, 1,2-dichloro-	Water	groundwater	kg	2,71E-20	Ethane, hexafluoro-, HFC-116	Air	high. pop.	kg	6,71E-11
Potassium, ion	Water	groundwater	kg	1,63E-06	Ethane, 1,2-dichloro-	Air	high. pop.	kg	2,57E-08
Potassium-40	Water	groundwater	Bq	1,53E-06	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	Air	high. pop.	kg	9,69E-13
Potassium	Water	groundwater	kg	1,78E-11	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	high. pop.	kg	2,28E-12
Polonium-210	Water	groundwater	Bq	1,92E-05	Ethane, 1,1-difluoro-, HFC-152a	Air	high. pop.	kg	1,26E-11
Plutonium-alpha	Water	groundwater	Bq	1,46E-06	Ethane	Air	high. pop.	kg	4,25E-07
Phosphorus	Water	groundwater	kg	1,12E-06	Dipropylamine	Air	high. pop.	kg	7,16E-11
Phosphate	Water	groundwater	kg	1,66E-05	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	high. pop.	kg	1,10E-13
Phenol	Water	groundwater	kg	7,11E-12	Dinitrogen monoxide	Air	high. pop.	kg	4,48E-06
Particulates, > 10 um	Water	groundwater	kg	1,74E-07	Dimethyl malonate	Air	high. pop.	kg	1,08E-09
Particulates, < 10 um	Water	groundwater	kg	4,08E-13	Diethylamine	Air	high. pop.	kg	1,50E-10
Nitrogen	Water	groundwater	kg	3,21E-08	Cyanoacetic acid	Air	high. pop.	kg	8,63E-10
Nitrate	Water	groundwater	kg	1,58E-03	Cyanide	Air	high. pop.	kg	3,80E-08
Nickel, ion	Water	groundwater	kg	6,02E-09	Cumene	Air	high. pop.	kg	3,64E-08
Nickel	Water	groundwater	kg	3,36E-10	Copper	Air	high. pop.	kg	4,32E-08
Naphthalene	Water	groundwater	kg	9,51E-14	Cobalt	Air	high. pop.	kg	3,76E-09
Molybdenum	Water	groundwater	kg	1,70E-08	Chromium VI	Air	high. pop.	kg	7,87E-11
Methanol	Water	groundwater	kg	4,31E-09	Chromium	Air	high. pop.	kg	2,72E-08

Methane, monochloro-, R-40	Water	groundwater	kg	8,84E-13	Chlorosulfonic acid	Air	high. pop.	kg	1,05E-09
Methane, dibromo-	Water	groundwater	kg	9,93E-18	Chlorosilane, trimethyl-	Air	high. pop.	kg	6,13E-12
Mercury	Water	groundwater	kg	2,26E-11	Chloroform	Air	high. pop.	kg	1,18E-09
Manganese-54	Water	groundwater	Bq	1,22E-05	Chloroacetic acid	Air	high. pop.	kg	7,20E-09
Manganese	Water	groundwater	kg	1,59E-07	Chlorine	Air	high. pop.	kg	1,91E-07
Magnesium	Water	groundwater	kg	3,16E-06	Chloramine	Air	high. pop.	kg	2,24E-10
Lead-210	Water	groundwater	Bq	1,26E-05	Carbon monoxide, fossil	Air	high. pop.	kg	2,51E-04
Lead	Water	groundwater	kg	2,18E-10	Carbon monoxide, biogenic	Air	high. pop.	kg	9,12E-06
Iron, ion	Water	groundwater	kg	1,22E-05	Carbon disulfide	Air	high. pop.	kg	1,04E-10
Iron	Water	groundwater	kg	2,21E-08	Carbon dioxide, fossil	Air	high. pop.	kg	1,30E-01
Iodine-131	Water	groundwater	Bq	2,69E-09	Carbon dioxide, biogenic	Air	high. pop.	kg	2,88E-02
Iodine-129	Water	groundwater	Bq	5,26E-05	Calcium	Air	high. pop.	kg	8,20E-07
Iodide	Water	groundwater	kg	6,91E-10	Cadmium	Air	high. pop.	kg	2,92E-09
Hydroxide	Water	groundwater	kg	1,71E-11	Butyrolactone	Air	high. pop.	kg	1,22E-13
Hydrogen fluoride	Water	groundwater	kg	9,94E-15	Butene	Air	high. pop.	kg	3,64E-08
Hydrogen chloride	Water	groundwater	kg	6,20E-13	Butane	Air	high. pop.	kg	1,18E-06
Hydrogen-3, Tritium	Water	groundwater	Bq	5,36E-01	Butadiene	Air	high. pop.	kg	2,24E-11
Hydrocarbons, unspecified	Water	groundwater	kg	8,82E-12	Bromine	Air	high. pop.	kg	7,79E-09
Hydrocarbons, aromatic	Water	groundwater	kg	6,27E-12	Boron trifluoride	Air	high. pop.	kg	3,26E-18
Hexane	Water	groundwater	kg	2,64E-17	Boron	Air	high. pop.	kg	3,34E-08
Heat, waste	Water	groundwater	MJ	4,61E-05	Beryllium	Air	high. pop.	kg	3,63E-11
Fluorine	Water	groundwater	kg	8,64E-12	Benzo(a)pyrene	Air	high. pop.	kg	6,65E-11
Fluoride	Water	groundwater	kg	8,66E-08	Benzene, pentachloro-	Air	high. pop.	kg	3,38E-11

Fluoranthene	Water	groundwater	kg	4,34E-16	Benzene, hexachloro-	Air	high. pop.	kg	1,35E-11
Ethene, chloro-	Water	groundwater	kg	4,66E-18	Benzene, ethyl-	Air	high. pop.	kg	3,00E-08
Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Water	groundwater	kg	1,28E-25	Benzene, 1,2-dichloro-	Air	high. pop.	kg	2,66E-09
Decane	Water	groundwater	kg	5,23E-11	Benzene, 1-methyl-2-nitro-	Air	high. pop.	kg	8,75E-11
Cyanide	Water	groundwater	kg	7,09E-14	Benzene	Air	high. pop.	kg	4,11E-07
Curium alpha	Water	groundwater	Bq	4,81E-07	Benzaldehyde	Air	high. pop.	kg	9,17E-11
Cresol	Water	groundwater	kg	2,36E-16	Barium	Air	high. pop.	kg	4,46E-09
Copper, ion	Water	groundwater	kg	3,53E-09	Arsine	Air	high. pop.	kg	2,38E-16
Copper	Water	groundwater	kg	4,82E-10	Arsenic	Air	high. pop.	kg	3,23E-09
COD, Chemical Oxygen Demand	Water	groundwater	kg	9,08E-06	Antimony	Air	high. pop.	kg	2,51E-09
Cobalt-60	Water	groundwater	Bq	7,90E-05	Anthranilic acid	Air	high. pop.	kg	7,49E-11
Cobalt-58	Water	groundwater	Bq	1,41E-07	Aniline	Air	high. pop.	kg	3,04E-10
Cobalt	Water	groundwater	kg	1,36E-09	Ammonium carbonate	Air	high. pop.	kg	1,06E-10
Chrysene	Water	groundwater	kg	1,05E-15	Ammonia	Air	high. pop.	kg	7,18E-07
Chromium, ion	Water	groundwater	kg	1,03E-08	Aluminium	Air	high. pop.	kg	4,13E-07
Chromium VI	Water	groundwater	kg	6,69E-09	Aldehydes, unspecified	Air	high. pop.	kg	9,68E-10
Chromium	Water	groundwater	kg	5,07E-12	Acrylic acid	Air	high. pop.	kg	2,04E-11
Chlorine	Water	groundwater	kg	4,26E-10	Acrolein	Air	high. pop.	kg	1,76E-10
Chloride	Water	groundwater	kg	1,08E-04	Acetone	Air	high. pop.	kg	2,83E-08
Cesium-137	Water	groundwater	Bq	1,70E-04	Acetic acid	Air	high. pop.	kg	1,33E-07
Cesium-134	Water	groundwater	Bq	1,92E-05	Acetaldehyde	Air	high. pop.	kg	3,30E-08
Carbonate	Water	groundwater	kg	5,38E-10	Acenaphthene	Air	high. pop.	kg	9,51E-14

Carbon-14	Water	groundwater	Bq	1,84E-05	2-Propanol	Air	high. pop.	kg	7,97E-09
Calcium, ion	Water	groundwater	kg	8,60E-06	2-Nitrobenzoic acid	Air	high. pop.	kg	1,01E-10
Cadmium, ion	Water	groundwater	kg	2,99E-10	2-Methyl-1-propanol	Air	high. pop.	kg	1,17E-10
Cadmium	Water	groundwater	kg	2,50E-11	2-Butene, 2-methyl-	Air	high. pop.	kg	5,84E-15
Bromine	Water	groundwater	kg	5,60E-09	2-Aminopropanol	Air	high. pop.	kg	4,01E-11
Boron	Water	groundwater	kg	3,61E-07	1,4-Butanediol	Air	high. pop.	kg	6,46E-09
BOD5, Biological Oxygen Demand	Water	groundwater	kg	1,94E-09	1-Propanol	Air	high. pop.	kg	4,87E-09
Beryllium	Water	groundwater	kg	1,45E-10	1-Pentene	Air	high. pop.	kg	2,63E-11
Benzo(b)fluoranthene	Water	groundwater	kg	1,27E-16	1-Pentanol	Air	high. pop.	kg	3,48E-11
Benzo(a)anthracene	Water	groundwater	kg	2,37E-16	1-Butanol	Air	high. pop.	kg	9,89E-10
Benzene, ethyl-	Water	groundwater	kg	8,26E-13	Zirconium-95	Air		Bq	-6,33E-11
Benzene	Water	groundwater	kg	7,20E-12	Zirconium	Air		kg	-3,14E-13
Barium	Water	groundwater	kg	9,93E-10	Zinc oxide	Air		kg	1,55E-18
Arsenic, ion	Water	groundwater	kg	1,22E-08	Zinc-65	Air		Bq	-4,30E-09
AOX, Adsorbable Organic Halogen as Cl	Water	groundwater	kg	2,32E-11	Zinc	Air		kg	2,96E-08
Antimony-125	Water	groundwater	Bq	2,57E-09	Xylene	Air		kg	1,31E-08
Antimony-124	Water	groundwater	Bq	3,77E-09	Xenon-138	Air		Bq	-2,88E-04
Antimony	Water	groundwater	kg	2,52E-09	Xenon-137	Air		Bq	-2,80E-05
Anthracene	Water	groundwater	kg	2,79E-15	Xenon-135m	Air		Bq	-1,14E-03
Ammonium, ion	Water	groundwater	kg	8,68E-09	Xenon-135	Air		Bq	-1,05E-02
Ammonia	Water	groundwater	kg	3,71E-08	Xenon-133m	Air		Bq	-3,23E-05
Americium-241	Water	groundwater	Bq	3,63E-07	Xenon-133	Air		Bq	-6,25E-02

Aluminium	Water	groundwater	kg	6,88E-08	Xenon-131m	Air	Bq	-2,16E-04
Acrylonitrile	Water	groundwater	kg	1,98E-15	Water	Air	kg	1,21E-03
Acidity, unspecified	Water	groundwater	kg	1,33E-12	VOC, volatile organic compounds	Air	kg	4,13E-10
Acetic acid	Water	groundwater	kg	9,76E-12	Vanadium	Air	kg	-3,23E-09
Acenaphthylene	Water	groundwater	kg	7,24E-16	Used air	Air	kg	2,86E-03
Acenaphthene	Water	groundwater	kg	1,83E-15	Uranium alpha	Air	Bq	-2,08E-05
Zirconium-95	Water		Bq	-4,92E-06	Uranium-238	Air	Bq	-4,61E-06
Zinc, ion	Water		kg	5,47E-08	Uranium-235	Air	Bq	2,98E-06
Zinc-65	Water		Bq	-8,49E-07	Uranium-234	Air	Bq	-6,08E-06
Yttrium-90	Water		Bq	-1,51E-09	Uranium	Air	kg	-6,35E-13
Xylene	Water		kg	-1,44E-08	Toluene	Air	kg	3,33E-08
VOC, volatile organic compounds as C	Water		kg	-5,34E-08	Titanium	Air	kg	-4,40E-11
Vanadium, ion	Water		kg	-5,50E-10	Tin oxide	Air	kg	7,75E-19
Uranium alpha	Water		Bq	-7,02E-04	Tin	Air	kg	2,55E-10
Uranium-238	Water		Bq	-3,63E-05	Thorium-234	Air	Bq	-5,81E-07
Uranium-235	Water		Bq	-2,13E-05	Thorium-232	Air	Bq	-7,69E-07
Uranium-234	Water		Bq	-1,43E-05	Thorium-230	Air	Bq	-6,43E-06
Undissolved substances	Water		kg	-8,25E-06	Thorium-228	Air	Bq	-1,21E-06
Tungsten	Water		kg	-2,24E-12	Thorium	Air	kg	-5,82E-13
Triethylene glycol	Water		kg	-1,88E-09	Thallium	Air	kg	5,40E-11
Tributyltin compounds	Water		kg	-1,33E-10	Tellurium-123m	Air	Bq	-4,35E-09
Toluene	Water		kg	-1,66E-08	Tellurium	Air	kg	3,29E-16
TOC, Total Organic Carbon	Water		kg	-2,74E-06	Technetium-99	Air	Bq	-4,04E-11
Titanium, ion	Water		kg	-4,95E-09	t-Butyl methyl ether	Air	kg	-1,22E-11
Tin, ion	Water		kg	1,11E-12	Sulfur oxides	Air	kg	-3,90E-06

Thorium-234	Water	Bq	-1,08E-05	Sulfur hexafluoride	Air	kg	3,67E-09
Thorium-232	Water	Bq	-1,65E-06	Sulfur dioxide	Air	kg	6,86E-05
Thorium-230	Water	Bq	-1,67E-03	Sulfate	Air	kg	3,17E-11
Thorium-228	Water	Bq	-3,05E-02	Styrene	Air	kg	4,72E-17
Thallium	Water	kg	3,41E-14	Strontium-90	Air	Bq	-9,54E-07
Terephthalate, dimethyl	Water	kg	-8,95E-14	Strontium-89	Air	Bq	-1,73E-09
Tellurium-132	Water	Bq	-2,25E-10	Strontium	Air	kg	-3,19E-11
Tellurium-123m	Water	Bq	-5,51E-10	Sodium	Air	kg	-1,42E-09
Technetium-99m	Water	Bq	-6,16E-09	Silver-110	Air	Bq	-9,79E-10
Technetium-99	Water	Bq	-6,08E-05	Silver	Air	kg	8,53E-22
t-Butyl methyl ether	Water	kg	-9,93E-13	Silicon	Air	kg	-3,20E-11
Suspended solids, unspecified	Water	kg	1,61E-06	Silicates, unspecified	Air	kg	-6,86E-09
Sulfur trioxide	Water	kg	-4,12E-10	Selenium	Air	kg	-4,97E-11
Sulfur	Water	kg	3,80E-11	Scandium	Air	kg	-3,12E-13
Sulfide	Water	kg	-4,99E-09	Ruthenium-106	Air	Bq	-5,78E-06
Sulfate	Water	kg	-3,77E-06	Ruthenium-103	Air	Bq	-9,97E-12
Strontium-90	Water	Bq	-1,16E-04	Rhodium	Air	kg	3,68E-21
Strontium-89	Water	Bq	-2,94E-08	Radon-222	Air	Bq	-1,22E+00
Strontium	Water	kg	-9,24E-07	Radon-220	Air	Bq	-1,30E-04
Solved substances	Water	kg	-3,39E-08	Radium-228	Air	Bq	-1,43E-06
Solved solids	Water	kg	6,37E-07	Radium-226	Air	Bq	-2,08E-05
Sodium, ion	Water	kg	-2,72E-05	Radioactive species, other beta emitters	Air	Bq	-1,31E-10
Sodium-24	Water	Bq	-4,02E-07	Protactinium-234	Air	Bq	-5,81E-07
Silver, ion	Water	kg	3,01E-11	Propionic acid	Air	kg	-7,44E-11
Silver-110	Water	Bq	-6,65E-06	Propene	Air	kg	-1,13E-08
Silver	Water	kg	-9,30E-11	Propane	Air	kg	-2,24E-07

Silicon	Water	kg	-1,36E-09	Propanal	Air	kg	5,50E-18
Selenium	Water	kg	-5,39E-10	Promethium-147	Air	Bq	-4,92E-07
Salts, unspecified	Water	kg	-1,26E-07	Potassium-40	Air	Bq	-2,90E-06
Ruthenium-106	Water	Bq	-5,78E-04	Potassium	Air	kg	-4,18E-09
Ruthenium-103	Water	Bq	-4,37E-09	Polychlorinated biphenyls	Air	kg	3,74E-11
Ruthenium	Water	kg	-1,53E-09	Polonium-210	Air	Bq	-2,51E-05
Radium-228	Water	Bq	-1,52E-02	Plutonium-alpha	Air	Bq	-5,75E-08
Radium-226	Water	Bq	-5,94E-02	Plutonium-241	Air	Bq	-2,38E-04
Radium-224	Water	Bq	-7,62E-03	Plutonium-238	Air	Bq	-2,17E-12
Radioactive species, Nuclides, unspecified	Water	Bq	-5,21E-09	Platinum	Air	kg	-7,06E-13
Radioactive species, from fission and activation	Water	Bq	-7,18E-06	Phosphorus, total	Air	kg	-1,23E-10
Radioactive species, alpha emitters	Water	Bq	-7,88E-10	Phosphorus	Air	kg	1,89E-10
Protactinium-234	Water	Bq	-1,07E-05	Phosphine	Air	kg	9,16E-18
Potassium-40	Water	Bq	-8,83E-06	Phenol, pentachloro-	Air	kg	-1,90E-16
Potassium	Water	kg	-7,85E-07	Phenol	Air	kg	2,13E-09
Polonium-210	Water	Bq	-7,02E-06	Phenanthrene	Air	kg	3,62E-14
Plutonium-alpha	Water	Bq	-9,54E-06	Pentane	Air	kg	-2,96E-07
Plutonium-241	Water	Bq	-9,23E-07	Particulates, unspecified	Air	kg	1,58E-06
Phthalate, p-dibutyl-	Water	kg	-1,42E-14	Particulates, diesel soot	Air	kg	-7,23E-06
Phthalate, dioctyl-	Water	kg	-1,21E-15	Particulates, > 2.5 um, and < 10um	Air	kg	4,50E-06

Phosphorus compounds, unspecified	Water	kg	-7,46E-11	Particulates, > 10 um (process)	Air	kg	-2,79E-07
Phosphorus	Water	kg	1,80E-09	Particulates, > 10 um	Air	kg	1,77E-06
Phosphate	Water	kg	1,63E-05	Particulates, < 2.5 um	Air	kg	1,19E-05
Phenols, unspecified	Water	kg	-1,89E-08	Particulates, < 10 um (stationary)	Air	kg	-4,10E-07
Phenol	Water	kg	1,81E-09	Particulates, < 10 um (mobile)	Air	kg	-1,35E-07
PAH, polycyclic aromatic hydrocarbons	Water	kg	-2,00E-09	Particulates, < 10 um	Air	kg	6,84E-10
Oils, unspecified	Water	kg	-2,76E-06	Particulates	Air	kg	8,21E-06
o-Xylene	Water	kg	3,16E-13	Palladium	Air	kg	3,81E-21
Nitrogen, total	Water	kg	-3,42E-07	PAH, polycyclic aromatic hydrocarbons	Air	kg	2,14E-07
Nitrogen, organic bound	Water	kg	-5,57E-08	Ozone	Air	kg	4,34E-07
Nitrite	Water	kg	-1,03E-10	Oxygen	Air	kg	3,29E-08
Nitrate	Water	kg	-7,94E-03	Octane	Air	kg	8,02E-12
Niobium-95	Water	Bq	-7,41E-09	Noble gases, radioactive, unspecified	Air	Bq	-1,38E-04
Nickel, ion	Water	kg	2,78E-09	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	kg	-2,37E-05

Neptunium-237	Water	Bq	-1,53E-07	Nitrogen oxides	Air	kg	5,57E-05
Molybdenum-99	Water	Bq	-9,13E-10	Nitrogen	Air	kg	4,83E-07
Molybdenum	Water	kg	-3,84E-10	Nitric oxide	Air	kg	5,50E-16
Methanol	Water	kg	5,41E-09	Niobium-95	Air	Bq	-1,75E-10
Methane, tetrachloro-, CFC-10	Water	kg	-3,96E-15	Nickel	Air	kg	3,21E-10
Methane, dichloro-, HCC-30	Water	kg	-1,22E-09	Neptunium-237	Air	Bq	-9,54E-13
Mercury	Water	kg	9,75E-11	Naphthalene	Air	kg	1,15E-13
Manganese-54	Water	Bq	-8,15E-05	Molybdenum	Air	kg	-1,09E-11
Manganese	Water	kg	-9,25E-09	Methanol	Air	kg	7,86E-07
Magnesium	Water	kg	-3,16E-07	Methane, trichlorofluoro-, CFC-11	Air	kg	2,14E-12
m-Xylene	Water	kg	4,34E-13	Methane, tetrafluoro-, CFC-14	Air	kg	6,01E-07
Lithium, ion	Water	kg	1,54E-08	Methane, tetrachloro-, CFC-10	Air	kg	-5,13E-13
Lead-210	Water	Bq	-2,87E-06	Methane, fossil	Air	kg	1,96E-06
Lead	Water	kg	9,56E-10	Methane, dichlorofluoro-, HCFC-21	Air	kg	-5,71E-10
Lanthanum-140	Water	Bq	-2,72E-09	Methane, dichlorodifluoro-, CFC-12	Air	kg	4,60E-13
Iron, ion	Water	kg	1,97E-07	Methane, dichloro-, HCC-30	Air	kg	-3,90E-13
Iron-59	Water	Bq	-2,31E-10	Methane, chlorotrifluoro-, CFC-13	Air	kg	2,89E-13

