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ZERO BRINE

D6.1 Wastewater and solution provider knowledge models, correlations and interlinks

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[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other

[2] **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services), **CI**=Classified

Contents

ABBREVIATIONS

BAT: Best Available Techniques

BOD: Biological Oxygen Demand

BREF: BAT Reference Documents

COD: Chemical Oxygen Demand

EC: Electrical Conductivity

EWC: European Waste Catalogue

NACE: Nomenclature Statistique des Activités Économiques

OBP: Online Brine Platform

PC: Product Category

SAR: Sodium Absorption Ratio

SB: Symbiotic Brine

SBI: Standard Industrial Classifications

SBO: Symbiotic Brine Ontology

SS: Suspended Solids

SU: Sector of Use

TP: Total Phosphorus

TS: Total Solids

TSS: Total Suspended Solids

TVS: Total Volatile Solids

VSS: Volatile Suspended Solids

WUC: Water Use Category

Ww: Wastewater

WWTP: Wastewater Treatment Plant

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1 INTRODUCTION

1.1 Scope of the deliverable

This deliverable includes the results from subtask 6.1.1 entitled "*Design and implementation of knowledge based support in both wastewater stream (brine) and solution provider domain*". The subtask is led by NTUA. During ZERO BRINE project an active web service for promoting and practically implement Industrial Symbiosis will be developed. The work presented in this deliverable was concentrated on the design and implementation of wastewater streams, solution provider and material recovery knowledge models to support description of user services. The knowledge model is built by ontology engineering. Before building the knowledge model, a detailed literature review was carried out in the domain of saline wastewater generation by process industries. This literature review prepared the ground for the design of light weight correlations and interlinks in order to capture knowledge in the domain of saline wastewater, solution provider technologies and material recovery. At a next stage, descriptive attributes, properties and restriction of properties was added to the knowledge model.

1.2 The Online Brine Platform

The Online Brine Platform (OBP) aims at promoting the secondary raw materials flow, by linking the brine owners with the end-users. Online Brine Platform will play a key role in replicating the paradigms generated in the framework of the ZERO BRINE project. In ZERO BRINE, a new, disruptive resource management concept of systemic eco-innovation is proposed, through the development of an industrial symbiosis platform for brine recovery. In OBP platform, the brine streams generated from process industries can be mapped and possible interactions for reuse and recycling of resources between the industries across the value chain can be identified.

The OBP will be applied for the case of the Netherlands. Brine owners and possible end-users of recovered materials will be able to register to the OBP by providing their address, contact information and industrial activity. Hence, a network of the interested stakeholders will be created. Users registered to the platform will have the possibility to have access to information with respect to the available quantities of both virgin and recovered materials, as well as, on the proximity of both supplier and process industries to their location. Thus, industries will be able to make informed decisions regarding the management of their own resources.

1.3 The role of Ontologies in the Online Brine Platform

Ontologies are widely recognized and established as a means to model, represent and share domain knowledge in a formal way. Ontologies in the Online Brine Platform (OBP) are semantic structures encoding concepts, relations and axioms applicable and necessary for the Symbiotic Brine (SB) domain. They are the backbone of the OBP allowing it to be semantically enriched. This is a pre-condition to provide new, advanced services over the web, such as the semantic search and retrieval of web resources.

The development of SB ontology aims to offer appropriate conceptual and representational semantics through the use of ontology engineering, ultimately aiming to provide added value in the domain of wastewater brines and their recovered products as resources to process industry. The proposed ontology offers classification of materials, technology, processes and uses related to the brine processing and engineering domain.

Knowledge modeling in process systems engineering and the potential of ontology engineering have already been realized and researched, hence efforts are directed to create semantic models representing the process industry domain (Munoz et al, 2013). Moreover, ontologies have been developed to represent the domain of process engineering (Morbach et al., 2007), industrial standards (Batres et al., 2007) and process in general (Hai et al., 2009). Specifically for the case of waste processing, an ontology model has already been proposed in order to support the reuse of waste and consequently to support waste processing (Trokanas et al., 2014), (Trokanas & Raafat, 2014). Nonetheless, no ontology has been proposed to support the reuse of recovered inorganic products by industrial wastewater brines and hence to create semantic and cognitive models for brine waste processing.

The SB ontology has the potential to play an important role in defining the terms used to describe and represent the domain of brine waste processing, thus providing a common vocabulary and a shared understanding of the structure of information among individuals and/or organizations, promoting collaboration, enabling reuse of domain knowledge, making domain assumption explicit, separating domain knowledge from operational knowledge, analyzing domain knowledge and contributing to the overall standardization of the domain (Sheeba et al., 2012).

Besides offering common knowledge upon the domain of brine processing and re-use of recovered by-products, the proposed ontology will be the common ground for the development of information applications and platforms, in order to generate and disseminate knowledge to final users. The development of user interface through the OBP will facilitate the use of the ontology as a tool for saline waste management.

2 ONTOLOGIES AND GRAPH THEORY

2.1 What is an Ontology

By Ontology we refer to the explanation (λόγος – logos) of being (ον – on) or to the science of the being, to the philosophical quest that examines the principles and constitution of it and studies the nature and essence of the beings. The term "Ontology" may also refer to a philosophical discipline that is the branch of philosophy which deals with the nature and structure of "reality" (Guarino et. al, 2009). In difference with experimental sciences, which aim at discovering and modeling reality under a certain perspective, Ontology concentrates on the nature and structure of things per se, independently of any further considerations, and even independently of their actual existence (Guarino et. al, 2009).

In computer science and knowledge engineering, the Artificial-Intelligence literature contains many definitions of an ontology; many of these contradict one another. An ontology is a formal naming and definition of the types, properties, and interrelationships of the entities that really exist in a particular domain of discourse.

It is a special kind of information object or computational artifact. Gruber (1993) defines ontology as an explicit specification of a conceptualization. This indicates that an ontology is a simplified view or representation of a given domain of interest.

Guarino and Giaretta (1995) identified several different notions for the term ontology:

- Ontology as a philosophical discipline
- Ontology as an informal conceptual system
- Ontology as a formal semantic account
- Ontology as a specification of a conceptualization
- Ontology as a representation of a conceptual system via a logical theory either characterized by specific formal properties or only by its specific purposes
- Ontology as the vocabulary used by a logical theory
- Ontology as a (meta-level) specification of a logical theory

In the same paper Guarino and Giaretta described the ontology as a logical theory that gives an explicit, partial account of a conceptualization.

The meaning of ontology is obviously highly dependent on the point of view of the author as well as on the use of the ontology itself. Its definition is not the most important aspect of it but instead the respective use, the capabilities, the potentials, the challenges and the benefits related to it are far more important. Summarizing, an ontology, provides a common vocabulary (terms) for a domain of interest as well as the properties of those terms and the relation among them.

2.2 Components of Ontologies

An ontology may consist of individuals, classes, attributes and relations. **Individuals** (also known as instances or particulars) are specific instances of the concept objects (Lord, 2