Iron	Water	kg	-1,43E-07	Methane, chlorodifluoro-, HCFC-22	Air	kg	5,02E-13
Iodine-133	Water	Bq	-5,99E-08	Methane, bromotrifluoro-, Halon 1301	Air	kg	-1,18E-09
Iodine-131	Water	Bq	-2,33E-07	Methane, bromo-, Halon 1001	Air	kg	2,32E-18
Iodine-129	Water	Bq	-3,48E-04	Methane, biogenic	Air	kg	8,28E-07
Iodide	Water	kg	-1,53E-08	Methane	Air	kg	1,36E-05
Hypochlorous acid	Water	kg	-3,84E-10	Mercury	Air	kg	2,17E-09
Hypochlorite	Water	kg	-3,84E-10	Manganese-54	Air	Bq	-9,91E-10
Hydrogen sulfide	Water	kg	-2,98E-11	Manganese	Air	kg	1,82E-09
Hydrogen-3, Tritium	Water	Bq	-3,61E+00	Magnesium	Air	kg	-7,65E-10
Hydrocarbons, unspecified	Water	kg	3,96E-09	Lead compounds	Air	kg	8,91E-18
Hydrocarbons, aromatic	Water	kg	-9,11E-08	Lead-210	Air	Bq	-1,67E-05
Hydrocarbons, aliphatic, alkenes, unspecified	Water	kg	-1,83E-09	Lead	Air	kg	1,20E-08
Hydrocarbons, aliphatic, alkanes, unspecified	Water	kg	-1,99E-08	Lanthanum-140	Air	Bq	-2,41E-09
Heat, waste	Water	MJ	-7,45E-04	Lanthanum	Air	kg	-9,24E-13
Glutaraldehyde	Water	kg	-3,27E-10	Krypton-89	Air	Bq	-3,51E-05
Formaldehyde	Water	kg	1,80E-08	Krypton-88	Air	Bq	-4,23E-03
Fluoride	Water	kg	3,28E-09	Krypton-87	Air	Bq	-4,90E-05
Fatty acids as C	Water	kg	-7,74E-07	Krypton-85m	Air	Bq	1,36E+01
Ethene, trichloro-	Water	kg	-1,61E-13	Krypton-85	Air	Bq	-8,96E+01
Ethene, tetrachloro-	Water	kg	-2,60E-15	Isoprene	Air	kg	1,64E-18
Ethene, chloro-	Water	kg	-7,36E-16	Iron-59	Air	Bq	-3,79E-11

Ethane, hexachloro-	Water	kg	-2,19E-17	Iron	Air	kg	9,56E-09
Ethane, dichloro-	Water	kg	-9,83E-13	Iodine-135	Air	Bq	-4,84E-07
Ethane, 1,1,1-trichloro-, HCFC-140	Water	kg	-1,48E-13	Iodine-133	Air	Bq	-3,24E-07
DOC, Dissolved Organic Carbon	Water	kg	2,16E-07	Iodine-131	Air	Bq	-4,77E-07
Cyanide	Water	kg	1,80E-09	Iodine-129	Air	Bq	-4,41E-06
Curium alpha	Water	Bq	-3,18E-06	Iodine	Air	kg	-6,30E-11
Copper, ion	Water	kg	2,54E-09	Indeno(1,2,3-cd)pyrene	Air	kg	3,67E-16
COD, Chemical Oxygen Demand	Water	kg	3,17E-07	Hydrogen sulfide	Air	kg	4,91E-08
Cobalt-60	Water	Bq	-5,31E-04	Hydrogen iodide	Air	kg	1,10E-16
Cobalt-58	Water	Bq	-1,08E-05	Hydrogen fluoride	Air	kg	1,43E-06
Cobalt-57	Water	Bq	-1,34E-08	Hydrogen cyanide	Air	kg	1,28E-12
Cobalt	Water	kg	-1,63E-10	Hydrogen chloride	Air	kg	8,11E-07
Chromium, ion	Water	kg	1,45E-09	Hydrogen bromide	Air	kg	1,01E-13
Chromium VI	Water	kg	3,28E-10	Hydrogen-3, Tritium	Air	Bq	-1,35E-02
Chromium-51	Water	Bq	-2,87E-07	Hydrogen	Air	kg	1,44E-07
Chromium	Water	kg	-2,22E-09	Hydrocarbons, chlorinated	Air	kg	2,26E-08
Chloroform	Water	kg	-6,04E-13	Hydrocarbons, aromatic	Air	kg	6,80E-08
Chlorinated solvents, unspecified	Water	kg	-2,56E-12	Hydrocarbons, aliphatic, unsaturated	Air	kg	1,12E-17

Chloride	Water	kg	-8,43E-05	Hydrocarbons, aliphatic, alkenes, unspecified	Air	kg	-1,71E-10
Cesium-137	Water	Bq	-1,13E-03	Hydrocarbons, aliphatic, alkanes, unspecified	Air	kg	3,80E-07
Cesium-136	Water	Bq	-7,01E-11	Hexane	Air	kg	-1,15E-07
Cesium-134	Water	Bq	-1,23E-04	Hexamethylene diamine	Air	kg	3,37E-17
Cesium	Water	kg	-1,53E-10	Heptane	Air	kg	-5,47E-08
Cerium-144	Water	Bq	-5,50E-05	Helium	Air	kg	-2,10E-07
Cerium-141	Water	Bq	-1,94E-09	Heat, waste	Air	MJ	3,61E-01
Carbon-14	Water	Bq	-1,22E-04	Furan	Air	kg	1,23E-19
Calcium, ion	Water	kg	-5,93E-06	Formaldehyde	Air	kg	4,21E-07
Cadmium, ion	Water	kg	3,31E-10	Fluorine	Air	kg	7,19E-10
Cadmium-109	Water	Bq	-7,55E-11	Fluoride	Air	kg	1,33E-11
Bromine	Water	kg	3,07E-09	Fluorene	Air	kg	1,13E-14
Boron	Water	kg	-5,20E-09	Fluoranthene	Air	kg	3,57E-15
BOD5, Biological Oxygen Demand	Water	kg	8,21E-07	Ethyne	Air	kg	2,33E-09
Beryllium	Water	kg	5,98E-14	Ethylene oxide	Air	kg	1,78E-12
Benzene, ethyl-	Water	kg	-3,65E-09	Ethene, tetrachloro-	Air	kg	1,25E-15
Benzene, chloro-	Water	kg	-5,89E-16	Ethene, chloro-	Air	kg	-9,51E-14
Benzene	Water	kg	-2,01E-08	Ethene	Air	kg	-7,74E-08
Barium-140	Water	Bq	-1,31E-08	Ethanol	Air	kg	5,71E-10
Barium	Water	kg	-3,88E-07	Ethane, hexafluoro-, HFC-116	Air	kg	6,68E-08
Barite	Water	kg	-2,66E-06	Ethane, dichloro-	Air	kg	-1,94E-12

Arsenic, ion	Water		kg	-4,56E-11	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	kg	-1,69E-11
AOX, Adsorbable Organic Halogen as Cl	Water		kg	-4,42E-10	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	kg	2,61E-08
Antimony-125	Water		Bq	-1,07E-07	Ethane, 1,1,1-trichloro-, HCFC-140	Air	kg	1,58E-18
Antimony-124	Water		Bq	-1,73E-06	Ethane	Air	kg	-5,62E-08
Antimony-122	Water		Bq	-1,31E-08	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	kg	2,70E-14
Antimony	Water		kg	-1,79E-12	Dinitrogen monoxide	Air	kg	-2,32E-06
Ammonium, ion	Water		kg	1,77E-10	Diethanolamine	Air	kg	1,74E-20
Ammonia, as N	Water		kg	-2,57E-07	Dibenz(a,h)anthracene	Air	kg	3,07E-16
Americium-241	Water		Bq	-2,39E-06	Cyclohexane	Air	kg	4,23E-14
Aluminium	Water		kg	-9,05E-08	Cyanide	Air	kg	-6,61E-12
Acids, unspecified	Water		kg	-8,14E-11	Curium alpha	Air	Bq	-2,90E-08
Acidity, unspecified	Water		kg	3,02E-12	Curium-244	Air	Bq	-8,71E-13
Acetone	Water		kg	1,43E-13	Curium-242	Air	Bq	-9,58E-14
Acenaphthylene	Water		kg	-1,40E-10	Cumene	Air	kg	7,67E-20
4-Methyl-2-pentanone	Water		kg	6,01E-14	Copper	Air	kg	1,45E-08
Zinc	Air	stratosphere + troposphere	kg	4,18E-15	Cobalt-60	Air	Bq	-2,53E-08
Water	Air	stratosphere + troposphere	kg	5,18E-09	Cobalt-58	Air	Bq	-2,70E-08

Sulfur dioxide	Air	stratosphere + troposphere	kg	4,18E-12	Cobalt-57	Air	Bq	-1,67E-12
Selenium	Air	stratosphere + troposphere	kg	4,18E-17	Cobalt	Air	kg	-3,25E-11
Particulates, < 2.5 um	Air	stratosphere + troposphere	kg	1,59E-13	Chrysene	Air	kg	1,36E-15
NMVOC, non-methane volatile organic compounds, unspecified origin	Air	stratosphere + troposphere	kg	2,80E-12	Chromium, ion	Air	kg	2,47E-15
Nitrogen oxides	Air	stratosphere + troposphere	kg	5,85E-11	Chromium VI	Air	kg	1,21E-12
Nickel	Air	stratosphere + troposphere	kg	2,93E-16	Chromium-51	Air	Bq	-3,44E-09
Methane, fossil	Air	stratosphere + troposphere	kg	2,09E-13	Chromium	Air	kg	2,82E-09
Mercury	Air	stratosphere + troposphere	kg	2,93E-19	Chloroform	Air	kg	-5,07E-14
Lead	Air	stratosphere + troposphere	kg	8,36E-17	Chlorine	Air	kg	1,90E-10
Hydrogen chloride	Air	stratosphere + troposphere	kg	3,59E-15	Chloride	Air	kg	6,34E-12
Heat, waste	Air	stratosphere + troposphere	MJ	1,91E-07	Cesium-137	Air	Bq	-1,13E-06
Formaldehyde	Air	stratosphere + troposphere	kg	6,58E-13	Cesium-134	Air	Bq	-5,91E-07
Ethylene oxide	Air	stratosphere + troposphere	kg	7,64E-13	Cerium-144	Air	Bq	-1,95E-07

Dinitrogen monoxide	Air	stratosphere + troposphere	kg	1,25E-13	Cerium-141	Air		Bq	-9,06E-11
Copper	Air	stratosphere + troposphere	kg	7,10E-15	Carbon monoxide, fossil	Air		kg	3,38E-04
Chromium	Air	stratosphere + troposphere	kg	2,09E-16	Carbon monoxide	Air		kg	-2,20E-05
Carbon monoxide, fossil	Air	stratosphere + troposphere	kg	1,55E-11	Carbon disulfide	Air		kg	1,85E-15
Carbon dioxide, fossil	Air	stratosphere + troposphere	kg	1,32E-08	Carbon dioxide, land transformation	Air		kg	4,87E-04
Cadmium	Air	stratosphere + troposphere	kg	4,18E-17	Carbon dioxide, fossil	Air		kg	1,90E-02
Butadiene	Air	stratosphere + troposphere	kg	7,90E-14	Carbon dioxide, biogenic	Air		kg	5,77E-05
Benzene	Air	stratosphere + troposphere	kg	8,34E-14	Carbon dioxide	Air		kg	-2,22E-03
Zinc	Air	low. pop., long-term	kg	2,48E-09	Carbon-14	Air		Bq	-1,10E-03
Vanadium	Air	low. pop., long-term	kg	2,39E-09	Calcium	Air		kg	-3,17E-09
Tungsten	Air	low. pop., long-term	kg	1,56E-10	Cadmium	Air		kg	1,06E-10
Titanium	Air	low. pop., long-term	kg	2,52E-08	Butene	Air		kg	-7,50E-09
Tin	Air	low. pop., long-term	kg	8,05E-11	Butane	Air		kg	-2,33E-07
Sulfate	Air	low. pop., long-term	kg	3,55E-07	Butadiene	Air		kg	1,85E-13

Strontium	Air	low. pop., long-term	kg	1,40E-09	Bromine	Air		kg	-1,18E-10
Sodium	Air	low. pop., long-term	kg	2,27E-08	Boron	Air		kg	-1,26E-09
Silver	Air	low. pop., long-term	kg	5,78E-11	Beryllium	Air		kg	3,67E-12
Silicon	Air	low. pop., long-term	kg	8,59E-08	Benzo(ghi)perylene	Air		kg	4,93E-16
Selenium	Air	low. pop., long-term	kg	1,93E-10	Benzo(b)fluoranthene	Air		kg	9,85E-16
Scandium	Air	low. pop., long-term	kg	1,38E-09	Benzo(a)pyrene	Air		kg	6,53E-09
Radon-222	Air	low. pop., long-term	Bq	1,46E+04	Benzo(a)anthracene	Air		kg	5,52E-16
Potassium	Air	low. pop., long-term	kg	6,60E-08	Benzene, pentachloro-	Air		kg	-1,18E-15
Phosphorus	Air	low. pop., long-term	kg	6,49E-10	Benzene, hexachloro-	Air		kg	1,73E-11
Particulates, > 2.5 um, and < 10um	Air	low. pop., long-term	kg	4,62E-07	Benzene, ethyl-	Air		kg	-5,55E-09
Particulates, > 10 um	Air	low. pop., long-term	kg	7,70E-07	Benzene, 1,3,5-trimethyl-	Air		kg	7,55E-18
Particulates, < 2.5 um	Air	low. pop., long-term	kg	3,08E-07	Benzene	Air		kg	3,67E-08
Nitrate	Air	low. pop., long-term	kg	3,31E-09	Benzaldehyde	Air		kg	-1,91E-12
Nickel	Air	low. pop., long-term	kg	7,09E-10	Benzal chloride	Air		kg	1,01E-17
Molybdenum	Air	low. pop., long-term	kg	6,72E-10	Barium-140	Air		Bq	-3,87E-09

Mercury	Air	low. pop., long-term	kg	2,66E-11	Barium	Air	kg	6,50E-11
Manganese	Air	low. pop., long-term	kg	8,68E-09	Arsine	Air	kg	6,36E-16
Magnesium	Air	low. pop., long-term	kg	3,85E-08	Arsenic trioxide	Air	kg	7,67E-18
Lead	Air	low. pop., long-term	kg	3,46E-09	Arsenic	Air	kg	-5,22E-11
Iron	Air	low. pop., long-term	kg	4,20E-07	Argon-41	Air	Bq	-1,30E-03
Fluorine	Air	low. pop., long-term	kg	2,35E-08	Antimony-125	Air	Bq	-3,57E-11
Copper	Air	low. pop., long-term	kg	3,27E-09	Antimony-124	Air	Bq	-1,40E-10
Cobalt	Air	low. pop., long-term	kg	3,10E-10	Antimony	Air	kg	9,48E-12
Chromium VI	Air	low. pop., long-term	kg	2,49E-10	Anthracene	Air	kg	1,10E-15
Chlorine	Air	low. pop., long-term	kg	4,79E-09	Ammonium, ion	Air	kg	9,43E-16
Calcium	Air	low. pop., long-term	kg	1,25E-07	Ammonia	Air	kg	3,50E-04
Cadmium	Air	low. pop., long-term	kg	5,27E-11	Americium-241	Air	Bq	-1,82E-08
Boron	Air	low. pop., long-term	kg	6,49E-10	Aluminium	Air	kg	3,27E-06
Beryllium	Air	low. pop., long-term	kg	4,87E-11	Aldehydes, unspecified	Air	kg	-1,30E-12
Barium	Air	low. pop., long-term	kg	2,24E-09	Acrolein	Air	kg	-5,47E-12

Arsenic	Air	low. pop., long-term	kg	2,05E-09	Acidity, unspecified	Air		kg	1,63E-12
Antimony	Air	low. pop., long-term	kg	3,48E-11	Acetone	Air		kg	2,70E-10
Aluminium	Air	low. pop., long-term	kg	3,86E-07	Acetic acid	Air		kg	1,56E-06
Zirconium-95	Air	low. pop.	Bq	7,80E-08	Acetaldehyde	Air		kg	1,61E-07
Zirconium	Air	low. pop.	kg	6,17E-11	Acenaphthene	Air		kg	1,38E-16
Zinc-65	Air	low. pop.	Bq	7,98E-08					
Zinc	Air	low. pop.	kg	1,66E-07					
Xylene	Air	low. pop.	kg	1,34E-06					
Xenon-138	Air	low. pop.	Bq	7,86E-02					
Xenon-137	Air	low. pop.	Bq	1,02E-02					
Xenon-135m	Air	low. pop.	Bq	3,59E-01					
Xenon-135	Air	low. pop.	Bq	5,80E-01					
Xenon-133m	Air	low. pop.	Bq	2,67E-03					
Xenon-133	Air	low. pop.	Bq	1,44E+00					
Xenon-131m	Air	low. pop.	Bq	4,09E-02					
Water	Air	low. pop.	kg	8,53E-10					

ANNEX C: organic strawberry jam quality parameters inventory

Project	WF_Rigoni
Product:	1 p 330g Rigoni di Asiago Organic Strawberry Jam (of project WF_Rigoni)
Method:	ReCiPe Midpoint (H) V1.06 / Europe ReCiPe H
Indicator:	Inventory

Substance	Compartment	Sub-compartment	Unit	Total	Substance	Compartment	Sub-compartment	Unit	Total
Chloride	Water	river, long-term	kg	4,72E-08	Sulfur hexafluoride	Air	low. pop.	kg	8,86E-11
Benzene, chloro-	Water	river, long-term	kg	1,01E-09	Sulfur dioxide	Air	low. pop.	kg	8,23E-03
Zirconium-95	Water	river	Bq	2,82E-05	Sulfate	Air	low. pop.	kg	6,41E-07
Zinc, ion	Water	river	kg	2,20E-06	Styrene	Air	low. pop.	kg	1,20E-10
Zinc-65	Water	river	Bq	2,44E-03	Strontium	Air	low. pop.	kg	3,95E-07
Xylene	Water	river	kg	1,64E-06	Sodium	Air	low. pop.	kg	5,08E-08
VOC, volatile organic compounds, unspecified origin	Water	river	kg	6,44E-06	Silver-110	Air	low. pop.	Bq	5,12E-08
Vanadium, ion	Water	river	kg	2,47E-07	Silver	Air	low. pop.	kg	4,57E-13
Urea	Water	river	kg	9,91E-10	Silicon tetrafluoride	Air	low. pop.	kg	7,26E-10
Uranium alpha	Water	river	Bq	9,04E+00	Silicon	Air	low. pop.	kg	9,27E-07
Uranium-238	Water	river	Bq	5,17E-01	Selenium	Air	low. pop.	kg	3,45E-07
Uranium-235	Water	river	Bq	3,11E-01	Scandium	Air	low. pop.	kg	3,20E-10
Uranium-234	Water	river	Bq	1,88E-01	Ruthenium-103	Air	low. pop.	Bq	5,16E-09
Tungsten	Water	river	kg	5,30E-08	Radon-222	Air	low. pop.	Bq	2,62E+04
Trimethylamine	Water	river	kg	3,19E-12	Radon-220	Air	low. pop.	Bq	3,24E+00
Toluene, 2-chloro-	Water	river	kg	7,30E-10	Radium-228	Air	low. pop.	Bq	3,26E-02
Toluene	Water	river	kg	2,00E-06	Radium-226	Air	low. pop.	Bq	3,51E-01
TOC, Total Organic Carbon	Water	river	kg	1,38E-03	Radioactive species, other beta emitters	Air	low. pop.	Bq	3,22E-05
Titanium, ion	Water	river	kg	1,34E-07	Protactinium-234	Air	low. pop.	Bq	8,52E-03
Tin, ion	Water	river	kg	8,21E-08	Propene	Air	low. pop.	kg	4,96E-07
Thorium-234	Water	river	Bq	1,57E-01	Propane	Air	low. pop.	kg	1,55E-05

Thorium-232	Water	river	Bq	2,05E-02	Potassium-40	Air	low. pop.	Bq	7,70E-02
Thorium-230	Water	river	Bq	2,14E+01	Potassium	Air	low. pop.	kg	6,93E-08
Thorium-228	Water	river	Bq	3,45E+00	Polonium-210	Air	low. pop.	Bq	5,25E-01
Thallium	Water	river	kg	3,27E-09	Plutonium-alpha	Air	low. pop.	Bq	1,87E-08
Tellurium-132	Water	river	Bq	1,38E-06	Plutonium-238	Air	low. pop.	Bq	8,14E-09
Tellurium-123m	Water	river	Bq	2,88E-03	Platinum	Air	low. pop.	kg	9,06E-14
Technetium-99m	Water	river	Bq	5,47E-04	Phosphorus	Air	low. pop.	kg	6,12E-09
t-Butylamine	Water	river	kg	5,51E-09	Phenol, pentachloro-	Air	low. pop.	kg	8,77E-09
t-Butyl methyl ether	Water	river	kg	9,07E-11	Phenol	Air	low. pop.	kg	3,22E-08
Suspended solids, unspecified	Water	river	kg	4,85E-04	Pentane	Air	low. pop.	kg	2,66E-06
Sulfur	Water	river	kg	5,95E-06	Particulates, > 2.5 um, and < 10um	Air	low. pop.	kg	3,96E-04
Sulfite	Water	river	kg	1,75E-06	Particulates, > 10 um	Air	low. pop.	kg	1,67E-03
Sulfide	Water	river	kg	7,31E-08	Particulates, < 2.5 um	Air	low. pop.	kg	5,91E-04
Sulfate	Water	river	kg	2,06E-03	PAH, polycyclic aromatic hydrocarbons	Air	low. pop.	kg	3,78E-08
Strontium-90	Water	river	Bq	7,26E+00	Ozone	Air	low. pop.	kg	1,30E-10
Strontium-89	Water	river	Bq	3,76E-03	Noble gases, radioactive, unspecified	Air	low. pop.	Bq	5,74E+05
Strontium	Water	river	kg	3,13E-05	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	low. pop.	kg	7,92E-04
Solved solids	Water	river	kg	2,88E-04	Nitrogen oxides	Air	low. pop.	kg	3,55E-03
Solids, inorganic	Water	river	kg	5,67E-04	Nitrate	Air	low. pop.	kg	8,48E-08
Sodium, ion	Water	river	kg	5,69E-03	Niobium-95	Air	low. pop.	Bq	2,35E-08
Sodium formate	Water	river	kg	1,17E-07	Nickel	Air	low. pop.	kg	1,17E-06
Sodium-24	Water	river	Bq	1,80E-04	Molybdenum	Air	low. pop.	kg	3,75E-08
Silver, ion	Water	river	kg	1,69E-08	Methanol	Air	low. pop.	kg	3,02E-07
Silver-110	Water	river	Bq	9,77E-02	Methane, monochloro-, R-40	Air	low. pop.	kg	1,79E-10

Silicon	Water	river	kg	2,79E-05	Methane, fossil	Air	low. pop.	kg	4,90E-03
Selenium	Water	river	kg	1,75E-07	Methane, dichlorodifluoro-, CFC-12	Air	low. pop.	kg	3,17E-11
Scandium	Water	river	kg	7,35E-08	Methane, dichloro-, HCC-30	Air	low. pop.	kg	9,82E-11
Ruthenium-103	Water	river	Bq	5,02E-06	Methane, chlorodifluoro-, HCFC-22	Air	low. pop.	kg	5,41E-08
Rubidium	Water	river	kg	1,73E-07	Methane, bromotrifluoro-, Halon 1301	Air	low. pop.	kg	1,61E-08
Radium-228	Water	river	Bq	1,73E+00	Methane, bromochlorodifluoro-, Halon 1211	Air	low. pop.	kg	1,38E-08
Radium-226	Water	river	Bq	9,91E+01	Methane, biogenic	Air	low. pop.	kg	9,78E-05
Radium-224	Water	river	Bq	8,63E-01	Mercury	Air	low. pop.	kg	1,17E-07
Radioactive species, Nuclides, unspecified	Water	river	Bq	4,89E-02	Manganese-54	Air	low. pop.	Bq	1,98E-07
Radioactive species, alpha emitters	Water	river	Bq	9,43E-04	Manganese	Air	low. pop.	kg	4,17E-07
Protactinium-234	Water	river	Bq	1,57E-01	Magnesium	Air	low. pop.	kg	2,07E-07
Propylene oxide	Water	river	kg	2,11E-07	Lead-210	Air	low. pop.	Bq	2,99E-01
Propylamine	Water	river	kg	3,45E-10	Lead	Air	low. pop.	kg	1,41E-06
Propionic acid	Water	river	kg	3,83E-11	Lanthanum-140	Air	low. pop.	Bq	2,13E-06
Propene	Water	river	kg	5,20E-07	Krypton-89	Air	low. pop.	Bq	4,65E-02
Propanal	Water	river	kg	8,61E-10	Krypton-88	Air	low. pop.	Bq	1,25E-01
Potassium, ion	Water	river	kg	1,26E-04	Krypton-87	Air	low. pop.	Bq	1,05E-01
Potassium-40	Water	river	Bq	1,10E-01	Krypton-85m	Air	low. pop.	Bq	3,92E-01
Polonium-210	Water	river	Bq	8,75E-02	Krypton-85	Air	low. pop.	Bq	2,16E+00
Phosphorus	Water	river	kg	7,36E-06	Isoprene	Air	low. pop.	kg	1,24E-09
Phosphate	Water	river	kg	5,87E-06	Iron	Air	low. pop.	kg	2,79E-07
Phenol	Water	river	kg	1,59E-06	Iodine-135	Air	low. pop.	Bq	1,86E-04
PAH, polycyclic aromatic hydrocarbons	Water	river	kg	1,31E-07	Iodine-133	Air	low. pop.	Bq	1,16E-04

Oils, unspecified	Water	river	kg	1,17E-03	Iodine-131	Air	low. pop.	Bq	2,67E-01
Nitrogen, organic bound	Water	river	kg	3,31E-06	Iodine-129	Air	low. pop.	Bq	5,97E-02
Nitrogen	Water	river	kg	5,10E-05	Iodine	Air	low. pop.	kg	1,71E-06
Nitrobenzene	Water	river	kg	4,64E-09	Hydrogen sulfide	Air	low. pop.	kg	8,83E-06
Nitrite	Water	river	kg	5,76E-07	Hydrogen fluoride	Air	low. pop.	kg	3,17E-05
Nitrate	Water	river	kg	1,17E-04	Hydrogen chloride	Air	low. pop.	kg	1,33E-04
Niobium-95	Water	river	Bq	4,33E-03	Hydrogen-3, Tritium	Air	low. pop.	Bq	3,60E+02
Nickel, ion	Water	river	kg	2,78E-07	Hydrocarbons, chlorinated	Air	low. pop.	kg	6,87E-11
Molybdenum-99	Water	river	Bq	2,38E-05	Hydrocarbons, aromatic	Air	low. pop.	kg	9,28E-07
Molybdenum	Water	river	kg	7,58E-07	Hydrocarbons, aliphatic, unsaturated	Air	low. pop.	kg	3,96E-06
Methyl formate	Water	river	kg	4,84E-11	Hydrocarbons, aliphatic, alkanes, unspecified	Air	low. pop.	kg	5,74E-06
Methyl amine	Water	river	kg	9,37E-12	Hydrocarbons, aliphatic, alkanes, cyclic	Air	low. pop.	kg	1,96E-10
Methyl acrylate	Water	river	kg	6,89E-09	Hexane	Air	low. pop.	kg	5,97E-07
Methyl acetate	Water	river	kg	1,53E-12	Helium	Air	low. pop.	kg	1,67E-06
Methanol	Water	river	kg	2,02E-08	Heat, waste	Air	low. pop.	MJ	2,52E+01
Methane, dichloro-, HCC-30	Water	river	kg	2,90E-07	Furan	Air	low. pop.	kg	2,66E-08
Mercury	Water	river	kg	2,89E-09	Formic acid	Air	low. pop.	kg	9,38E-08
Manganese-54	Water	river	Bq	1,21E-02	Formaldehyde	Air	low. pop.	kg	1,16E-06
Manganese	Water	river	kg	3,65E-06	Fluorine	Air	low. pop.	kg	6,57E-08
Magnesium	Water	river	kg	1,19E-04	Ethyne	Air	low. pop.	kg	8,13E-08
m-Xylene	Water	river	kg	1,17E-09	Ethylene oxide	Air	low. pop.	kg	1,65E-12
Lithium, ion	Water	river	kg	2,08E-08	Ethene, tetrachloro-	Air	low. pop.	kg	1,45E-11
Lead-210	Water	river	Bq	8,75E-02	Ethene	Air	low. pop.	kg	1,70E-06
Lead	Water	river	kg	7,27E-07	Ethanol	Air	low. pop.	kg	1,18E-08
Lanthanum-140	Water	river	Bq	6,90E-05	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	low. pop.	kg	3,00E-08
Lactic acid	Water	river	kg	4,60E-10	Ethane, 1,2-dichloro-	Air	low. pop.	kg	1,35E-11
Isopropylamine	Water	river	kg	6,45E-09	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	low. pop.	kg	2,07E-09

Iron, ion	Water	river	kg	8,71E-06	Ethane, 1,1,1-trichloro-, HCFC-140	Air	low. pop.	kg	6,77E-12
Iron-59	Water	river	Bq	1,12E-05	Ethane	Air	low. pop.	kg	4,68E-05
Iodine-133	Water	river	Bq	4,07E-05	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	low. pop.	kg	2,00E-13
Iodine-131	Water	river	Bq	4,00E-03	Dinitrogen monoxide	Air	low. pop.	kg	4,14E-05
Iodide	Water	river	kg	2,14E-06	Cyanide	Air	low. pop.	kg	9,71E-08
Hypochlorite	Water	river	kg	2,89E-07	Cumene	Air	low. pop.	kg	1,84E-12
Hydroxide	Water	river	kg	2,45E-08	Copper	Air	low. pop.	kg	1,66E-06
Hydrogen sulfide	Water	river	kg	8,75E-08	Cobalt-60	Air	low. pop.	Bq	4,76E-06
Hydrogen peroxide	Water	river	kg	1,75E-07	Cobalt-58	Air	low. pop.	Bq	5,38E-07
Hydrogen-3, Tritium	Water	river	Bq	2,75E+03	Cobalt	Air	low. pop.	kg	9,54E-08
Hydrocarbons, unspecified	Water	river	kg	4,55E-07	Chromium VI	Air	low. pop.	kg	1,54E-07
Hydrocarbons, aromatic	Water	river	kg	9,09E-06	Chromium-51	Air	low. pop.	Bq	3,87E-07
Hydrocarbons, aliphatic, unsaturated	Water	river	kg	2,07E-07	Chromium	Air	low. pop.	kg	5,91E-06
Hydrocarbons, aliphatic, alkanes, unspecified	Water	river	kg	2,24E-06	Chloroform	Air	low. pop.	kg	3,32E-11
Heat, waste	Water	river	MJ	3,80E+00	Chlorine	Air	low. pop.	kg	8,17E-09
Formic acid	Water	river	kg	3,16E-10	Cesium-137	Air	low. pop.	Bq	5,12E-06
Formate	Water	river	kg	7,07E-07	Cesium-134	Air	low. pop.	Bq	2,89E-07
Formamide	Water	river	kg	1,09E-09	Cerium-141	Air	low. pop.	Bq	6,03E-06
Formaldehyde	Water	river	kg	2,94E-08	Carbon monoxide, fossil	Air	low. pop.	kg	7,06E-04
Fluosilicic acid	Water	river	kg	4,30E-08	Carbon monoxide, biogenic	Air	low. pop.	kg	1,37E-06
Fluoride	Water	river	kg	1,61E-05	Carbon disulfide	Air	low. pop.	kg	9,46E-06
Ethylene oxide	Water	river	kg	2,83E-09	Carbon dioxide, land transformation	Air	low. pop.	kg	2,14E-04
Ethylene diamine	Water	river	kg	2,38E-08	Carbon dioxide, fossil	Air	low. pop.	kg	1,97E+00

Ethylamine	Water	river	kg	1,70E-08	Carbon dioxide, biogenic	Air	low. pop.	kg	1,57E-03
Ethyl acetate	Water	river	kg	9,81E-10	Carbon-14	Air	low. pop.	Bq	5,83E+01
Ethene, chloro-	Water	river	kg	9,26E-10	Calcium	Air	low. pop.	kg	8,47E-08
Ethene	Water	river	kg	1,25E-07	Cadmium	Air	low. pop.	kg	1,44E-07
Ethanol	Water	river	kg	4,78E-08	Butane	Air	low. pop.	kg	2,94E-06
Ethane, 1,2-dichloro-	Water	river	kg	5,12E-08	Butadiene	Air	low. pop.	kg	1,71E-13
DOC, Dissolved Organic Carbon	Water	river	kg	1,15E-03	Bromine	Air	low. pop.	kg	3,02E-06
Dipropylamine	Water	river	kg	5,88E-10	Boron	Air	low. pop.	kg	1,98E-05
Dimethylamine	Water	river	kg	4,27E-10	Beryllium	Air	low. pop.	kg	3,07E-10
Diethylamine	Water	river	kg	9,31E-10	Benzo(a)pyrene	Air	low. pop.	kg	2,17E-08
Dichromate	Water	river	kg	1,00E-07	Benzene, ethyl-	Air	low. pop.	kg	3,18E-11
Cyanide	Water	river	kg	5,64E-07	Benzene	Air	low. pop.	kg	7,15E-06
Cumene	Water	river	kg	9,13E-07	Barium-140	Air	low. pop.	Bq	2,49E-05
Copper, ion	Water	river	kg	1,84E-07	Barium	Air	low. pop.	kg	4,09E-07
COD, Chemical Oxygen Demand	Water	river	kg	5,58E-03	Arsenic	Air	low. pop.	kg	5,01E-07
Cobalt-60	Water	river	Bq	1,38E-01	Argon-41	Air	low. pop.	Bq	6,85E-01
Cobalt-58	Water	river	Bq	1,79E-01	Antimony-125	Air	low. pop.	Bq	3,83E-07
Cobalt-57	Water	river	Bq	1,46E-04	Antimony-124	Air	low. pop.	Bq	3,67E-08
Cobalt	Water	river	kg	2,47E-08	Antimony	Air	low. pop.	kg	6,16E-08
Chromium, ion	Water	river	kg	1,02E-07	Ammonia	Air	low. pop.	kg	7,85E-05
Chromium VI	Water	river	kg	3,93E-06	Aluminium	Air	low. pop.	kg	5,63E-07
Chromium-51	Water	river	Bq	2,45E-02	Aldehydes, unspecified	Air	low. pop.	kg	2,80E-08
Chlorosulfonic acid	Water	river	kg	1,15E-11	Aerosols, radioactive, unspecified	Air	low. pop.	Bq	1,71E-02
Chloroform	Water	river	kg	2,85E-10	Actinides, radioactive, unspecified	Air	low. pop.	Bq	7,01E-04
Chloroacetyl chloride	Water	river	kg	1,70E-11	Acrolein	Air	low. pop.	kg	2,31E-10
Chloroacetic acid	Water	river	kg	3,02E-07	Acetonitrile	Air	low. pop.	kg	1,40E-08
Chlorine	Water	river	kg	3,67E-08	Acetone	Air	low. pop.	kg	1,62E-07

Chlorinated solvents, unspecified	Water	river	kg	3,23E-09	Acetic acid	Air	low. pop.	kg	3,35E-07
Chloride	Water	river	kg	1,22E-02	Acetaldehyde	Air	low. pop.	kg	5,10E-08
Chlorate	Water	river	kg	6,39E-06	Acenaphthene	Air	low. pop.	kg	1,73E-13
Chloramine	Water	river	kg	7,82E-09	Zinc	Air	high. pop.	kg	5,74E-07
Cesium-137	Water	river	Bq	6,78E-02	Xylene	Air	high. pop.	kg	3,16E-06
Cesium-136	Water	river	Bq	4,60E-06	Water	Air	high. pop.	kg	2,95E-09
Cesium-134	Water	river	Bq	2,68E-02	Vanadium	Air	high. pop.	kg	9,54E-06
Cesium	Water	river	kg	1,73E-08	Uranium-238	Air	high. pop.	Bq	6,51E-03
Cerium-144	Water	river	Bq	7,88E-06	Uranium	Air	high. pop.	kg	1,92E-09
Cerium-141	Water	river	Bq	2,59E-05	Trimethylamine	Air	high. pop.	kg	1,33E-12
Carboxylic acids, unspecified	Water	river	kg	6,35E-05	Toluene, 2-chloro-	Air	high. pop.	kg	3,50E-10
Carbonate	Water	river	kg	1,62E-06	Toluene	Air	high. pop.	kg	5,00E-06
Carbon disulfide	Water	river	kg	6,01E-08	Titanium	Air	high. pop.	kg	2,33E-07
Calcium, ion	Water	river	kg	1,26E-03	Tin	Air	high. pop.	kg	1,90E-09
Cadmium, ion	Water	river	kg	2,78E-08	Thorium-232	Air	high. pop.	Bq	2,26E-03
Butyrolactone	Water	river	kg	4,47E-12	Thorium-228	Air	high. pop.	Bq	3,59E-03
Butyl acetate	Water	river	kg	2,65E-09	Thorium	Air	high. pop.	kg	1,32E-09
Butene	Water	river	kg	1,01E-09	Thallium	Air	high. pop.	kg	7,20E-10
Bromine	Water	river	kg	1,44E-05	t-Butylamine	Air	high. pop.	kg	2,29E-09
Bromide	Water	river	kg	2,34E-06	t-Butyl methyl ether	Air	high. pop.	kg	5,09E-09
Bromate	Water	river	kg	6,63E-07	Sulfuric acid	Air	high. pop.	kg	6,53E-10
Boron	Water	river	kg	8,57E-07	Sulfur trioxide	Air	high. pop.	kg	9,29E-09
Borate	Water	river	kg	4,53E-08	Sulfur dioxide	Air	high. pop.	kg	1,75E-03
BOD5, Biological Oxygen Demand	Water	river	kg	4,13E-03	Sulfate	Air	high. pop.	kg	2,94E-05
Beryllium	Water	river	kg	5,84E-10	Styrene	Air	high. pop.	kg	4,48E-09
Benzene, ethyl-	Water	river	kg	4,14E-07	Strontium	Air	high. pop.	kg	1,26E-07
Benzene, chloro-	Water	river	kg	5,78E-08	Sodium hydroxide	Air	high. pop.	kg	3,12E-09

Benzene, 1,2-dichloro-	Water	river	kg	3,81E-09	Sodium formate	Air	high. pop.	kg	4,88E-08
Benzene	Water	river	kg	1,81E-06	Sodium dichromate	Air	high. pop.	kg	2,76E-08
Barium-140	Water	river	Bq	6,48E-05	Sodium chlorate	Air	high. pop.	kg	4,75E-08
Barium	Water	river	kg	1,52E-05	Sodium	Air	high. pop.	kg	2,02E-06
Arsenic, ion	Water	river	kg	1,62E-06	Silver	Air	high. pop.	kg	2,91E-11
AOX, Adsorbable Organic Halogen as Cl	Water	river	kg	1,03E-06	Silicon	Air	high. pop.	kg	2,68E-05
Antimony-125	Water	river	Bq	2,71E-02	Selenium	Air	high. pop.	kg	1,56E-06
Antimony-124	Water	river	Bq	2,01E-02	Scandium	Air	high. pop.	kg	6,49E-10
Antimony-122	Water	river	Bq	1,48E-05	Radon-222	Air	high. pop.	Bq	1,08E-03
Antimony	Water	river	kg	3,95E-07	Radon-220	Air	high. pop.	Bq	1,08E-03
Aniline	Water	river	kg	2,08E-09	Radium-228	Air	high. pop.	Bq	2,96E-02
Ammonium, ion	Water	river	kg	3,50E-05	Radium-226	Air	high. pop.	Bq	7,80E-03
Aluminium	Water	river	kg	1,32E-05	Radioactive species, other beta emitters	Air	high. pop.	Bq	7,36E-01
Acrylate, ion	Water	river	kg	7,36E-10	Propylene oxide	Air	high. pop.	kg	8,78E-08
Acidity, unspecified	Water	river	kg	3,86E-07	Propylamine	Air	high. pop.	kg	1,44E-10
Acetyl chloride	Water	river	kg	4,67E-10	Propionic acid	Air	high. pop.	kg	1,24E-07
Acetonitrile	Water	river	kg	3,15E-12	Propene	Air	high. pop.	kg	2,36E-06
Acetone	Water	river	kg	1,95E-09	Propane	Air	high. pop.	kg	2,77E-05
Acetic acid	Water	river	kg	9,04E-08	Propanal	Air	high. pop.	kg	1,56E-09
Acetaldehyde	Water	river	kg	1,10E-08	Potassium-40	Air	high. pop.	Bq	8,56E-03
Acenaphthylene	Water	river	kg	6,72E-12	Potassium	Air	high. pop.	kg	8,03E-06
Acenaphthene	Water	river	kg	1,07E-10	Polychlorinated biphenyls	Air	high. pop.	kg	1,13E-14
2-Propanol	Water	river	kg	1,49E-08	Polonium-210	Air	high. pop.	Bq	5,54E-02
2-Methyl-2-butene	Water	river	kg	9,97E-14	Platinum	Air	high. pop.	kg	1,13E-14
2-Methyl-1-propanol	Water	river	kg	1,03E-09	Phosphorus	Air	high. pop.	kg	1,40E-07

2-Aminopropanol	Water	river	kg	1,27E-11	Phosphine	Air	high. pop.	kg	2,69E-13
1,4-Butanediol	Water	river	kg	5,68E-12	Phenol, pentachloro-	Air	high. pop.	kg	1,97E-11
1-Propanol	Water	river	kg	7,99E-10	Phenol, 2,4-dichloro-	Air	high. pop.	kg	4,25E-12
1-Pentene	Water	river	kg	4,50E-10	Phenol	Air	high. pop.	kg	2,76E-07
1-Pentanol	Water	river	kg	5,95E-10	Pentane	Air	high. pop.	kg	3,89E-05
1-Butanol	Water	river	kg	2,04E-09	Particulates, > 2.5 um, and < 10um	Air	high. pop.	kg	7,48E-05
Zinc, ion	Water	lake	kg	3,57E-14	Particulates, > 10 um	Air	high. pop.	kg	7,14E-05
Nickel, ion	Water	lake	kg	4,92E-14	Particulates, < 2.5 um	Air	high. pop.	kg	2,18E-04
Mercury	Water	lake	kg	3,13E-16	PAH, polycyclic aromatic hydrocarbons	Air	high. pop.	kg	6,93E-08
Lead	Water	lake	kg	3,62E-14	Ozone	Air	high. pop.	kg	2,32E-09
DOC, Dissolved Organic Carbon	Water	lake	kg	7,24E-09	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	high. pop.	kg	1,26E-04
Copper, ion	Water	lake	kg	5,55E-13	Nitrogen oxides	Air	high. pop.	kg	1,86E-03
Calcium, ion	Water	lake	kg	7,10E-08	Nitrobenzene	Air	high. pop.	kg	1,16E-09
Cadmium, ion	Water	lake	kg	1,22E-14	Nitrate	Air	high. pop.	kg	2,17E-09
Arsenic, ion	Water	lake	kg	1,44E-14	Nickel	Air	high. pop.	kg	2,70E-06
Zinc, ion	Water	groundwater, long-term	kg	4,29E-04	Monoethanolamine	Air	high. pop.	kg	9,42E-07
Vanadium, ion	Water	groundwater, long-term	kg	2,83E-05	Molybdenum	Air	high. pop.	kg	8,46E-08
Tungsten	Water	groundwater, long-term	kg	3,33E-06	Methyl lactate	Air	high. pop.	kg	2,11E-10
TOC, Total Organic Carbon	Water	groundwater, long-term	kg	6,35E-04	Methyl formate	Air	high. pop.	kg	1,21E-10
Titanium, ion	Water	groundwater, long-term	kg	1,68E-04	Methyl ethyl ketone	Air	high. pop.	kg	5,58E-07
Tin, ion	Water	groundwater, long-term	kg	4,58E-06	Methyl borate	Air	high. pop.	kg	9,19E-11

Thallium	Water	groundwater, long-term	kg	4,50E-07	Methyl amine	Air	high. pop.	kg	3,91E-12
Sulfate	Water	groundwater, long-term	kg	2,70E-01	Methyl acrylate	Air	high. pop.	kg	3,53E-10
Strontium	Water	groundwater, long-term	kg	1,19E-03	Methyl acetate	Air	high. pop.	kg	6,38E-13
Sodium, ion	Water	groundwater, long-term	kg	3,23E-02	Methanol	Air	high. pop.	kg	6,57E-07
Silver, ion	Water	groundwater, long-term	kg	1,94E-07	Methanesulfonic acid	Air	high. pop.	kg	3,80E-12
Silicon	Water	groundwater, long-term	kg	5,58E-02	Methane, trifluoro-, HFC-23	Air	high. pop.	kg	3,14E-11
Selenium	Water	groundwater, long-term	kg	1,14E-05	Methane, trichlorofluoro-, CFC-11	Air	high. pop.	kg	1,60E-13
Scandium	Water	groundwater, long-term	kg	7,62E-06	Methane, tetrafluoro-, CFC-14	Air	high. pop.	kg	9,28E-12
Potassium, ion	Water	groundwater, long-term	kg	1,96E-02	Methane, tetrachloro-, CFC-10	Air	high. pop.	kg	2,45E-09
Phosphate	Water	groundwater, long-term	kg	1,03E-02	Methane, monochloro-, R-40	Air	high. pop.	kg	1,65E-12
Nitrogen, organic bound	Water	groundwater, long-term	kg	1,13E-06	Methane, fossil	Air	high. pop.	kg	1,89E-04
Nitrite	Water	groundwater, long-term	kg	3,77E-08	Methane, dichlorofluoro-, HCFC-21	Air	high. pop.	kg	9,87E-14
Nitrate	Water	groundwater, long-term	kg	3,32E-03	Methane, dichlorodifluoro-, CFC-12	Air	high. pop.	kg	7,14E-11
Nickel, ion	Water	groundwater, long-term	kg	3,33E-04	Methane, dichloro-, HCC-30	Air	high. pop.	kg	8,48E-10
Molybdenum	Water	groundwater, long-term	kg	1,47E-05	Methane, chlorodifluoro-, HCFC-22	Air	high. pop.	kg	5,98E-10
Mercury	Water	groundwater, long-term	kg	9,75E-07	Methane, bromotrifluoro-, Halon 1301	Air	high. pop.	kg	2,18E-14
Manganese	Water	groundwater, long-term	kg	2,80E-03	Methane, biogenic	Air	high. pop.	kg	2,01E-06
Magnesium	Water	groundwater, long-term	kg	3,45E-02	Mercury	Air	high. pop.	kg	8,07E-09

Lead	Water	groundwater, long-term	kg	9,27E-06	Manganese	Air	high. pop.	kg	1,75E-07
Iron, ion	Water	groundwater, long-term	kg	8,20E-03	Magnesium	Air	high. pop.	kg	3,02E-06
Iodide	Water	groundwater, long-term	kg	3,47E-12	m-Xylene	Air	high. pop.	kg	3,75E-08
Hydrogen sulfide	Water	groundwater, long-term	kg	2,17E-06	Lead-210	Air	high. pop.	Bq	3,02E-02
Heat, waste	Water	groundwater, long-term	MJ	1,57E-02	Lead	Air	high. pop.	kg	5,39E-07
Fluoride	Water	groundwater, long-term	kg	2,83E-04	Lactic acid	Air	high. pop.	kg	1,92E-10
DOC, Dissolved Organic Carbon	Water	groundwater, long-term	kg	6,35E-04	Isopropylamine	Air	high. pop.	kg	2,69E-09
Copper, ion	Water	groundwater, long-term	kg	9,23E-05	Isocyanic acid	Air	high. pop.	kg	3,59E-08
COD, Chemical Oxygen Demand	Water	groundwater, long-term	kg	1,45E-03	Iron	Air	high. pop.	kg	4,30E-06
Cobalt	Water	groundwater, long-term	kg	7,76E-05	Iodine	Air	high. pop.	kg	1,23E-08
Chromium VI	Water	groundwater, long-term	kg	3,45E-05	Hydrogen sulfide	Air	high. pop.	kg	3,16E-06
Chloride	Water	groundwater, long-term	kg	7,98E-03	Hydrogen peroxide	Air	high. pop.	kg	8,36E-10
Calcium, ion	Water	groundwater, long-term	kg	6,83E-02	Hydrogen fluoride	Air	high. pop.	kg	4,38E-06
Cadmium, ion	Water	groundwater, long-term	kg	4,02E-06	Hydrogen chloride	Air	high. pop.	kg	2,96E-05
Bromine	Water	groundwater, long-term	kg	5,94E-07	Hydrogen	Air	high. pop.	kg	3,19E-05
Boron	Water	groundwater, long-term	kg	1,10E-04	Hydrocarbons, chlorinated	Air	high. pop.	kg	3,39E-09
BOD5, Biological Oxygen Demand	Water	groundwater, long-term	kg	4,71E-04	Hydrocarbons, aromatic	Air	high. pop.	kg	6,36E-07

Beryllium	Water	groundwater, long-term	kg	5,01E-06	Hydrocarbons, aliphatic, unsaturated	Air	high. pop.	kg	2,05E-06
Barium	Water	groundwater, long-term	kg	1,41E-04	Hydrocarbons, aliphatic, alkanes, unspecified	Air	high. pop.	kg	3,18E-06
Arsenic, ion	Water	groundwater, long-term	kg	1,38E-05	Hydrocarbons, aliphatic, alkanes, cyclic	Air	high. pop.	kg	9,39E-09
Antimony	Water	groundwater, long-term	kg	3,30E-06	Hexane	Air	high. pop.	kg	1,42E-05
Ammonium, ion	Water	groundwater, long-term	kg	6,93E-07	Heptane	Air	high. pop.	kg	5,47E-06
Aluminium	Water	groundwater, long-term	kg	6,99E-03	Heat, waste	Air	high. pop.	MJ	1,39E+01
Zinc, ion	Water	groundwater	kg	7,96E-07	Formic acid	Air	high. pop.	kg	8,30E-10
Zinc	Water	groundwater	kg	1,38E-04	Formamide	Air	high. pop.	kg	4,53E-10
Xylene	Water	groundwater	kg	5,11E-10	Formaldehyde	Air	high. pop.	kg	1,72E-06
VOC, volatile organic compounds, unspecified origin	Water	groundwater	kg	3,25E-11	Fluosilicic acid	Air	high. pop.	kg	2,39E-08
Vanadium, ion	Water	groundwater	kg	1,30E-07	Fluorine	Air	high. pop.	kg	1,54E-08
Vanadium	Water	groundwater	kg	5,19E-11	Ethyne	Air	high. pop.	kg	1,03E-06
Uranium-238	Water	groundwater	Bq	2,15E-03	Ethylene oxide	Air	high. pop.	kg	5,71E-09
Tungsten	Water	groundwater	kg	2,68E-07	Ethylene diamine	Air	high. pop.	kg	9,90E-09
Toluene	Water	groundwater	kg	9,98E-11	Ethylamine	Air	high. pop.	kg	7,08E-09
TOC, Total Organic Carbon	Water	groundwater	kg	2,69E-08	Ethyl cellulose	Air	high. pop.	kg	1,13E-09
Titanium, ion	Water	groundwater	kg	1,16E-07	Ethyl acetate	Air	high. pop.	kg	5,58E-07
Titanium	Water	groundwater	kg	4,13E-11	Ethene, tetrachloro-	Air	high. pop.	kg	1,98E-13
Tin, ion	Water	groundwater	kg	3,41E-09	Ethene, chloro-	Air	high. pop.	kg	6,75E-08
Tin	Water	groundwater	kg	1,14E-14	Ethene	Air	high. pop.	kg	7,44E-06
Thorium-228	Water	groundwater	Bq	2,84E-06	Ethanol	Air	high. pop.	kg	5,46E-07

Thallium	Water	groundwater	kg	6,82E-10	Ethane, hexafluoro-, HFC-116	Air	high. pop.	kg	1,02E-09
Sulfur	Water	groundwater	kg	1,74E-13	Ethane, 1,2-dichloro-	Air	high. pop.	kg	1,21E-07
Sulfite	Water	groundwater	kg	2,37E-10	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	Air	high. pop.	kg	1,48E-11
Sulfide	Water	groundwater	kg	1,91E-09	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	high. pop.	kg	3,47E-11
Sulfate	Water	groundwater	kg	1,43E-02	Ethane, 1,1-difluoro-, HFC-152a	Air	high. pop.	kg	1,80E-10
Strontium-90	Water	groundwater	Bq	3,39E-04	Ethane	Air	high. pop.	kg	1,20E-05
Strontium	Water	groundwater	kg	1,03E-05	Dipropylamine	Air	high. pop.	kg	2,45E-10
Solved solids	Water	groundwater	kg	5,37E-05	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	high. pop.	kg	5,41E-13
Solids, inorganic	Water	groundwater	kg	5,29E-03	Dinitrogen monoxide	Air	high. pop.	kg	2,50E-05
Sodium, ion	Water	groundwater	kg	7,47E-04	Dimethyl malonate	Air	high. pop.	kg	4,72E-12
Silver, ion	Water	groundwater	kg	7,71E-09	Diethylamine	Air	high. pop.	kg	3,88E-10
Silver-110	Water	groundwater	Bq	1,05E-08	Cyanoacetic acid	Air	high. pop.	kg	3,76E-12
Silicon	Water	groundwater	kg	2,04E-04	Cyanide	Air	high. pop.	kg	2,83E-07
Selenium	Water	groundwater	kg	4,96E-07	Cumene	Air	high. pop.	kg	3,80E-07
Scandium	Water	groundwater	kg	2,50E-07	Copper	Air	high. pop.	kg	6,85E-07
Ruthenium-106	Water	groundwater	Bq	6,90E-06	Cobalt	Air	high. pop.	kg	3,42E-07
Radium-226	Water	groundwater	Bq	1,14E-01	Chromium VI	Air	high. pop.	kg	1,70E-09
Propane, 1,2-dichloro-	Water	groundwater	kg	5,15E-19	Chromium	Air	high. pop.	kg	1,48E-07
Potassium, ion	Water	groundwater	kg	2,90E-04	Chlorosulfonic acid	Air	high. pop.	kg	4,59E-12
Potassium-40	Water	groundwater	Bq	2,80E-05	Chlorosilane, trimethyl-	Air	high. pop.	kg	1,11E-10
Potassium	Water	groundwater	kg	3,38E-10	Chloroform	Air	high. pop.	kg	2,29E-09
Polonium-210	Water	groundwater	Bq	3,53E-04	Chloroacetic acid	Air	high. pop.	kg	1,78E-09
Plutonium-alpha	Water	groundwater	Bq	2,77E-05	Chlorine	Air	high. pop.	kg	1,01E-06
Phosphorus, total	Water	groundwater	kg	2,94E-05	Chloramine	Air	high. pop.	kg	8,76E-10
Phosphorus	Water	groundwater	kg	2,26E-09	Carbon monoxide, fossil	Air	high. pop.	kg	9,21E-04

Phosphate	Water	groundwater	kg	1,31E-03	Carbon monoxide, biogenic	Air	high. pop.	kg	2,29E-05
Phenol	Water	groundwater	kg	1,35E-10	Carbon disulfide	Air	high. pop.	kg	2,52E-08
Particulates, > 10 um	Water	groundwater	kg	3,31E-06	Carbon dioxide, fossil	Air	high. pop.	kg	8,37E-01
Particulates, < 10 um	Water	groundwater	kg	7,76E-12	Carbon dioxide, biogenic	Air	high. pop.	kg	2,75E-01
Nitrogen	Water	groundwater	kg	6,11E-07	Calcium	Air	high. pop.	kg	1,07E-05
Nitrate	Water	groundwater	kg	1,66E-03	Cadmium	Air	high. pop.	kg	6,35E-08
Nickel, ion	Water	groundwater	kg	6,50E-07	Butyrolactone	Air	high. pop.	kg	1,86E-12
Nickel	Water	groundwater	kg	6,38E-09	Butene	Air	high. pop.	kg	5,48E-07
Naphthalene	Water	groundwater	kg	1,81E-12	Butane	Air	high. pop.	kg	2,88E-05
Molybdenum	Water	groundwater	kg	4,49E-06	Butadiene	Air	high. pop.	kg	1,60E-10
Methanol	Water	groundwater	kg	8,20E-08	Bromine	Air	high. pop.	kg	2,99E-08
Methane, monochloro-, R-40	Water	groundwater	kg	1,68E-11	Boron trifluoride	Air	high. pop.	kg	4,96E-17
Methane, dibromo-	Water	groundwater	kg	1,89E-16	Boron	Air	high. pop.	kg	2,08E-06
Mercury	Water	groundwater	kg	1,95E-09	Beryllium	Air	high. pop.	kg	1,06E-09
Manganese-54	Water	groundwater	Bq	2,33E-04	Benzo(a)pyrene	Air	high. pop.	kg	3,48E-09
Manganese	Water	groundwater	kg	1,68E-05	Benzene, pentachloro-	Air	high. pop.	kg	1,58E-10
Magnesium	Water	groundwater	kg	3,46E-04	Benzene, hexachloro-	Air	high. pop.	kg	6,28E-11
Lead-210	Water	groundwater	Bq	2,32E-04	Benzene, ethyl-	Air	high. pop.	kg	5,60E-07
Lead	Water	groundwater	kg	5,83E-09	Benzene, 1,2-dichloro-	Air	high. pop.	kg	4,26E-10
Iron, ion	Water	groundwater	kg	2,42E-03	Benzene, 1-methyl-2-nitro-	Air	high. pop.	kg	2,38E-12
Iron	Water	groundwater	kg	4,20E-07	Benzene	Air	high. pop.	kg	6,74E-06
Iodine-131	Water	groundwater	Bq	5,12E-08	Benzaldehyde	Air	high. pop.	kg	8,33E-11
Iodine-129	Water	groundwater	Bq	1,00E-03	Barium	Air	high. pop.	kg	1,02E-07
Iodide	Water	groundwater	kg	1,20E-07	Arsine	Air	high. pop.	kg	3,62E-15
Hydroxide	Water	groundwater	kg	3,26E-10	Arsenic	Air	high. pop.	kg	9,84E-08
Hydrogen fluoride	Water	groundwater	kg	1,89E-13	Antimony	Air	high. pop.	kg	1,87E-08

Hydrogen chloride	Water	groundwater	kg	1,18E-11	Anthranilic acid	Air	high. pop.	kg	2,14E-12
Hydrogen-3, Tritium	Water	groundwater	Bq	1,02E+01	Aniline	Air	high. pop.	kg	8,66E-10
Hydrocarbons, unspecified	Water	groundwater	kg	1,68E-10	Ammonium carbonate	Air	high. pop.	kg	4,75E-09
Hydrocarbons, aromatic	Water	groundwater	kg	1,19E-10	Ammonia	Air	high. pop.	kg	1,83E-05
Hexane	Water	groundwater	kg	5,02E-16	Aluminium	Air	high. pop.	kg	6,68E-06
Heat, waste	Water	groundwater	MJ	8,76E-04	Aldehydes, unspecified	Air	high. pop.	kg	9,25E-09
Fluorine	Water	groundwater	kg	1,64E-10	Acrylic acid	Air	high. pop.	kg	3,11E-10
Fluoride	Water	groundwater	kg	4,18E-06	Acrolein	Air	high. pop.	kg	1,60E-10
Fluoranthene	Water	groundwater	kg	8,26E-15	Acetone	Air	high. pop.	kg	4,11E-07
Ethene, chloro-	Water	groundwater	kg	8,86E-17	Acetic acid	Air	high. pop.	kg	2,08E-06
Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Water	groundwater	kg	2,43E-24	Acetaldehyde	Air	high. pop.	kg	2,90E-07
Decane	Water	groundwater	kg	9,95E-10	Acenaphthene	Air	high. pop.	kg	1,91E-12
Cyanide	Water	groundwater	kg	1,35E-12	2-Propanol	Air	high. pop.	kg	1,23E-07
Curium alpha	Water	groundwater	Bq	9,14E-06	2-Nitrobenzoic acid	Air	high. pop.	kg	2,76E-12
Cresol	Water	groundwater	kg	4,50E-15	2-Methyl-1-propanol	Air	high. pop.	kg	4,29E-10
Copper, ion	Water	groundwater	kg	9,89E-08	2-Butene, 2-methyl-	Air	high. pop.	kg	4,15E-14
Copper	Water	groundwater	kg	9,17E-09	2-Aminopropanol	Air	high. pop.	kg	5,29E-12
COD, Chemical Oxygen Demand	Water	groundwater	kg	1,73E-04	1,4-Butanediol	Air	high. pop.	kg	1,42E-11
Cobalt-60	Water	groundwater	Bq	1,50E-03	1-Propanol	Air	high. pop.	kg	1,75E-09
Cobalt-58	Water	groundwater	Bq	2,68E-06	1-Pentene	Air	high. pop.	kg	1,87E-10
Cobalt	Water	groundwater	kg	1,19E-07	1-Pentanol	Air	high. pop.	kg	2,48E-10
Chrysene	Water	groundwater	kg	2,00E-14	1-Butanol	Air	high. pop.	kg	2,31E-12
Chromium, ion	Water	groundwater	kg	8,11E-08	Zinc oxide	Air		kg	2,95E-17
Chromium VI	Water	groundwater	kg	2,22E-06	Zinc	Air		kg	1,49E-06

Chromium	Water	groundwater	kg	9,64E-11	Xylene	Air	kg	1,33E-07
Chlorine	Water	groundwater	kg	8,10E-09	Xenon-138	Air	Bq	3,85E-04
Chloride	Water	groundwater	kg	4,14E-03	Xenon-137	Air	Bq	2,99E-06
Cesium-137	Water	groundwater	Bq	3,24E-03	Xenon-135	Air	Bq	1,14E-02
Cesium-134	Water	groundwater	Bq	3,64E-04	Xenon-133	Air	Bq	3,45E-02
Carbonate	Water	groundwater	kg	1,02E-08	Xenon-131m	Air	Bq	2,11E-04
Carbon-14	Water	groundwater	Bq	3,50E-04	Water	Air	kg	1,25E+02
Calcium, ion	Water	groundwater	kg	8,82E-04	VOC, volatile organic compounds	Air	kg	7,85E-09
Cadmium, ion	Water	groundwater	kg	8,15E-09	Vanadium	Air	kg	3,62E-09
Cadmium	Water	groundwater	kg	4,76E-10	Used air	Air	kg	5,45E-02
Bromine	Water	groundwater	kg	1,08E-06	Uranium-238	Air	Bq	8,44E-05
Boron	Water	groundwater	kg	7,35E-06	Uranium-235	Air	Bq	6,32E-05
BOD5, Biological Oxygen Demand	Water	groundwater	kg	5,40E-08	Uranium-234	Air	Bq	1,63E-05
Beryllium	Water	groundwater	kg	9,40E-09	Toluene	Air	kg	1,81E-07
Benzo(b)fluoranthene	Water	groundwater	kg	2,42E-15	Titanium	Air	kg	1,18E-09
Benzo(a)anthracene	Water	groundwater	kg	4,50E-15	Tin oxide	Air	kg	1,47E-17
Benzene, ethyl-	Water	groundwater	kg	1,57E-11	Tin	Air	kg	3,03E-09
Benzene	Water	groundwater	kg	1,37E-10	Thorium-232	Air	Bq	3,11E-11
Barium	Water	groundwater	kg	9,92E-08	Thorium-228	Air	Bq	1,98E-11
Arsenic, ion	Water	groundwater	kg	2,53E-06	Thallium	Air	kg	9,56E-10
AOX, Adsorbable Organic Halogen as Cl	Water	groundwater	kg	4,41E-10	Tellurium	Air	kg	6,26E-15
Antimony-125	Water	groundwater	Bq	4,89E-08	Sulfur hexafluoride	Air	kg	3,13E-07
Antimony-124	Water	groundwater	Bq	7,17E-08	Sulfur dioxide	Air	kg	1,61E-04

Antimony	Water	groundwater	kg	4,83E-07	Sulfate	Air	kg	7,47E-04
Anthracene	Water	groundwater	kg	5,30E-14	Styrene	Air	kg	8,92E-16
Ammonium, ion	Water	groundwater	kg	2,54E-07	Strontium	Air	kg	4,61E-13
Ammonia	Water	groundwater	kg	7,06E-07	Sodium	Air	kg	3,94E-11
Americium-241	Water	groundwater	Bq	6,90E-06	Silver	Air	kg	1,62E-20
Aluminium	Water	groundwater	kg	8,17E-06	Silicon	Air	kg	2,46E-14
Acrylonitrile	Water	groundwater	kg	3,77E-14	Selenium	Air	kg	1,76E-09
Acidity, unspecified	Water	groundwater	kg	2,54E-11	Scandium	Air	kg	1,26E-14
Acetic acid	Water	groundwater	kg	1,86E-10	Rhodium	Air	kg	7,00E-20
Acenaphthylene	Water	groundwater	kg	1,38E-14	Radon-222	Air	Bq	3,76E+00
Acenaphthene	Water	groundwater	kg	3,49E-14	Radon-220	Air	Bq	2,58E-09
Zinc, ion	Water		kg	3,15E-06	Radium-228	Air	Bq	3,67E-11
Xylene	Water		kg	5,93E-11	Radium-226	Air	Bq	1,24E-10
Vanadium, ion	Water		kg	2,01E-12	Propionic acid	Air	kg	1,32E-11
Toluene	Water		kg	1,17E-10	Propene	Air	kg	1,31E-10
TOC, Total Organic Carbon	Water		kg	1,84E-06	Propane	Air	kg	1,28E-07
Titanium, ion	Water		kg	1,28E-11	Propanal	Air	kg	2,84E-17
Tin, ion	Water		kg	8,15E-12	Potassium-40	Air	Bq	1,18E-10
Thallium	Water		kg	1,76E-13	Polychlorinated biphenyls	Air	kg	1,41E-09
Suspended solids, unspecified	Water		kg	1,63E-05	Polonium-210	Air	Bq	8,78E-10
Sulfur	Water		kg	1,96E-10	Plutonium-alpha	Air	Bq	4,54E-09
Sulfate	Water		kg	3,67E-08	Phosphorus	Air	kg	5,81E-11
Strontium	Water		kg	4,04E-09	Phosphine	Air	kg	1,74E-16
Solved solids	Water		kg	3,29E-06	Phosphate	Air	kg	5,06E-04
Sodium, ion	Water		kg	6,39E-04	Phenol	Air	kg	8,69E-10
Silver, ion	Water		kg	1,55E-10	Phenanthrene	Air	kg	6,89E-13
Selenium	Water		kg	1,65E-13	Pentane	Air	kg	2,81E-08
Radium-228	Water		Bq	1,38E-04	Particulates, > 2.5 um, and < 10um	Air	kg	7,97E-05
Radium-226	Water		Bq	9,81E-05	Particulates, > 10 um	Air	kg	5,41E-05

Phosphorus	Water	kg	2,21E-09	Particulates, < 2.5 um	Air	kg	1,80E-04
Phenol	Water	kg	2,22E-09	Particulates, < 10 um	Air	kg	1,30E-08
Oils, unspecified	Water	kg	9,71E-07	Palladium	Air	kg	7,25E-20
o-Xylene	Water	kg	1,63E-12	PAH, polycyclic aromatic hydrocarbons	Air	kg	1,51E-07
Nickel, ion	Water	kg	1,33E-07	Ozone	Air	kg	1,75E-05
Molybdenum	Water	kg	1,70E-12	Oxygen	Air	kg	6,26E-07
Methanol	Water	kg	6,57E-09	Octane	Air	kg	1,53E-10
Mercury	Water	kg	3,68E-09	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	kg	4,84E-04
Manganese	Water	kg	6,12E-08	Nitrogen oxides	Air	kg	4,94E-03
Magnesium	Water	kg	4,65E-08	Nitrogen	Air	kg	9,79E-06
m-Xylene	Water	kg	2,24E-12	Nitric oxide	Air	kg	1,05E-14
Lithium, ion	Water	kg	7,96E-08	Nickel	Air	kg	7,58E-08
Lead-210	Water	Bq	2,14E-05	Naphthalene	Air	kg	2,19E-12
Lead	Water	kg	8,74E-08	Molybdenum	Air	kg	2,73E-12
Iron, ion	Water	kg	3,11E-06	Methanol	Air	kg	2,05E-07
Hydrocarbons, unspecified	Water	kg	1,89E-07	Methane, trichlorofluoro-, CFC-11	Air	kg	5,50E-11
Heat, waste	Water	MJ	8,89E-03	Methane, tetrafluoro-, CFC-14	Air	kg	1,84E-07
Formaldehyde	Water	kg	2,19E-08	Methane, tetrachloro-, CFC-10	Air	kg	3,56E-15
Fluoride	Water	kg	4,41E-07	Methane, fossil	Air	kg	4,03E-05
DOC, Dissolved Organic Carbon	Water	kg	1,84E-06	Methane, dichlorodifluoro-, CFC-12	Air	kg	1,18E-11
Cyanide	Water	kg	6,89E-08	Methane, dichloro-, HCC-30	Air	kg	1,01E-18
Copper, ion	Water	kg	1,34E-07	Methane, chlorotrifluoro-, CFC-13	Air	kg	7,42E-12
COD, Chemical Oxygen Demand	Water	kg	1,49E-05	Methane, chlorodifluoro-, HCFC-22	Air	kg	1,29E-11
Cobalt	Water	kg	1,64E-12	Methane, bromo-, Halon 1001	Air	kg	1,20E-17

Chromium, ion	Water		kg	5,91E-08	Methane, biogenic	Air	kg	8,18E-06
Chromium VI	Water		kg	9,90E-09	Methane	Air	kg	1,02E-05
Chloride	Water		kg	7,70E-06	Mercury	Air	kg	9,63E-08
Calcium, ion	Water		kg	2,38E-07	Manganese	Air	kg	8,64E-08
Cadmium, ion	Water		kg	2,29E-08	Magnesium	Air	kg	1,54E-12
Bromine	Water		kg	1,59E-08	Lead compounds	Air	kg	1,69E-16
Boron	Water		kg	2,33E-10	Lead-210	Air	Bq	4,81E-10
BOD5, Biological Oxygen Demand	Water		kg	1,48E-05	Lead	Air	kg	4,11E-07
Beryllium	Water		kg	7,42E-13	Krypton-85m	Air	Bq	2,59E+02
Benzene, ethyl-	Water		kg	6,98E-12	Isoprene	Air	kg	8,49E-18
Benzene	Water		kg	1,24E-10	Iron	Air	kg	6,22E-07
Barium	Water		kg	2,11E-08	Iodine-131	Air	Bq	2,25E-06
Arsenic, ion	Water		kg	6,91E-09	Iodine-129	Air	Bq	1,50E-05
AOX, Adsorbable Organic Halogen as Cl	Water		kg	2,19E-10	Iodine	Air	kg	1,16E-15
Antimony	Water		kg	8,34E-13	Indeno(1,2,3-cd)pyrene	Air	kg	6,97E-15
Ammonium, ion	Water		kg	9,13E-10	Hydrogen sulfide	Air	kg	9,78E-07
Aluminium	Water		kg	2,35E-08	Hydrogen iodide	Air	kg	2,09E-15
Acidity, unspecified	Water		kg	1,56E-11	Hydrogen fluoride	Air	kg	1,38E-06
Acetone	Water		kg	7,40E-13	Hydrogen cyanide	Air	kg	2,43E-11
4-Methyl-2-pentanone	Water		kg	3,11E-13	Hydrogen chloride	Air	kg	8,46E-06
Zinc	Air	stratosphere + troposphere	kg	5,49E-14	Hydrogen bromide	Air	kg	1,92E-12
Water	Air	stratosphere + troposphere	kg	6,81E-08	Hydrogen-3, Tritium	Air	Bq	2,97E-02
Sulfur dioxide	Air	stratosphere + troposphere	kg	5,49E-11	Hydrogen	Air	kg	1,01E-06

Selenium	Air	stratosphere + troposphere	kg	5,49E-16	Hydrocarbons, chlorinated	Air	kg	2,11E-08
Particulates, < 2.5 um	Air	stratosphere + troposphere	kg	2,09E-12	Hydrocarbons, aromatic	Air	kg	3,10E-06
NMVOC, non-methane volatile organic compounds, unspecified origin	Air	stratosphere + troposphere	kg	3,68E-11	Hydrocarbons, aliphatic, unsaturated	Air	kg	8,55E-16
Nitrogen oxides	Air	stratosphere + troposphere	kg	7,68E-10	Hydrocarbons, aliphatic, alkanes, unspecified	Air	kg	1,13E-05
Nickel	Air	stratosphere + troposphere	kg	3,84E-15	Hexane	Air	kg	1,07E-09
Methane, fossil	Air	stratosphere + troposphere	kg	2,74E-12	Hexamethylene diamine	Air	kg	6,42E-16
Mercury	Air	stratosphere + troposphere	kg	3,84E-18	Heptane	Air	kg	2,77E-10
Lead	Air	stratosphere + troposphere	kg	1,10E-15	Helium	Air	kg	3,33E-10
Hydrogen chloride	Air	stratosphere + troposphere	kg	4,72E-14	Heat, waste	Air	MJ	1,03E+01
Heat, waste	Air	stratosphere + troposphere	MJ	2,50E-06	Furan	Air	kg	6,36E-19
Formaldehyde	Air	stratosphere + troposphere	kg	8,64E-12	Formaldehyde	Air	kg	7,54E-07
Ethylene oxide	Air	stratosphere + troposphere	kg	1,00E-11	Fluorine	Air	kg	3,12E-11

Dinitrogen monoxide	Air	stratosphere + troposphere	kg	1,65E-12	Fluoride	Air	kg	2,53E-10
Copper	Air	stratosphere + troposphere	kg	9,33E-14	Fluorene	Air	kg	2,16E-13
Chromium	Air	stratosphere + troposphere	kg	2,74E-15	Fluoranthene	Air	kg	6,80E-14
Carbon monoxide, fossil	Air	stratosphere + troposphere	kg	2,03E-10	Ethyne	Air	kg	1,34E-09
Carbon dioxide, fossil	Air	stratosphere + troposphere	kg	1,73E-07	Ethylene oxide	Air	kg	2,34E-11
Cadmium	Air	stratosphere + troposphere	kg	5,49E-16	Ethene, tetrachloro-	Air	kg	6,47E-15
Butadiene	Air	stratosphere + troposphere	kg	1,04E-12	Ethene, chloro-	Air	kg	4,12E-12
Benzene	Air	stratosphere + troposphere	kg	1,09E-12	Ethene	Air	kg	5,06E-04
Zinc	Air	low. pop., long-term	kg	1,84E-07	Ethanol	Air	kg	1,02E-09
Vanadium	Air	low. pop., long-term	kg	1,78E-07	Ethane, hexafluoro-, HFC-116	Air	kg	2,04E-08
Tungsten	Air	low. pop., long-term	kg	1,16E-08	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	kg	5,63E-11
Titanium	Air	low. pop., long-term	kg	1,88E-06	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	kg	1,16E-06
Tin	Air	low. pop., long-term	kg	5,99E-09	Ethane, 1,1,1-trichloro-, HCFC-140	Air	kg	8,17E-18
Sulfate	Air	low. pop., long-term	kg	2,65E-05	Ethane	Air	kg	1,56E-07
Strontium	Air	low. pop., long-term	kg	1,04E-07	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	kg	7,22E-13
Sodium	Air	low. pop., long-term	kg	1,69E-06	Dinitrogen monoxide	Air	kg	3,64E-05
Silver	Air	low. pop., long-term	kg	4,30E-09	Diethanolamine	Air	kg	3,30E-19

Silicon	Air	low. pop., long-term	kg	6,40E-06	Dibenz(a,h)ant hracene	Air		kg	5,84E-15
Selenium	Air	low. pop., long-term	kg	1,44E-08	Cyclohexane	Air		kg	8,04E-13
Scandium	Air	low. pop., long-term	kg	1,03E-07	Cyanide	Air		kg	2,88E-12
Radon-222	Air	low. pop., long-term	Bq	1,10E+06	Cumene	Air		kg	3,96E-19
Potassium	Air	low. pop., long-term	kg	4,91E-06	Copper	Air		kg	1,12E-06
Phosphoru s	Air	low. pop., long-term	kg	4,83E-08	Cobalt-60	Air		Bq	3,04E-07
Particulate s, > 2.5 um, and < 10um	Air	low. pop., long-term	kg	3,44E-05	Cobalt-58	Air		Bq	1,20E-08
Particulate s, > 10 um	Air	low. pop., long-term	kg	5,73E-05	Cobalt	Air		kg	8,41E-11
Particulate s, < 2.5 um	Air	low. pop., long-term	kg	2,29E-05	Chrysene	Air		kg	2,58E-14
Nitrate	Air	low. pop., long-term	kg	2,47E-07	Chromium, ion	Air		kg	4,69E-14
Nickel	Air	low. pop., long-term	kg	5,28E-08	Chromium VI	Air		kg	2,58E-11
Molybdenu m	Air	low. pop., long-term	kg	5,00E-08	Chromium	Air		kg	1,24E-07
Mercury	Air	low. pop., long-term	kg	1,98E-09	Chloroform	Air		kg	4,42E-18
Manganes e	Air	low. pop., long-term	kg	6,46E-07	Chlorine	Air		kg	2,82E-10
Magnesiu m	Air	low. pop., long-term	kg	2,87E-06	Chloride	Air		kg	1,21E-10
Lead	Air	low. pop., long-term	kg	2,57E-07	Cesium-137	Air		Bq	3,91E-06
Iron	Air	low. pop., long-term	kg	3,12E-05	Cesium-134	Air		Bq	1,92E-06
Fluorine	Air	low. pop., long-term	kg	1,75E-06	Carbon monoxide, fossil	Air		kg	3,52E-03
Copper	Air	low. pop., long-term	kg	2,43E-07	Carbon disulfide	Air		kg	3,51E-14
Cobalt	Air	low. pop., long-term	kg	2,31E-08	Carbon dioxide, land transformation	Air		kg	9,27E-03
Chromium VI	Air	low. pop., long-term	kg	1,85E-08	Carbon dioxide, fossil	Air		kg	6,91E-01
Chlorine	Air	low. pop., long-term	kg	3,56E-07	Carbon dioxide, biogenic	Air		kg	6,66E-04
Calcium	Air	low. pop., long-term	kg	9,34E-06	Carbon-14	Air		Bq	7,00E-03
Cadmium	Air	low. pop., long-term	kg	3,93E-09	Cadmium	Air		kg	4,96E-09
Boron	Air	low. pop., long-term	kg	4,83E-08	Butane	Air		kg	4,59E-08

Beryllium	Air	low. pop., long-term	kg	3,63E-09	Butadiene	Air	kg	2,43E-12
Barium	Air	low. pop., long-term	kg	1,66E-07	Bromine	Air	kg	4,69E-10
Arsenic	Air	low. pop., long-term	kg	1,52E-07	Boron	Air	kg	1,42E-09
Antimony	Air	low. pop., long-term	kg	2,59E-09	Beryllium	Air	kg	5,90E-11
Aluminium	Air	low. pop., long-term	kg	2,87E-05	Benzo(ghi)perylene	Air	kg	9,37E-15
Zirconium-95	Air	low. pop.	Bq	9,67E-07	Benzo(b)fluoranthene	Air	kg	1,87E-14
Zirconium	Air	low. pop.	kg	1,63E-09	Benzo(a)pyrene	Air	kg	2,84E-09
Zinc-65	Air	low. pop.	Bq	9,89E-07	Benzo(a)anthracene	Air	kg	1,05E-14
Zinc	Air	low. pop.	kg	2,01E-06	Benzene, hexachloro-	Air	kg	8,04E-10
Xylene	Air	low. pop.	kg	1,68E-05	Benzene, ethyl-	Air	kg	1,44E-09
Xenon-138	Air	low. pop.	Bq	9,87E-01	Benzene, 1,3,5-trimethyl-	Air	kg	1,44E-16
Xenon-137	Air	low. pop.	Bq	1,27E-01	Benzene	Air	kg	2,77E-07
Xenon-135m	Air	low. pop.	Bq	4,57E+00	Benzal chloride	Air	kg	5,23E-17
Xenon-135	Air	low. pop.	Bq	7,41E+00	Barium	Air	kg	1,83E-09
Xenon-133m	Air	low. pop.	Bq	3,71E-02	Arsine	Air	kg	1,21E-14
Xenon-133	Air	low. pop.	Bq	1,84E+01	Arsenic trioxide	Air	kg	1,46E-16
Xenon-131m	Air	low. pop.	Bq	5,26E-01	Arsenic	Air	kg	2,66E-10
Water	Air	low. pop.	kg	1,12E-08	Argon-41	Air	Bq	1,53E-02
Vanadium	Air	low. pop.	kg	9,23E-08	Antimony-124	Air	Bq	2,42E-09
Uranium alpha	Air	low. pop.	Bq	4,62E-01	Antimony	Air	kg	2,07E-10
Uranium-238	Air	low. pop.	Bq	1,52E-01	Anthracene	Air	kg	2,09E-14
Uranium-235	Air	low. pop.	Bq	4,80E-03	Ammonium, ion	Air	kg	1,79E-14
Uranium-234	Air	low. pop.	Bq	1,01E-01	Ammonia	Air	kg	3,17E-05
Uranium	Air	low. pop.	kg	6,64E-11	Aluminium	Air	kg	4,77E-05
Tungsten	Air	low. pop.	kg	2,54E-11	Aldehydes, unspecified	Air	kg	3,03E-12
Toluene	Air	low. pop.	kg	2,13E-06	Acrolein	Air	kg	5,60E-13
Titanium	Air	low. pop.	kg	2,01E-08	Acidity, unspecified	Air	kg	3,11E-11
Tin	Air	low. pop.	kg	9,03E-08	Acetone	Air	kg	5,36E-10
Thorium-234	Air	low. pop.	Bq	8,52E-03	Acetic acid	Air	kg	4,08E-07
Thorium-232	Air	low. pop.	Bq	2,76E-02	Acetaldehyde	Air	kg	3,38E-07
Thorium-230	Air	low. pop.	Bq	3,31E-02	Acenaphthene	Air	kg	7,12E-16

Thorium-228	Air	low. pop.	Bq	1,75E-02
Thorium	Air	low. pop.	kg	1,31E-10
Thallium	Air	low. pop.	kg	3,68E-11
Terpenes	Air	low. pop.	kg	1,17E-08
Sulfuric acid	Air	low. pop.	kg	1,79E-13

ANNEX D: tomato sauce quality parameters inventory

Project Tomato sauce
Product: 1 p 24oz tomato sauce
Indicator: Inventory

Substance	Compartment	Sub-compartment	Unit	Total	Substance	Compartment	Sub-compartment	Unit	Total
Chloride	Water	river, long-term	kg	3,06E-08	Xenon-135	Air	low. pop.	Bq	1,89E+00
Benzene, chloro-	Water	river, long-term	kg	4,61E-10	Xenon-133m	Air	low. pop.	Bq	1,14E-02
Zirconium-95	Water	river	Bq	6,63E-06	Xenon-133	Air	low. pop.	Bq	4,67E+00
Zinc, ion	Water	river	kg	8,58E-07	Xenon-131m	Air	low. pop.	Bq	1,36E-01
Zinc-65	Water	river	Bq	5,73E-04	Water	Air	low. pop.	kg	2,68E-09
Xylene	Water	river	kg	7,37E-07	Vanadium	Air	low. pop.	kg	3,60E-09
VOC, volatile organic compounds, unspecified origin	Water	river	kg	2,75E-06	Uranium alpha	Air	low. pop.	Bq	2,50E-02
Vanadium, ion	Water	river	kg	4,61E-08	Uranium-238	Air	low. pop.	Bq	1,74E-02
Urea	Water	river	kg	3,11E-10	Uranium-235	Air	low. pop.	Bq	2,60E-04
Uranium alpha	Water	river	Bq	4,90E-01	Uranium-234	Air	low. pop.	Bq	1,52E-02
Uranium-238	Water	river	Bq	3,72E-02	Uranium	Air	low. pop.	kg	6,98E-12
Uranium-235	Water	river	Bq	1,68E-02	Tungsten	Air	low. pop.	kg	1,38E-12
Uranium-234	Water	river	Bq	1,02E-02	Toluene	Air	low. pop.	kg	1,65E-07
Tungsten	Water	river	kg	1,75E-08	Titanium	Air	low. pop.	kg	2,11E-09
Trimethylamine	Water	river	kg	1,39E-10	Tin	Air	low. pop.	kg	6,45E-09
Toluene, 2-chloro-	Water	river	kg	5,30E-10	Thorium-234	Air	low. pop.	Bq	3,04E-03
Toluene	Water	river	kg	8,94E-07	Thorium-232	Air	low. pop.	Bq	2,51E-03
TOC, Total Organic Carbon	Water	river	kg	6,59E-04	Thorium-230	Air	low. pop.	Bq	9,13E-03
Titanium, ion	Water	river	kg	1,04E-07	Thorium-228	Air	low. pop.	Bq	2,14E-03
Tin, ion	Water	river	kg	8,49E-08	Thorium	Air	low. pop.	kg	1,37E-11
Thorium-234	Water	river	Bq	8,51E-03	Thallium	Air	low. pop.	kg	3,70E-12

Thorium-232	Water	river	Bq	5,51E-03	Terpenes	Air	low. pop.	kg	4,10E-08
Thorium-230	Water	river	Bq	1,16E+00	Sulfuric acid	Air	low. pop.	kg	6,29E-14
Thorium-228	Water	river	Bq	1,56E+00	Sulfur hexafluoride	Air	low. pop.	kg	2,53E-10
Thallium	Water	river	kg	2,24E-09	Sulfur dioxide	Air	low. pop.	kg	1,29E-03
Tellurium-132	Water	river	Bq	3,23E-07	Sulfate	Air	low. pop.	kg	3,57E-08
Tellurium-123m	Water	river	Bq	7,28E-05	Styrene	Air	low. pop.	kg	5,17E-10
Technetium-99m	Water	river	Bq	1,29E-04	Strontium	Air	low. pop.	kg	1,17E-08
t-Butylamine	Water	river	kg	1,01E-09	Sodium	Air	low. pop.	kg	9,76E-09
t-Butyl methyl ether	Water	river	kg	1,26E-11	Silver-110	Air	low. pop.	Bq	1,20E-08
Suspended solids, unspecified	Water	river	kg	3,47E-05	Silver	Air	low. pop.	kg	1,86E-13
Sulfur	Water	river	kg	6,26E-06	Silicon tetrafluoride	Air	low. pop.	kg	5,84E-10
Sulfite	Water	river	kg	1,14E-06	Silicon	Air	low. pop.	kg	4,47E-07
Sulfide	Water	river	kg	8,08E-07	Selenium	Air	low. pop.	kg	3,68E-08
Sulfate	Water	river	kg	9,95E-04	Scandium	Air	low. pop.	kg	2,40E-11
Strontium-90	Water	river	Bq	2,55E+00	Ruthenium-103	Air	low. pop.	Bq	1,21E-09
Strontium-89	Water	river	Bq	1,36E-04	Radon-222	Air	low. pop.	Bq	1,43E+03
Strontium	Water	river	kg	1,41E-05	Radon-220	Air	low. pop.	Bq	4,97E-01
Solved solids	Water	river	kg	2,48E-05	Radium-228	Air	low. pop.	Bq	3,42E-03
Solids, inorganic	Water	river	kg	6,33E-04	Radium-226	Air	low. pop.	Bq	2,77E-02
Sodium, ion	Water	river	kg	2,73E-03	Radioactive species, other beta emitters	Air	low. pop.	Bq	1,11E-05
Sodium formate	Water	river	kg	2,03E-08	Protactinium-234	Air	low. pop.	Bq	3,04E-03
Sodium-24	Water	river	Bq	4,22E-05	Propene	Air	low. pop.	kg	3,91E-07
Silver, ion	Water	river	kg	7,19E-09	Propane	Air	low. pop.	kg	7,24E-06
Silver-110	Water	river	Bq	6,23E-03	Potassium-40	Air	low. pop.	Bq	2,05E-02
Silicon	Water	river	kg	9,84E-06	Potassium	Air	low. pop.	kg	1,23E-08
Selenium	Water	river	kg	2,36E-08	Polonium-210	Air	low. pop.	Bq	3,94E-02
Scandium	Water	river	kg	1,62E-08	Plutonium-alpha	Air	low. pop.	Bq	7,14E-10
Ruthenium-103	Water	river	Bq	1,18E-06	Plutonium-238	Air	low. pop.	Bq	3,12E-10
Rubidium	Water	river	kg	7,79E-08	Platinum	Air	low. pop.	kg	2,99E-14
Radium-228	Water	river	Bq	7,79E-01	Phosphorus	Air	low. pop.	kg	5,01E-10

Radium-226	Water	river	Bq	5,93E+00	Phenol, pentachloro-	Air	low. pop.	kg	5,08E-10
Radium-224	Water	river	Bq	3,89E-01	Phenol	Air	low. pop.	kg	1,33E-08
Radioactive species, Nuclides, unspecified	Water	river	Bq	1,16E-01	Pentane	Air	low. pop.	kg	8,18E-08
Radioactive species, alpha emitters	Water	river	Bq	1,99E-03	Particulates, > 2.5 um, and < 10um	Air	low. pop.	kg	5,80E-05
Protactinium-234	Water	river	Bq	8,51E-03	Particulates, > 10 um	Air	low. pop.	kg	2,40E-04
Propylene oxide	Water	river	kg	3,31E-08	Particulates, < 2.5 um	Air	low. pop.	kg	5,15E-05
Propylamine	Water	river	kg	8,26E-11	PAH, polycyclic aromatic hydrocarbons	Air	low. pop.	kg	2,37E-08
Propionic acid	Water	river	kg	8,76E-10	Ozone	Air	low. pop.	kg	1,12E-07
Propene	Water	river	kg	5,17E-06	Noble gases, radioactive, unspecified	Air	low. pop.	Bq	2,20E+04
Propanal	Water	river	kg	2,06E-10	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	low. pop.	kg	2,90E-04
Potassium, ion	Water	river	kg	6,13E-05	Nitrogen oxides	Air	low. pop.	kg	5,36E-04
Potassium-40	Water	river	Bq	2,95E-02	Nitrate	Air	low. pop.	kg	4,59E-09
Polonium-210	Water	river	Bq	2,35E-02	Niobium-95	Air	low. pop.	Bq	5,52E-09
Phosphorus	Water	river	kg	5,87E-06	Nickel	Air	low. pop.	kg	1,20E-07
Phosphate	Water	river	kg	6,96E-06	Molybdenum	Air	low. pop.	kg	6,58E-10
Phenol	Water	river	kg	4,52E-06	Methanol	Air	low. pop.	kg	8,15E-07
PAH, polycyclic aromatic hydrocarbons	Water	river	kg	3,87E-08	Methane, monochloro-, R-40	Air	low. pop.	kg	1,09E-08
Oils, unspecified	Water	river	kg	6,30E-04	Methane, fossil	Air	low. pop.	kg	1,31E-03
Nitrogen, organic bound	Water	river	kg	6,06E-07	Methane, dichlorodifluoro-, CFC-12	Air	low. pop.	kg	2,33E-11

Nitrogen	Water	river	kg	1,21E-05	Methane, dichloro-, HCC-30	Air	low. pop.	kg	5,97E-09
Nitrobenzene	Water	river	kg	2,63E-09	Methane, chlorodifluoro-, HCFC-22	Air	low. pop.	kg	2,35E-08
Nitrite	Water	river	kg	1,82E-06	Methane, bromotrifluoro-, Halon 1301	Air	low. pop.	kg	6,62E-09
Nitrate	Water	river	kg	1,88E-04	Methane, bromochlorodifluoro-, Halon 1211	Air	low. pop.	kg	6,72E-09
Niobium-95	Water	river	Bq	7,23E-05	Methane, biogenic	Air	low. pop.	kg	6,05E-04
Nickel, ion	Water	river	kg	1,81E-07	Mercury	Air	low. pop.	kg	6,66E-09
Molybdenum-99	Water	river	Bq	5,58E-06	Manganese-54	Air	low. pop.	Bq	4,65E-08
Molybdenum	Water	river	kg	1,30E-07	Manganese	Air	low. pop.	kg	2,90E-08
Methyl formate	Water	river	kg	1,16E-11	Magnesium	Air	low. pop.	kg	2,51E-07
Methyl amine	Water	river	kg	8,34E-10	Lead-210	Air	low. pop.	Bq	2,92E-02
Methyl acrylate	Water	river	kg	1,60E-09	Lead	Air	low. pop.	kg	1,30E-07
Methyl acetate	Water	river	kg	7,00E-11	Lanthanum-140	Air	low. pop.	Bq	4,99E-07
Methanol	Water	river	kg	5,95E-08	Krypton-89	Air	low. pop.	Bq	1,11E-02
Methane, dichloro-, HCC-30	Water	river	kg	1,47E-07	Krypton-88	Air	low. pop.	Bq	3,17E-02
Mercury	Water	river	kg	3,98E-09	Krypton-87	Air	low. pop.	Bq	2,77E-02
Manganese-54	Water	river	Bq	5,00E-04	Krypton-85m	Air	low. pop.	Bq	9,59E-02
Manganese	Water	river	kg	7,43E-07	Krypton-85	Air	low. pop.	Bq	7,51E-01
Magnesium	Water	river	kg	6,88E-05	Isoprene	Air	low. pop.	kg	4,34E-09
m-Xylene	Water	river	kg	2,31E-10	Iron	Air	low. pop.	kg	2,67E-08
Lithium, ion	Water	river	kg	4,98E-09	Iodine-135	Air	low. pop.	Bq	6,33E-03
Lead-210	Water	river	Bq	2,35E-02	Iodine-133	Air	low. pop.	Bq	2,92E-03
Lead	Water	river	kg	1,88E-07	Iodine-131	Air	low. pop.	Bq	9,45E-02
Lanthanum-140	Water	river	Bq	1,62E-05	Iodine-129	Air	low. pop.	Bq	2,28E-03
Lactic acid	Water	river	kg	1,83E-10	Iodine	Air	low. pop.	kg	4,44E-08
Isopropylamine	Water	river	kg	8,24E-10	Hydrogen sulfide	Air	low. pop.	kg	3,34E-06
Iron, ion	Water	river	kg	9,45E-06	Hydrogen fluoride	Air	low. pop.	kg	4,47E-06
Iron-59	Water	river	Bq	2,62E-06	Hydrogen chloride	Air	low. pop.	kg	3,05E-05
Iodine-133	Water	river	Bq	9,54E-06	Hydrogen-3, Tritium	Air	low. pop.	Bq	2,00E+01
Iodine-131	Water	river	Bq	1,42E-04	Hydrocarbons, chlorinated	Air	low. pop.	kg	4,18E-09

Iodide	Water	river	kg	9,17E-07	Hydrocarbons, aromatic	Air	low. pop.	kg	6,82E-07
Hypochlorite	Water	river	kg	2,04E-07	Hydrocarbons, aliphatic, unsaturated	Air	low. pop.	kg	1,25E-07
Hydroxide	Water	river	kg	5,78E-09	Hydrocarbons, aliphatic, alkanes, unspecified	Air	low. pop.	kg	1,44E-06
Hydrogen sulfide	Water	river	kg	8,88E-09	Hydrocarbons, aliphatic, alkanes, cyclic	Air	low. pop.	kg	1,19E-08
Hydrogen peroxide	Water	river	kg	8,09E-09	Hexane	Air	low. pop.	kg	3,37E-08
Hydrogen-3, Tritium	Water	river	Bq	1,34E+02	Helium	Air	low. pop.	kg	5,41E-07
Hydrocarbons, unspecified	Water	river	kg	2,69E-07	Heat, waste	Air	low. pop.	MJ	2,02E+00
Hydrocarbons, aromatic	Water	river	kg	4,09E-06	Furan	Air	low. pop.	kg	9,35E-08
Hydrocarbons, aliphatic, unsaturated	Water	river	kg	9,38E-08	Formic acid	Air	low. pop.	kg	3,29E-07
Hydrocarbons, aliphatic, alkanes, unspecified	Water	river	kg	1,01E-06	Formaldehyde	Air	low. pop.	kg	3,41E-07
Heat, waste	Water	river	MJ	6,27E-01	Fluorine	Air	low. pop.	kg	4,73E-09
Formic acid	Water	river	kg	7,57E-11	Ethyne	Air	low. pop.	kg	1,15E-07
Formate	Water	river	kg	1,30E-07	Ethylene oxide	Air	low. pop.	kg	3,94E-13
Formamide	Water	river	kg	2,61E-10	Ethene, tetrachloro-	Air	low. pop.	kg	8,85E-10
Formaldehyde	Water	river	kg	6,24E-07	Ethene	Air	low. pop.	kg	7,37E-07
Fluosilicic acid	Water	river	kg	1,71E-07	Ethanol	Air	low. pop.	kg	5,46E-09
Fluoride	Water	river	kg	1,40E-05	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	low. pop.	kg	2,43E-09
Ethylene oxide	Water	river	kg	9,70E-10	Ethane, 1,2-dichloro-	Air	low. pop.	kg	8,23E-10
Ethylene diamine	Water	river	kg	1,23E-09	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	low. pop.	kg	1,59E-10
Ethylamine	Water	river	kg	2,41E-09	Ethane, 1,1,1-trichloro-, HCFC-140	Air	low. pop.	kg	4,12E-10

Ethyl acetate	Water	river	kg	3,77E-10	Ethane	Air	low. pop.	kg	2,31E-05
Ethene, chloro-	Water	river	kg	6,90E-11	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	low. pop.	kg	3,05E-14
Ethene	Water	river	kg	3,72E-08	Dinitrogen monoxide	Air	low. pop.	kg	2,32E-05
Ethanol	Water	river	kg	3,57E-08	Cyanide	Air	low. pop.	kg	1,37E-07
Ethane, 1,2-dichloro-	Water	river	kg	1,37E-08	Cumene	Air	low. pop.	kg	1,12E-10
DOC, Dissolved Organic Carbon	Water	river	kg	6,52E-04	Copper	Air	low. pop.	kg	1,24E-07
Dipropylamine	Water	river	kg	2,34E-10	Cobalt-60	Air	low. pop.	Bq	1,12E-06
Dimethylamine	Water	river	kg	2,13E-09	Cobalt-58	Air	low. pop.	Bq	1,26E-07
Diethylamine	Water	river	kg	4,95E-10	Cobalt	Air	low. pop.	kg	8,60E-09
Dichromate	Water	river	kg	2,38E-09	Chromium VI	Air	low. pop.	kg	8,52E-09
Cyanide	Water	river	kg	6,41E-08	Chromium-51	Air	low. pop.	Bq	9,08E-08
Cumene	Water	river	kg	1,39E-05	Chromium	Air	low. pop.	kg	2,77E-07
Copper, ion	Water	river	kg	1,43E-07	Chloroform	Air	low. pop.	kg	2,02E-09
COD, Chemical Oxygen Demand	Water	river	kg	2,28E-03	Chlorine	Air	low. pop.	kg	4,48E-10
Cobalt-60	Water	river	Bq	6,71E-03	Cesium-137	Air	low. pop.	Bq	1,20E-06
Cobalt-58	Water	river	Bq	8,11E-03	Cesium-134	Air	low. pop.	Bq	6,78E-08
Cobalt-57	Water	river	Bq	3,42E-05	Cerium-141	Air	low. pop.	Bq	1,42E-06
Cobalt	Water	river	kg	1,03E-08	Carbon monoxide, fossil	Air	low. pop.	kg	1,63E-04
Chromium, ion	Water	river	kg	3,72E-08	Carbon monoxide, biogenic	Air	low. pop.	kg	4,08E-06
Chromium VI	Water	river	kg	7,38E-07	Carbon disulfide	Air	low. pop.	kg	8,57E-07
Chromium-51	Water	river	Bq	1,43E-03	Carbon dioxide, land transformation	Air	low. pop.	kg	8,01E-04
Chlorosulfonic acid	Water	river	kg	3,27E-10	Carbon dioxide, fossil	Air	low. pop.	kg	1,94E-01
Chloroform	Water	river	kg	1,73E-10	Carbon dioxide, biogenic	Air	low. pop.	kg	4,43E-03
Chloroacetyl chloride	Water	river	kg	1,94E-10	Carbon-14	Air	low. pop.	Bq	2,38E+00
Chloroacetic acid	Water	river	kg	7,80E-08	Calcium	Air	low. pop.	kg	1,08E-08
Chlorine	Water	river	kg	2,60E-07	Cadmium	Air	low. pop.	kg	1,24E-08

Chlorinated solvents, unspecified	Water	river	kg	7,16E-10	Butane	Air	low. pop.	kg	1,34E-06
Chloride	Water	river	kg	6,10E-03	Butadiene	Air	low. pop.	kg	4,08E-14
Chlorate	Water	river	kg	1,92E-06	Bromine	Air	low. pop.	kg	8,44E-08
Chloramine	Water	river	kg	3,12E-09	Boron	Air	low. pop.	kg	7,71E-07
Cesium-137	Water	river	Bq	2,98E-03	Beryllium	Air	low. pop.	kg	4,60E-10
Cesium-136	Water	river	Bq	1,08E-06	Benzo(a)pyrene	Air	low. pop.	kg	1,35E-09
Cesium-134	Water	river	Bq	5,75E-04	Benzene, ethyl-	Air	low. pop.	kg	1,94E-09
Cesium	Water	river	kg	7,79E-09	Benzene	Air	low. pop.	kg	5,08E-07
Cerium-144	Water	river	Bq	1,85E-06	Barium-140	Air	low. pop.	Bq	5,84E-06
Cerium-141	Water	river	Bq	6,08E-06	Barium	Air	low. pop.	kg	1,19E-08
Carboxylic acids, unspecified	Water	river	kg	2,86E-05	Arsenic	Air	low. pop.	kg	4,65E-08
Carbonate	Water	river	kg	8,37E-07	Argon-41	Air	low. pop.	Bq	2,39E-01
Carbon disulfide	Water	river	kg	3,12E-09	Antimony-125	Air	low. pop.	Bq	8,98E-08
Calcium, ion	Water	river	kg	1,01E-03	Antimony-124	Air	low. pop.	Bq	8,61E-09
Cadmium, ion	Water	river	kg	1,91E-08	Antimony	Air	low. pop.	kg	5,39E-09
Butyrolactone	Water	river	kg	1,04E-12	Ammonia	Air	low. pop.	kg	2,99E-05
Butyl acetate	Water	river	kg	6,27E-10	Aluminium	Air	low. pop.	kg	7,51E-08
Butene	Water	river	kg	6,85E-10	Aldehydes, unspecified	Air	low. pop.	kg	2,11E-08
Bromine	Water	river	kg	5,92E-06	Aerosols, radioactive, unspecified	Air	low. pop.	Bq	1,32E-03
Bromide	Water	river	kg	1,10E-06	Actinides, radioactive, unspecified	Air	low. pop.	Bq	4,26E-02
Bromate	Water	river	kg	2,06E-07	Acrolein	Air	low. pop.	kg	5,98E-09
Boron	Water	river	kg	4,10E-07	Acetonitrile	Air	low. pop.	kg	4,92E-08
Borate	Water	river	kg	1,79E-08	Acetone	Air	low. pop.	kg	1,96E-07
BOD5, Biological Oxygen Demand	Water	river	kg	2,15E-03	Acetic acid	Air	low. pop.	kg	1,18E-06
Beryllium	Water	river	kg	8,75E-11	Acetaldehyde	Air	low. pop.	kg	1,79E-07
Benzene, ethyl-	Water	river	kg	1,87E-07	Acenaphthene	Air	low. pop.	kg	1,05E-11
Benzene, chloro-	Water	river	kg	6,21E-08	Zinc	Air	high. pop.	kg	2,10E-07

Benzene, 1,2-dichloro-	Water	river	kg	3,98E-09	Xylene	Air	high. pop.	kg	1,02E-06
Benzene	Water	river	kg	1,01E-05	Water	Air	high. pop.	kg	9,55E-10
Barium-140	Water	river	Bq	1,52E-05	Vanadium	Air	high. pop.	kg	1,06E-06
Barium	Water	river	kg	6,88E-06	Uranium-238	Air	high. pop.	Bq	8,81E-04
Arsenic, ion	Water	river	kg	4,15E-07	Uranium	Air	high. pop.	kg	2,30E-10
AOX, Adsorbable Organic Halogen as Cl	Water	river	kg	3,21E-08	Trimethylamine	Air	high. pop.	kg	5,81E-11
Antimony-125	Water	river	Bq	7,03E-04	Toluene, 2-chloro-	Air	high. pop.	kg	3,26E-10
Antimony-124	Water	river	Bq	7,14E-04	Toluene	Air	high. pop.	kg	2,30E-06
Antimony-122	Water	river	Bq	3,47E-06	Titanium	Air	high. pop.	kg	3,49E-08
Antimony	Water	river	kg	1,36E-07	Tin	Air	high. pop.	kg	2,60E-10
Aniline	Water	river	kg	1,02E-09	Thorium-232	Air	high. pop.	Bq	3,08E-04
Ammonium, ion	Water	river	kg	4,72E-05	Thorium-228	Air	high. pop.	Bq	4,84E-04
Aluminium	Water	river	kg	8,03E-06	Thorium	Air	high. pop.	kg	1,69E-10
Acrylate, ion	Water	river	kg	1,71E-10	Thallium	Air	high. pop.	kg	1,31E-10
Acidity, unspecified	Water	river	kg	1,34E-06	t-Butylamine	Air	high. pop.	kg	4,21E-10
Acetyl chloride	Water	river	kg	1,12E-10	t-Butyl methyl ether	Air	high. pop.	kg	7,61E-10
Acetonitrile	Water	river	kg	8,99E-11	Sulfuric acid	Air	high. pop.	kg	1,52E-10
Acetone	Water	river	kg	6,04E-10	Sulfur trioxide	Air	high. pop.	kg	4,17E-09
Acetic acid	Water	river	kg	7,27E-08	Sulfur dioxide	Air	high. pop.	kg	1,44E-03
Acetaldehyde	Water	river	kg	3,01E-08	Sulfate	Air	high. pop.	kg	2,07E-05
Acenaphthylene	Water	river	kg	3,03E-12	Styrene	Air	high. pop.	kg	2,03E-09
Acenaphthene	Water	river	kg	4,84E-11	Strontium	Air	high. pop.	kg	1,68E-08
2-Propanol	Water	river	kg	1,90E-09	Sodium hydroxide	Air	high. pop.	kg	7,24E-10
2-Methyl-2-butene	Water	river	kg	2,39E-14	Sodium formate	Air	high. pop.	kg	8,45E-09
2-Methyl-1-propanol	Water	river	kg	4,24E-10	Sodium dichromate	Air	high. pop.	kg	6,68E-10
2-Aminopropanol	Water	river	kg	1,45E-10	Sodium chlorate	Air	high. pop.	kg	7,95E-09

1,4-Butanediol	Water	river	kg	1,69E-10	Sodium	Air	high. pop.	kg	8,90E-07
1-Propanol	Water	river	kg	3,18E-10	Silver	Air	high. pop.	kg	1,03E-11
1-Pentene	Water	river	kg	1,08E-10	Silicon	Air	high. pop.	kg	1,91E-06
1-Pentanol	Water	river	kg	1,43E-10	Selenium	Air	high. pop.	kg	1,60E-06
1-Butanol	Water	river	kg	7,58E-10	Scandium	Air	high. pop.	kg	1,06E-10
Zinc, ion	Water	lake	kg	8,30E-15	Radon-222	Air	high. pop.	Bq	1,14E-04
Water	Water	lake	kg	9,77E-01	Radon-220	Air	high. pop.	Bq	1,25E-04
Suspended solids, unspecified	Water	lake	kg	6,45E-04	Radium-228	Air	high. pop.	Bq	5,37E-03
Phosphorus	Water	lake	kg	9,65E-06	Radium-226	Air	high. pop.	Bq	1,06E-03
Nickel, ion	Water	lake	kg	1,14E-14	Radioactive species, other beta emitters	Air	high. pop.	Bq	1,01E-01
Mercury	Water	lake	kg	7,29E-17	Propylene oxide	Air	high. pop.	kg	1,37E-08
Lead	Water	lake	kg	8,43E-15	Propylamine	Air	high. pop.	kg	3,44E-11
DOC, Dissolved Organic Carbon	Water	lake	kg	1,14E-09	Propionic acid	Air	high. pop.	kg	6,93E-08
Copper, ion	Water	lake	kg	1,29E-13	Propene	Air	high. pop.	kg	2,72E-06
Calcium, ion	Water	lake	kg	9,92E-08	Propane	Air	high. pop.	kg	1,13E-05
Cadmium, ion	Water	lake	kg	2,84E-15	Propanal	Air	high. pop.	kg	6,87E-10
BOD5, Biological Oxygen Demand	Water	lake	kg	1,61E-03	Potassium-40	Air	high. pop.	Bq	1,18E-03
Arsenic, ion	Water	lake	kg	3,35E-15	Potassium	Air	high. pop.	kg	7,85E-06
Zinc, ion	Water	ground water, long-term	kg	5,63E-05	Polychlorinated biphenyls	Air	high. pop.	kg	2,63E-15
Vanadium, ion	Water	ground water, long-term	kg	4,38E-06	Polonium-210	Air	high. pop.	Bq	7,49E-03
Tungsten	Water	ground water, long-term	kg	2,84E-07	Platinum	Air	high. pop.	kg	2,67E-15
TOC, Total Organic Carbon	Water	ground water, long-term	kg	1,79E-03	Phosphorus	Air	high. pop.	kg	1,11E-07
Titanium, ion	Water	ground water, long-	kg	6,55E-05	Phosphine	Air	high. pop.	kg	6,24E-14

		term							
Tin, ion	Water	ground water, long-term	kg	1,95E-06	Phenol, pentachloro-	Air	high. pop.	kg	3,33E-12
Thallium	Water	ground water, long-term	kg	5,26E-08	Phenol, 2,4-dichloro-	Air	high. pop.	kg	2,28E-10
Sulfate	Water	ground water, long-term	kg	1,28E-02	Phenol	Air	high. pop.	kg	4,30E-06
Strontium	Water	ground water, long-term	kg	4,74E-05	Pentane	Air	high. pop.	kg	1,79E-05
Sodium, ion	Water	ground water, long-term	kg	2,32E-03	Particulates, > 2.5 um, and < 10um	Air	high. pop.	kg	1,56E-05
Silver, ion	Water	ground water, long-term	kg	2,82E-08	Particulates, > 10 um	Air	high. pop.	kg	2,86E-04
Silicon	Water	ground water, long-term	kg	3,31E-03	Particulates, < 2.5 um	Air	high. pop.	kg	9,02E-05
Selenium	Water	ground water, long-term	kg	5,63E-07	PAH, polycyclic aromatic hydrocarbons	Air	high. pop.	kg	3,94E-08
Scandium	Water	ground water, long-term	kg	4,34E-07	Ozone	Air	high. pop.	kg	1,73E-08
Potassium, ion	Water	ground water, long-term	kg	9,85E-04	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	high. pop.	kg	4,55E-05
Phosphate	Water	ground water, long-term	kg	4,22E-04	Nitrogen oxides	Air	high. pop.	kg	8,96E-04
Nitrogen, organic bound	Water	ground water, long-term	kg	2,22E-05	Nitrobenzene	Air	high. pop.	kg	6,56E-10
Nitrite	Water	ground water, long-term	kg	7,43E-07	Nitrate	Air	high. pop.	kg	8,52E-10
Nitrate	Water	ground water, long-term	kg	1,33E-04	Nickel	Air	high. pop.	kg	3,42E-07
Nickel, ion	Water	ground water, long-term	kg	1,82E-05	Monoethanolamine	Air	high. pop.	kg	3,55E-08

Molybdenum	Water	ground water, long-term	kg	7,60E-07	Molybdenum	Air	high. pop.	kg	1,04E-08
Mercury	Water	ground water, long-term	kg	7,06E-08	Methyl lactate	Air	high. pop.	kg	8,38E-11
Manganese	Water	ground water, long-term	kg	1,50E-04	Methyl formate	Air	high. pop.	kg	2,91E-11
Magnesium	Water	ground water, long-term	kg	1,53E-03	Methyl ethyl ketone	Air	high. pop.	kg	1,30E-07
Lead	Water	ground water, long-term	kg	1,41E-05	Methyl borate	Air	high. pop.	kg	2,70E-11
Iron, ion	Water	ground water, long-term	kg	5,01E-04	Methyl amine	Air	high. pop.	kg	3,47E-10
Iodide	Water	ground water, long-term	kg	7,56E-11	Methyl acrylate	Air	high. pop.	kg	8,19E-11
Hydrogen sulfide	Water	ground water, long-term	kg	4,16E-05	Methyl acetate	Air	high. pop.	kg	2,92E-11
Heat, waste	Water	ground water, long-term	MJ	2,69E-01	Methanol	Air	high. pop.	kg	4,20E-07
Fluoride	Water	ground water, long-term	kg	4,57E-05	Methanesulfonic acid	Air	high. pop.	kg	1,08E-10
DOC, Dissolved Organic Carbon	Water	ground water, long-term	kg	1,79E-03	Methane, trifluoro-, HFC-23	Air	high. pop.	kg	7,69E-12
Copper, ion	Water	ground water, long-term	kg	2,98E-05	Methane, trichlorofluoro-, CFC-11	Air	high. pop.	kg	3,92E-14
COD, Chemical Oxygen Demand	Water	ground water, long-term	kg	2,06E-03	Methane, tetrafluoro-, CFC-14	Air	high. pop.	kg	3,26E-12
Cobalt	Water	ground water, long-term	kg	3,65E-06	Methane, tetrachloro-, CFC-10	Air	high. pop.	kg	1,44E-09
Chromium VI	Water	ground water, long-term	kg	3,03E-06	Methane, monochloro-, R-40	Air	high. pop.	kg	5,91E-13
Chloride	Water	ground water, long-term	kg	9,93E-04	Methane, fossil	Air	high. pop.	kg	1,52E-04

Calcium, ion	Water	ground water, long-term	kg	2,32E-02	Methane, dichlorofluoro-, HCFC-21	Air	high. pop.	kg	2,42E-14
Cadmium, ion	Water	ground water, long-term	kg	5,79E-07	Methane, dichlorodifluoro-, CFC-12	Air	high. pop.	kg	2,30E-11
Bromine	Water	ground water, long-term	kg	3,43E-07	Methane, dichloro-, HCC-30	Air	high. pop.	kg	3,92E-10
Boron	Water	ground water, long-term	kg	8,80E-06	Methane, chlorodifluoro-, HCFC-22	Air	high. pop.	kg	1,60E-10
BOD5, Biological Oxygen Demand	Water	ground water, long-term	kg	5,10E-04	Methane, bromotrifluoro-, Halon 1301	Air	high. pop.	kg	3,01E-15
Beryllium	Water	ground water, long-term	kg	2,44E-07	Methane, biogenic	Air	high. pop.	kg	2,77E-05
Barium	Water	ground water, long-term	kg	9,15E-06	Mercury	Air	high. pop.	kg	2,22E-09
Arsenic, ion	Water	ground water, long-term	kg	1,21E-06	Manganese	Air	high. pop.	kg	8,12E-08
Antimony	Water	ground water, long-term	kg	3,28E-07	Magnesium	Air	high. pop.	kg	4,70E-07
Ammonium, ion	Water	ground water, long-term	kg	1,36E-05	m-Xylene	Air	high. pop.	kg	3,78E-08
Aluminium	Water	ground water, long-term	kg	4,29E-03	Lead-210	Air	high. pop.	Bq	4,09E-03
Zinc, ion	Water	ground water	kg	5,88E-08	Lead	Air	high. pop.	kg	2,23E-07
Zinc	Water	ground water	kg	2,26E-11	Lactic acid	Air	high. pop.	kg	7,63E-11
Xylene	Water	ground water	kg	3,73E-11	Isopropylamine	Air	high. pop.	kg	3,43E-10
Water	Water	ground water	kg	9,47E-01	Isocyanic acid	Air	high. pop.	kg	6,58E-09
VOC, volatile organic compounds, unspecified origin	Water	ground water	kg	3,48E-12	Iron	Air	high. pop.	kg	5,12E-07
Vanadium, ion	Water	ground water	kg	3,52E-09	Iodine	Air	high. pop.	kg	1,15E-09
Vanadium	Water	ground water	kg	6,35E-12	Hydrogen sulfide	Air	high. pop.	kg	8,82E-08

Uranium-238	Water	ground water	Bq	3,73E-04	Hydrogen peroxide	Air	high. pop.	kg	1,94E-10
Tungsten	Water	ground water	kg	8,38E-09	Hydrogen fluoride	Air	high. pop.	kg	4,10E-06
Toluene	Water	ground water	kg	8,95E-12	Hydrogen chloride	Air	high. pop.	kg	1,50E-05
TOC, Total Organic Carbon	Water	ground water	kg	2,24E-09	Hydrogen	Air	high. pop.	kg	1,52E-05
Titanium, ion	Water	ground water	kg	3,64E-09	Hydrocarbons, chlorinated	Air	high. pop.	kg	1,17E-09
Titanium	Water	ground water	kg	3,77E-12	Hydrocarbons, aromatic	Air	high. pop.	kg	4,80E-07
Tin, ion	Water	ground water	kg	2,96E-10	Hydrocarbons, aliphatic, unsaturated	Air	high. pop.	kg	1,07E-06
Tin	Water	ground water	kg	1,26E-15	Hydrocarbons, aliphatic, alkanes, unspecified	Air	high. pop.	kg	1,39E-06
Thorium-228	Water	ground water	Bq	2,29E-06	Hydrocarbons, aliphatic, alkanes, cyclic	Air	high. pop.	kg	3,93E-07
Thallium	Water	ground water	kg	4,54E-11	Hexane	Air	high. pop.	kg	4,17E-05
Sulfur	Water	ground water	kg	1,74E-14	Heptane	Air	high. pop.	kg	2,52E-06
Sulfite	Water	ground water	kg	2,97E-11	Heat, waste	Air	high. pop.	MJ	7,83E+00
Sulfide	Water	ground water	kg	2,36E-10	Formic acid	Air	high. pop.	kg	1,94E-10
Sulfate	Water	ground water	kg	5,42E-04	Formamide	Air	high. pop.	kg	1,09E-10
Strontium-90	Water	ground water	Bq	4,61E-05	Formaldehyde	Air	high. pop.	kg	1,71E-06
Strontium	Water	ground water	kg	7,24E-07	Fluosilicic acid	Air	high. pop.	kg	9,53E-08
Solved solids	Water	ground water	kg	9,52E-06	Fluorine	Air	high. pop.	kg	1,66E-08
Solids, inorganic	Water	ground water	kg	1,06E-04	Ethyne	Air	high. pop.	kg	6,35E-08
Sodium, ion	Water	ground water	kg	1,70E-05	Ethylene oxide	Air	high. pop.	kg	6,99E-10
Silver, ion	Water	ground water	kg	3,90E-10	Ethylene diamine	Air	high. pop.	kg	5,14E-10
Silver-110	Water	ground water	Bq	1,44E-09	Ethylamine	Air	high. pop.	kg	1,00E-09
Silicon	Water	ground water	kg	5,38E-06	Ethyl cellulose	Air	high. pop.	kg	2,62E-10
Selenium	Water	ground water	kg	7,78E-09	Ethyl acetate	Air	high. pop.	kg	1,30E-07
Scandium	Water	ground water	kg	3,68E-09	Ethene, tetrachloro-	Air	high. pop.	kg	6,40E-14
Ruthenium-106	Water	ground water	Bq	9,45E-07	Ethene, chloro-	Air	high. pop.	kg	3,57E-09

Radium-226	Water	ground water	Bq	1,58E-02	Ethene	Air	high. pop.	kg	9,21E-07
Propane, 1,2-dichloro-	Water	ground water	kg	5,72E-20	Ethanol	Air	high. pop.	kg	3,52E-07
Potassium, ion	Water	ground water	kg	6,64E-06	Ethane, hexafluoro-, HFC-116	Air	high. pop.	kg	2,38E-10
Potassium-40	Water	ground water	Bq	2,26E-05	Ethane, 1,2-dichloro-	Air	high. pop.	kg	1,19E-08
Potassium	Water	ground water	kg	2,63E-11	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	Air	high. pop.	kg	3,43E-12
Polonium-210	Water	ground water	Bq	2,84E-04	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	high. pop.	kg	8,50E-12
Plutonium-alpha	Water	ground water	Bq	3,78E-06	Ethane, 1,1-difluoro-, HFC-152a	Air	high. pop.	kg	6,34E-11
Phosphorus	Water	ground water	kg	6,73E-05	Ethane	Air	high. pop.	kg	3,06E-06
Phosphate	Water	ground water	kg	6,36E-05	Dipropylamine	Air	high. pop.	kg	9,74E-11
Phenol	Water	ground water	kg	1,54E-11	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	high. pop.	kg	4,84E-14
Particulates, > 10 um	Water	ground water	kg	3,25E-07	Dinitrogen monoxide	Air	high. pop.	kg	1,30E-05
Particulates, < 10 um	Water	ground water	kg	5,55E-13	Dimethyl malonate	Air	high. pop.	kg	1,35E-10
Nitrogen	Water	ground water	kg	3,22E-04	Diethylamine	Air	high. pop.	kg	2,06E-10
Nitrate	Water	ground water	kg	7,31E-04	Cyanoacetic acid	Air	high. pop.	kg	1,07E-10
Nickel, ion	Water	ground water	kg	3,64E-08	Cyanide	Air	high. pop.	kg	1,51E-08
Nickel	Water	ground water	kg	4,51E-10	Cumene	Air	high. pop.	kg	5,80E-06
Naphthalene	Water	ground water	kg	2,21E-13	Copper	Air	high. pop.	kg	1,54E-07
Molybdenum	Water	ground water	kg	6,35E-08	Cobalt	Air	high. pop.	kg	4,94E-08
Methanol	Water	ground water	kg	5,80E-09	Chromium VI	Air	high. pop.	kg	4,81E-10
Methane, monochloro-, R-40	Water	ground water	kg	1,20E-12	Chromium	Air	high. pop.	kg	3,73E-08
Methane, dibromo-	Water	ground water	kg	7,20E-17	Chlorosulfonic acid	Air	high. pop.	kg	1,31E-10
Mercury	Water	ground water	kg	9,93E-11	Chlorosilane, trimethyl-	Air	high. pop.	kg	3,90E-11
Manganese-54	Water	ground water	Bq	3,19E-05	Chloroform	Air	high. pop.	kg	1,65E-09
Manganese	Water	ground water	kg	8,78E-07	Chloroacetic acid	Air	high. pop.	kg	2,76E-09

Magnesium	Water	ground water	kg	1,62E-05	Chlorine	Air	high. pop.	kg	5,56E-07
Lead-210	Water	ground water	Bq	1,87E-04	Chloramine	Air	high. pop.	kg	3,47E-10
Lead	Water	ground water	kg	4,52E-10	Carbon monoxide, fossil	Air	high. pop.	kg	1,31E-04
Iron, ion	Water	ground water	kg	4,74E-05	Carbon monoxide, biogenic	Air	high. pop.	kg	2,68E-03
Iron	Water	ground water	kg	4,24E-08	Carbon disulfide	Air	high. pop.	kg	1,37E-09
Iodine-131	Water	ground water	Bq	7,01E-09	Carbon dioxide, fossil	Air	high. pop.	kg	4,41E-01
Iodine-129	Water	ground water	Bq	1,37E-04	Carbon dioxide, biogenic	Air	high. pop.	kg	4,61E-02
Iodide	Water	ground water	kg	2,61E-09	Calcium	Air	high. pop.	kg	2,34E-06
Hydroxide	Water	ground water	kg	8,10E-09	Cadmium	Air	high. pop.	kg	2,58E-08
Hydrogen fluoride	Water	ground water	kg	1,63E-14	Butyrolactone	Air	high. pop.	kg	4,33E-13
Hydrogen chloride	Water	ground water	kg	8,31E-13	Butene	Air	high. pop.	kg	2,46E-07
Hydrogen-3, Tritium	Water	ground water	Bq	1,40E+00	Butane	Air	high. pop.	kg	1,30E-05
Hydrocarbons, unspecified	Water	ground water	kg	2,59E-11	Butadiene	Air	high. pop.	kg	3,83E-11
Hydrocarbons, aromatic	Water	ground water	kg	1,17E-11	Bromine	Air	high. pop.	kg	2,16E-08
Hexane	Water	ground water	kg	5,07E-17	Boron trifluoride	Air	high. pop.	kg	1,15E-17
Heat, waste	Water	ground water	MJ	1,06E-04	Boron	Air	high. pop.	kg	1,07E-07
Fluorine	Water	ground water	kg	1,16E-11	Beryllium	Air	high. pop.	kg	1,50E-10
Fluoride	Water	ground water	kg	3,93E-07	Benzo(a)pyrene	Air	high. pop.	kg	2,95E-10
Fluoranthene	Water	ground water	kg	8,90E-16	Benzene, pentachloro-	Air	high. pop.	kg	7,19E-12
Ethene, chloro-	Water	ground water	kg	1,36E-17	Benzene, hexachloro-	Air	high. pop.	kg	2,87E-12
Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Water	ground water	kg	3,73E-25	Benzene, ethyl-	Air	high. pop.	kg	2,57E-07
Decane	Water	ground water	kg	8,70E-11	Benzene, 1,2-dichloro-	Air	high. pop.	kg	5,72E-10
Cyanide	Water	ground water	kg	7,46E-13	Benzene, 1-methyl-2-nitro-	Air	high. pop.	kg	1,09E-10
Curium alpha	Water	ground water	Bq	1,25E-06	Benzene	Air	high. pop.	kg	6,82E-06

Cresol	Water	ground water	kg	4,51E-16	Benzaldehyde	Air	high. pop.	kg	2,66E-11
Copper, ion	Water	ground water	kg	6,63E-09	Barium	Air	high. pop.	kg	1,26E-08
Copper	Water	ground water	kg	6,47E-10	Arsine	Air	high. pop.	kg	8,42E-16
COD, Chemical Oxygen Demand	Water	ground water	kg	1,21E-05	Arsenic	Air	high. pop.	kg	2,56E-08
Cobalt-60	Water	ground water	Bq	2,06E-04	Antimony	Air	high. pop.	kg	1,50E-08
Cobalt-58	Water	ground water	Bq	3,67E-07	Anthranilic acid	Air	high. pop.	kg	9,60E-11
Cobalt	Water	ground water	kg	6,24E-09	Aniline	Air	high. pop.	kg	4,17E-10
Chrysene	Water	ground water	kg	2,17E-15	Ammonium carbonate	Air	high. pop.	kg	1,60E-10
Chromium, ion	Water	ground water	kg	8,23E-09	Ammonia	Air	high. pop.	kg	2,42E-05
Chromium VI	Water	ground water	kg	2,72E-08	Aluminium	Air	high. pop.	kg	1,03E-06
Chromium	Water	ground water	kg	1,03E-11	Aldehydes, unspecified	Air	high. pop.	kg	1,37E-09
Chlorine	Water	ground water	kg	9,30E-10	Acrylic acid	Air	high. pop.	kg	7,22E-11
Chloride	Water	ground water	kg	5,90E-04	Acrolein	Air	high. pop.	kg	5,11E-11
Cesium-137	Water	ground water	Bq	4,44E-04	Acetone	Air	high. pop.	kg	2,05E-07
Cesium-134	Water	ground water	Bq	4,91E-05	Acetic acid	Air	high. pop.	kg	1,24E-06
Carbonate	Water	ground water	kg	1,25E-09	Acetaldehyde	Air	high. pop.	kg	1,98E-07
Carbon-14	Water	ground water	Bq	4,79E-05	Acenaphthene	Air	high. pop.	kg	1,95E-13
Calcium, ion	Water	ground water	kg	4,15E-05	2-Propanol	Air	high. pop.	kg	2,83E-08
Cadmium, ion	Water	ground water	kg	9,54E-10	2-Nitrobenzoic acid	Air	high. pop.	kg	1,26E-10
Cadmium	Water	ground water	kg	3,54E-11	2-Methyl-1-propanol	Air	high. pop.	kg	1,77E-10
Bromine	Water	ground water	kg	2,13E-08	2-Butene, 2-methyl-	Air	high. pop.	kg	9,96E-15
Boron	Water	ground water	kg	6,56E-07	2-Aminopropanol	Air	high. pop.	kg	5,94E-11
BOD5, Biological Oxygen Demand	Water	ground water	kg	9,12E-09	1,4-Butanediol	Air	high. pop.	kg	4,22E-10
Beryllium	Water	ground water	kg	7,18E-10	1-Propanol	Air	high. pop.	kg	9,81E-10
Benzo(b)fluoranthene	Water	ground water	kg	2,34E-16	1-Pentene	Air	high. pop.	kg	4,49E-11

Benzo(a)anthracene	Water	ground water	kg	5,03E-16	1-Pentanol	Air	high. pop.	kg	5,94E-11
Benzene, ethyl-	Water	ground water	kg	1,29E-12	1-Butanol	Air	high. pop.	kg	1,14E-10
Benzene	Water	ground water	kg	1,29E-11	Zirconium-95	Air		Bq	5,04E-11
Barium	Water	ground water	kg	6,05E-09	Zirconium	Air		kg	1,28E-12
Arsenic, ion	Water	ground water	kg	4,66E-08	Zinc oxide	Air		kg	4,14E-18
AOX, Adsorbable Organic Halogen as Cl	Water	ground water	kg	4,33E-11	Zinc-65	Air		Bq	3,43E-09
Antimony-125	Water	ground water	Bq	6,69E-09	Zinc	Air		kg	2,04E-07
Antimony-124	Water	ground water	Bq	9,82E-09	Xylene	Air		kg	1,72E-06
Antimony	Water	ground water	kg	9,33E-09	Xenon-138	Air		Bq	3,13E-04
Anthracene	Water	ground water	kg	6,41E-15	Xenon-137	Air		Bq	2,38E-05
Ammonium, ion	Water	ground water	kg	6,41E-08	Xenon-135m	Air		Bq	9,60E-04
Ammonia	Water	ground water	kg	5,00E-08	Xenon-135	Air		Bq	1,05E-02
Americium-241	Water	ground water	Bq	9,45E-07	Xenon-133m	Air		Bq	2,56E-05
Aluminium	Water	ground water	kg	2,94E-07	Xenon-133	Air		Bq	5,61E-02
Acrylonitrile	Water	ground water	kg	4,18E-15	Xenon-131m	Air		Bq	2,17E-04
Acidity, unspecified	Water	ground water	kg	3,23E-12	Water	Air		kg	1,91E-01
Acetic acid	Water	ground water	kg	1,71E-11	VOC, volatile organic compounds	Air		kg	7,96E-10
Acenaphthylene	Water	ground water	kg	1,61E-15	Vanadium	Air		kg	2,30E-09
Acenaphthene	Water	ground water	kg	4,02E-15	Used air	Air		kg	4,04E-03
Zirconium-95	Water		Bq	3,92E-06	Uranium alpha	Air		Bq	1,65E-05
Zinc, ion	Water		kg	4,72E-07	Uranium-238	Air		Bq	1,90E-05
Zinc-65	Water		Bq	7,47E-07	Uranium-235	Air		Bq	8,91E-06
Yttrium-90	Water		Bq	1,33E-09	Uranium-234	Air		Bq	7,77E-06
Xylene	Water		kg	5,72E-08	Uranium	Air		kg	5,98E-13

VOC, volatile organic compounds as C	Water	kg	2,77E-09	Toluene	Air	kg	2,56E-06
Vanadium, ion	Water	kg	2,44E-09	Titanium	Air	kg	2,13E-10
Uranium alpha	Water	Bq	5,59E-04	Tin oxide	Air	kg	2,07E-18
Uranium-238	Water	Bq	2,90E-05	Tin	Air	kg	8,29E-10
Uranium-235	Water	Bq	1,70E-05	Thorium-234	Air	Bq	4,61E-07
Uranium-234	Water	Bq	1,14E-05	Thorium-232	Air	Bq	6,97E-07
Undissolved substances	Water	kg	1,71E-05	Thorium-230	Air	Bq	5,13E-06
Tungsten	Water	kg	2,00E-12	Thorium-228	Air	Bq	1,10E-06
Triethylene glycol	Water	kg	3,42E-07	Thorium	Air	kg	5,94E-13
Tributyltin compounds	Water	kg	1,52E-11	Thallium	Air	kg	1,28E-10
Toluene	Water	kg	1,03E-07	Tellurium-123m	Air	Bq	3,46E-09
TOC, Total Organic Carbon	Water	kg	5,68E-06	Tellurium	Air	kg	6,03E-16
Titanium, ion	Water	kg	2,07E-08	Technetium-99	Air	Bq	3,23E-11
Tin, ion	Water	kg	5,98E-09	t-Butyl methyl ether	Air	kg	7,36E-13
Thorium-234	Water	Bq	8,63E-06	Sulfur oxides	Air	kg	5,84E-06
Thorium-232	Water	Bq	1,35E-06	Sulfur hexafluoride	Air	kg	1,01E-08
Thorium-230	Water	Bq	1,34E-03	Sulfur dioxide	Air	kg	4,69E-04
Thorium-228	Water	Bq	1,59E-03	Sulfate	Air	kg	1,16E-10
Thallium	Water	kg	1,29E-10	Styrene	Air	kg	1,71E-15
Terephthalate, dimethyl	Water	kg	6,90E-12	Strontium-90	Air	Bq	7,62E-07
Tellurium-132	Water	Bq	1,98E-10	Strontium-89	Air	Bq	1,38E-09
Tellurium-123m	Water	Bq	4,84E-10	Strontium	Air	kg	3,41E-11
Technetium-99m	Water	Bq	5,41E-09	Sodium	Air	kg	7,80E-10
Technetium-99	Water	Bq	4,84E-05	Silver-110	Air	Bq	7,76E-10

t-Butyl methyl ether	Water	kg	6,06E-14	Silver	Air	kg	2,28E-21
Suspended solids, unspecified	Water	kg	3,21E-06	Silicon	Air	kg	6,16E-09
Sulfur trioxide	Water	kg	6,22E-11	Silicates, unspecified	Air	kg	7,78E-11
Sulfur	Water	kg	1,44E-07	Selenium	Air	kg	8,53E-10
Sulfide	Water	kg	2,68E-10	Scandium	Air	kg	3,59E-13
Sulfate	Water	kg	9,29E-06	Ruthenium-106	Air	Bq	4,61E-06
Strontium-90	Water	Bq	9,23E-05	Ruthenium-103	Air	Bq	8,03E-12
Strontium-89	Water	Bq	2,59E-08	Rhodium	Air	kg	1,07E-20
Strontium	Water	kg	3,02E-06	Radon-222	Air	Bq	1,74E+00
Solved substances	Water	kg	7,69E-08	Radon-220	Air	Bq	1,10E-04
Solved solids	Water	kg	2,42E-03	Radium-228	Air	Bq	1,30E-06
Sodium, ion	Water	kg	6,74E-04	Radium-226	Air	Bq	1,69E-05
Sodium-24	Water	Bq	3,53E-07	Radioactive species, other beta emitters	Air	Bq	1,12E-10
Silver, ion	Water	kg	1,14E-07	Protactinium-234	Air	Bq	4,61E-07
Silver-110	Water	Bq	5,29E-06	Propionic acid	Air	kg	1,56E-08
Silver	Water	kg	1,12E-11	Propene	Air	kg	1,32E-09
Silicon	Water	kg	2,64E-09	Propane	Air	kg	1,02E-06
Selenium	Water	kg	1,08E-09	Propanal	Air	kg	2,08E-14
Salts, unspecified	Water	kg	1,13E-07	Promethium-147	Air	Bq	3,92E-07
Ruthenium-106	Water	Bq	4,61E-04	Potassium-40	Air	Bq	2,64E-06
Ruthenium-103	Water	Bq	3,85E-09	Potassium	Air	kg	1,72E-08
Ruthenium	Water	kg	7,93E-11	Polychlorinated biphenyls	Air	kg	1,50E-10
Radium-228	Water	Bq	1,02E-01	Polonium-210	Air	Bq	2,21E-05
Radium-226	Water	Bq	1,08E-01	Plutonium-alpha	Air	Bq	4,65E-08
Radium-224	Water	Bq	3,96E-04	Plutonium-241	Air	Bq	4,13E-06
Radioactive species, Nuclides, unspecified	Water	Bq	4,18E-09	Plutonium-238	Air	Bq	1,72E-12

Radioactive species, from fission and activation	Water	Bq	5,69E-06	Platinum	Air	kg	4,25E-14
Radioactive species, alpha emitters	Water	Bq	6,25E-10	Phosphorus, total	Air	kg	3,80E-11
Protactinium -234	Water	Bq	8,56E-06	Phosphorus	Air	kg	2,32E-10
Potassium-40	Water	Bq	7,26E-06	Phosphine	Air	kg	2,29E-17
Potassium	Water	kg	1,41E-07	Phenol, pentachloro-	Air	kg	6,47E-17
Polonium-210	Water	Bq	5,79E-06	Phenol	Air	kg	4,83E-10
Plutonium-alpha	Water	Bq	7,62E-06	Phenanthrene	Air	kg	6,84E-14
Plutonium-241	Water	Bq	1,86E-04	Pentane	Air	kg	1,18E-06
Phthalate, p-dibutyl-	Water	kg	1,09E-12	Particulates, > 2.5 um, and < 10um	Air	kg	2,49E-05
Phthalate, dioctyl-	Water	kg	3,32E-16	Particulates, > 10 um (process)	Air	kg	8,62E-07
Phosphorus compounds, unspecified	Water	kg	1,38E-10	Particulates, > 10 um	Air	kg	3,44E-05
Phosphorus	Water	kg	4,45E-09	Particulates, < 2.5 um	Air	kg	6,12E-05
Phosphate	Water	kg	1,64E-04	Particulates, < 10 um (stationary)	Air	kg	7,05E-07
Phenols, unspecified	Water	kg	1,77E-08	Particulates, < 10 um (mobile)	Air	kg	1,40E-08
Phenol	Water	kg	2,88E-08	Particulates, < 10 um	Air	kg	1,98E-09
PAH, polycyclic aromatic hydrocarbons	Water	kg	1,16E-10	Palladium	Air	kg	1,11E-20
Oils, unspecified	Water	kg	2,50E-06	PAH, polycyclic aromatic hydrocarbons	Air	kg	2,77E-07
o-Xylene	Water	kg	1,20E-09	Ozone	Air	kg	9,05E-07

Nitrogen, total	Water	kg	1,17E-08	Oxygen	Air	kg	6,73E-08
Nitrogen, organic bound	Water	kg	1,48E-09	Octane	Air	kg	1,91E-11
Nitrite	Water	kg	7,63E-11	Noble gases, radioactive, unspecified	Air	Bq	1,21E-04
Nitrate	Water	kg	7,30E-09	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	kg	1,82E-04
Niobium-95	Water	Bq	6,51E-09	Nitrogen oxides	Air	kg	1,85E-03
Nickel, ion	Water	kg	2,52E-08	Nitrogen	Air	kg	4,24E-06
Neptunium-237	Water	Bq	1,22E-07	Nitric oxide	Air	kg	1,10E-15
Molybdenum-99	Water	Bq	8,03E-10	Niobium-95	Air	Bq	1,39E-10
Molybdenum	Water	kg	1,77E-09	Nickel	Air	kg	1,16E-08
Methanol	Water	kg	1,33E-08	Neptunium-237	Air	Bq	7,62E-13
Methane, tetrachloro-, CFC-10	Water	kg	1,11E-14	Naphthalene	Air	kg	2,18E-13
Methane, dichloro-, HCC-30	Water	kg	2,39E-09	Molybdenum	Air	kg	1,37E-11
Mercury	Water	kg	4,87E-10	Methanol	Air	kg	5,90E-08
Manganese-54	Water	Bq	6,51E-05	Methane, trichlorofluoro-, CFC-11	Air	kg	7,34E-12
Manganese	Water	kg	6,69E-08	Methane, tetrafluoro-, CFC-14	Air	kg	7,34E-07
Magnesium	Water	kg	3,43E-05	Methane, tetrachloro-, CFC-10	Air	kg	4,93E-12
m-Xylene	Water	kg	1,65E-09	Methane, fossil	Air	kg	2,00E-04
Lithium, ion	Water	kg	5,85E-05	Methane, dichlorofluoro-, HCFC-21	Air	kg	9,91E-11
Lead-210	Water	Bq	1,57E-02	Methane, dichlorodifluoro-, CFC-12	Air	kg	1,58E-12
Lead	Water	kg	3,09E-08	Methane, dichloro-, HCC-30	Air	kg	6,35E-12
Lanthanum-140	Water	Bq	2,37E-09	Methane, chlorotrifluoro-, CFC-13	Air	kg	9,90E-13
Iron, ion	Water	kg	4,23E-06	Methane, chlorodifluoro-, HCFC-22	Air	kg	1,73E-12
Iron-59	Water	Bq	2,03E-10	Methane, bromotrifluoro-	Air	kg	6,15E-11

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Iron	Water	kg	1,97E-07	Methane, bromo-, Halon 1001	Air	kg	8,79E-15
Iodine-133	Water	Bq	5,24E-08	Methane, biogenic	Air	kg	2,70E-06
Iodine-131	Water	Bq	1,90E-07	Methane	Air	kg	3,54E-05
Iodine-129	Water	Bq	2,77E-04	Mercury	Air	kg	1,08E-08
Iodide	Water	kg	7,93E-10	Manganese-54	Air	Bq	7,88E-10
Hypochlorous acid	Water	kg	3,08E-10	Manganese	Air	kg	1,32E-08
Hypochlorite	Water	kg	3,08E-10	Magnesium	Air	kg	2,16E-09
Hydrogen sulfide	Water	kg	1,25E-10	Lead compounds	Air	kg	2,38E-17
Hydrogen-3, Tritium	Water	Bq	2,87E+00	Lead-210	Air	Bq	1,45E-05
Hydrocarbons, unspecified	Water	kg	2,05E-08	Lead	Air	kg	4,60E-08
Hydrocarbons, aromatic	Water	kg	3,52E-08	Lanthanum-140	Air	Bq	1,93E-09
Hydrocarbons, aliphatic, alkenes, unspecified	Water	kg	1,71E-09	Lanthanum	Air	kg	1,02E-12
Hydrocarbons, aliphatic, alkanes, unspecified	Water	kg	1,88E-08	Krypton-89	Air	Bq	2,98E-05
Heat, waste	Water	MJ	1,61E-03	Krypton-88	Air	Bq	3,36E-03
Glutaraldehyde	Water	kg	6,83E-10	Krypton-87	Air	Bq	4,09E-05
Formaldehyde	Water	kg	4,44E-08	Krypton-85m	Air	Bq	3,54E+01
Fluoride	Water	kg	4,06E-07	Krypton-85	Air	Bq	7,16E+01
Fatty acids as C	Water	kg	9,66E-08	Isoprene	Air	kg	6,23E-15
Ethene, trichloro-	Water	kg	4,58E-13	Iron-59	Air	Bq	3,00E-11
Ethene, tetrachloro-	Water	kg	7,25E-15	Iron	Air	kg	6,67E-08
Ethene, chloro-	Water	kg	2,06E-15	Iodine-135	Air	Bq	3,83E-07

Ethane, hexachloro-	Water	kg	6,11E-17	Iodine-133	Air	Bq	2,57E-07
Ethane, dichloro-	Water	kg	3,05E-12	Iodine-131	Air	Bq	8,01E-07
Ethane, 1,1,1-trichloro-, HCFC-140	Water	kg	1,16E-14	Iodine-129	Air	Bq	6,20E-06
DOC, Dissolved Organic Carbon	Water	kg	7,94E-07	Iodine	Air	kg	5,17E-11
Cyanide	Water	kg	7,51E-09	Indeno(1,2,3-cd)pyrene	Air	kg	6,93E-16
Curium alpha	Water	Bq	2,54E-06	Hydrogen sulfide	Air	kg	1,91E-07
Copper, ion	Water	kg	2,56E-08	Hydrogen iodide	Air	kg	2,45E-16
COD, Chemical Oxygen Demand	Water	kg	1,81E-05	Hydrogen fluoride	Air	kg	1,87E-06
Cobalt-60	Water	Bq	4,25E-04	Hydrogen cyanide	Air	kg	1,72E-12
Cobalt-58	Water	Bq	8,95E-06	Hydrogen chloride	Air	kg	2,32E-06
Cobalt-57	Water	Bq	1,18E-08	Hydrogen bromide	Air	kg	2,24E-13
Cobalt	Water	kg	1,58E-09	Hydrogen-3, Tritium	Air	Bq	1,61E-02
Chromium, ion	Water	kg	3,83E-08	Hydrogen	Air	kg	2,07E-07
Chromium VI	Water	kg	1,03E-09	Hydrocarbons, chlorinated	Air	kg	3,17E-08
Chromium-51	Water	Bq	2,52E-07	Hydrocarbons, aromatic	Air	kg	3,22E-04
Chromium	Water	kg	6,51E-12	Hydrocarbons, aliphatic, unsaturated	Air	kg	2,90E-14
Chloroform	Water	kg	1,68E-12	Hydrocarbons, aliphatic, alkenes, unspecified	Air	kg	1,98E-10
Chlorinated solvents, unspecified	Water	kg	1,09E-11	Hydrocarbons, aliphatic, alkanes, unspecified	Air	kg	1,23E-06
Chloride	Water	kg	1,98E-03	Hexane	Air	kg	4,77E-07
Cesium-137	Water	Bq	9,02E-04	Hexamethylene diamine	Air	kg	7,12E-17
Cesium-136	Water	Bq	6,14E-11	Heptane	Air	kg	2,91E-09
Cesium-134	Water	Bq	9,80E-05	Helium	Air	kg	1,10E-08
Cesium	Water	kg	7,93E-12	Heat, waste	Air	MJ	3,01E+00

Cerium-144	Water	Bq	4,38E-05	Furan	Air	kg	4,67E-16
Cerium-141	Water	Bq	1,71E-09	Formaldehyde	Air	kg	7,68E-06
Carbon-14	Water	Bq	9,69E-05	Fluorine	Air	kg	4,87E-12
Calcium, ion	Water	kg	1,78E-04	Fluoride	Air	kg	4,29E-11
Cadmium, ion	Water	kg	4,26E-09	Fluorene	Air	kg	2,14E-14
Cadmium-109	Water	Bq	6,63E-11	Fluoranthene	Air	kg	6,76E-15
Bromine	Water	kg	1,17E-05	Ethyne	Air	kg	5,63E-10
Boron	Water	kg	1,71E-07	Ethylene oxide	Air	kg	5,59E-12
BOD5, Biological Oxygen Demand	Water	kg	1,15E-05	Ethene, tetrachloro-	Air	kg	4,75E-12
Beryllium	Water	kg	5,45E-10	Ethene, chloro-	Air	kg	1,24E-12
Benzene, ethyl-	Water	kg	5,32E-09	Ethene	Air	kg	1,25E-08
Benzene, chloro-	Water	kg	2,64E-16	Ethanol	Air	kg	2,89E-10
Benzene, 1,4-dichloro-	Water	kg	7,01E-04	Ethane, hexafluoro-, HFC-116	Air	kg	8,15E-08
Benzene	Water	kg	1,10E-07	Ethane, dichloro-	Air	kg	5,35E-12
Barium-140	Water	Bq	1,15E-08	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	kg	2,27E-11
Barium	Water	kg	1,55E-05	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	kg	1,78E-07
Barite	Water	kg	5,53E-06	Ethane, 1,1,1-trichloro-, HCFC-140	Air	kg	6,00E-15
Arsenic, ion	Water	kg	1,31E-08	Ethane	Air	kg	2,96E-06
AOX, Adsorbable Organic Halogen as Cl	Water	kg	4,74E-10	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	kg	1,77E-13
Antimony-125	Water	Bq	9,35E-08	Dinitrogen monoxide	Air	kg	6,04E-06
Antimony-124	Water	Bq	1,39E-06	Diethanolamine	Air	kg	3,72E-20
Antimony-122	Water	Bq	1,15E-08	Dibenz(a,h)anthracene	Air	kg	5,80E-16
Antimony	Water	kg	6,18E-10	Cyclohexane	Air	kg	3,06E-13
Ammonium, ion	Water	kg	6,70E-07	Cyanide	Air	kg	2,97E-11

Ammonia, as N	Water		kg	6,06E-08	Curium alpha	Air	Bq	2,31E-08
Americium-241	Water		Bq	1,91E-06	Curium-244	Air	Bq	6,90E-13
Aluminium	Water		kg	1,21E-06	Curium-242	Air	Bq	7,60E-14
Acids, unspecified	Water		kg	3,22E-10	Cumene	Air	kg	2,91E-16
Acidity, unspecified	Water		kg	1,14E-08	Copper	Air	kg	1,92E-07
Acetone	Water		kg	5,43E-10	Cobalt-60	Air	Bq	7,46E-08
Acenaphthylene	Water		kg	1,08E-08	Cobalt-58	Air	Bq	2,36E-08
4-Methyl-2-pentanone	Water		kg	2,28E-10	Cobalt-57	Air	Bq	1,33E-12
Zinc	Air	stratosphere + troposphere	kg	1,31E-14	Cobalt	Air	kg	1,16E-10
Water	Air	stratosphere + troposphere	kg	1,63E-08	Chrysene	Air	kg	2,56E-15
Sulfur dioxide	Air	stratosphere + troposphere	kg	1,31E-11	Chromium, ion	Air	kg	4,53E-15
Selenium	Air	stratosphere + troposphere	kg	1,31E-16	Chromium VI	Air	kg	1,34E-11
Particulates, < 2.5 um	Air	stratosphere + troposphere	kg	4,98E-13	Chromium-51	Air	Bq	2,73E-09
NMVOC, non-methane volatile organic compounds, unspecified origin	Air	stratosphere + troposphere	kg	8,80E-12	Chromium	Air	kg	1,48E-08
Nitrogen oxides	Air	stratosphere + troposphere	kg	1,84E-10	Chloroform	Air	kg	1,44E-13
Nickel	Air	stratosphere + troposphere	kg	9,18E-16	Chlorine	Air	kg	1,28E-08

Methane, fossil	Air	stratosphere + troposphere	kg	6,56E-13	Chloride	Air	kg	5,30E-10
Mercury	Air	stratosphere + troposphere	kg	9,18E-19	Cesium-137	Air	Bq	1,60E-06
Lead	Air	stratosphere + troposphere	kg	2,62E-16	Cesium-134	Air	Bq	8,14E-07
Hydrogen chloride	Air	stratosphere + troposphere	kg	1,13E-14	Cerium-144	Air	Bq	1,55E-07
Heat, waste	Air	stratosphere + troposphere	MJ	5,98E-07	Cerium-141	Air	Bq	7,20E-11
Formaldehyde	Air	stratosphere + troposphere	kg	2,07E-12	Carbon monoxide, fossil	Air	kg	9,63E-04
Ethylene oxide	Air	stratosphere + troposphere	kg	2,40E-12	Carbon monoxide	Air	kg	8,41E-05
Dinitrogen monoxide	Air	stratosphere + troposphere	kg	3,93E-13	Carbon disulfide	Air	kg	2,05E-14
Copper	Air	stratosphere + troposphere	kg	2,23E-14	Carbon dioxide, land transformation	Air	kg	7,01E-04
Chromium	Air	stratosphere + troposphere	kg	6,56E-16	Carbon dioxide, fossil	Air	kg	2,03E-01
Carbon monoxide, fossil	Air	stratosphere + troposphere	kg	4,85E-11	Carbon dioxide, biogenic	Air	kg	2,25E-04
Carbon dioxide, fossil	Air	stratosphere + troposphere	kg	4,13E-08	Carbon dioxide	Air	kg	3,99E-02
Cadmium	Air	stratosphere + troposphere	kg	1,31E-16	Carbon-14	Air	Bq	2,13E-03
Butadiene	Air	stratosphere + troposphere	kg	2,48E-13	Calcium	Air	kg	5,40E-09

Benzene	Air	stratosphere + troposphere	kg	2,62E-13	Cadmium	Air	kg	1,13E-09
Zinc	Air	low. pop., long-term	kg	1,00E-08	Butene	Air	kg	6,08E-10
Vanadium	Air	low. pop., long-term	kg	9,66E-09	Butane	Air	kg	1,02E-06
Tungsten	Air	low. pop., long-term	kg	6,30E-10	Butadiene	Air	kg	5,79E-13
Titanium	Air	low. pop., long-term	kg	1,02E-07	Bromine	Air	kg	1,77E-10
Tin	Air	low. pop., long-term	kg	3,25E-10	Boron	Air	kg	1,24E-09
Sulfate	Air	low. pop., long-term	kg	1,43E-06	Beryllium	Air	kg	2,49E-11
Strontium	Air	low. pop., long-term	kg	5,66E-09	Benzo(g,h,i)perylene	Air	kg	9,31E-16
Sodium	Air	low. pop., long-term	kg	9,15E-08	Benzo(b)fluoranthene	Air	kg	1,86E-15
Silver	Air	low. pop., long-term	kg	2,33E-10	Benzo(a)pyrene	Air	kg	8,06E-09
Silicon	Air	low. pop., long-term	kg	3,47E-07	Benzo(a)anthracene	Air	kg	1,04E-15
Selenium	Air	low. pop., long-term	kg	7,79E-10	Benzene, pentachloro-	Air	kg	4,01E-16
Scandium	Air	low. pop., long-term	kg	5,57E-09	Benzene, hexachloro-	Air	kg	8,71E-11
Radon-222	Air	low. pop., long-term	Bq	5,97E+04	Benzene, ethyl-	Air	kg	5,85E-10
Potassium	Air	low. pop., long-term	kg	2,66E-07	Benzene, 1,4-dichloro-	Air	kg	5,48E-03
Phosphorus	Air	low. pop., long-term	kg	2,62E-09	Benzene, 1,3,5-trimethyl-	Air	kg	2,01E-17

Particulates, > 2.5 um, and < 10um	Air	low. pop., long-term	kg	1,86E-06	Benzene	Air		kg	2,92E-06
Particulates, > 10 um	Air	low. pop., long-term	kg	3,11E-06	Benzaldehyde	Air		kg	2,89E-14
Particulates, < 2.5 um	Air	low. pop., long-term	kg	1,24E-06	Benzal chloride	Air		kg	3,84E-14
Nitrate	Air	low. pop., long-term	kg	1,34E-08	Barium-140	Air		Bq	3,14E-09
Nickel	Air	low. pop., long-term	kg	2,86E-09	Barium	Air		kg	1,96E-10
Molybdenum	Air	low. pop., long-term	kg	2,71E-09	Arsine	Air		kg	1,05E-15
Mercury	Air	low. pop., long-term	kg	1,07E-10	Arsenic trioxide	Air		kg	1,27E-17
Manganese	Air	low. pop., long-term	kg	3,50E-08	Arsenic	Air		kg	2,09E-10
Magnesium	Air	low. pop., long-term	kg	1,55E-07	Argon-41	Air		Bq	3,77E-03
Lead	Air	low. pop., long-term	kg	1,40E-08	Antimony-125	Air		Bq	2,97E-11
Iron	Air	low. pop., long-term	kg	1,69E-06	Antimony-124	Air		Bq	5,45E-10
Fluorine	Air	low. pop., long-term	kg	9,49E-08	Antimony	Air		kg	2,78E-11
Copper	Air	low. pop., long-term	kg	1,32E-08	Anthracene	Air		kg	2,07E-15
Cobalt	Air	low. pop., long-term	kg	1,25E-09	Ammonium, ion	Air		kg	1,83E-15
Chromium VI	Air	low. pop., long-term	kg	1,00E-09	Ammonia	Air		kg	1,20E-05
Chlorine	Air	low. pop., long-term	kg	1,93E-08	Americium-241	Air		Bq	1,45E-08
Calcium	Air	low. pop., long-term	kg	5,06E-07	Aluminium	Air		kg	1,88E-05

Cadmium	Air	low. pop., long-term	kg	2,13E-10	Aldehydes, unspecified	Air	kg	2,23E-09
Boron	Air	low. pop., long-term	kg	2,62E-09	Acrolein	Air	kg	3,03E-10
Beryllium	Air	low. pop., long-term	kg	1,97E-10	Acidity, unspecified	Air	kg	2,19E-12
Barium	Air	low. pop., long-term	kg	9,02E-09	Acetone	Air	kg	1,46E-10
Arsenic	Air	low. pop., long-term	kg	8,25E-09	Acetic acid	Air	kg	2,34E-07
Antimony	Air	low. pop., long-term	kg	1,40E-10	Acetaldehyde	Air	kg	7,42E-08
Aluminium	Air	low. pop., long-term	kg	1,56E-06	Acenaphthene	Air	kg	5,23E-13
Zirconium-95	Air	low. pop.	Bq	2,27E-07				
Zirconium	Air	low. pop.	kg	1,70E-10				
Zinc-65	Air	low. pop.	Bq	2,32E-07				
Zinc	Air	low. pop.	kg	2,47E-07				
Xylene	Air	low. pop.	kg	5,56E-07				
Xenon-138	Air	low. pop.	Bq	2,40E-01				
Xenon-137	Air	low. pop.	Bq	3,04E-02				
Xenon-135m	Air	low. pop.	Bq	1,16E+00				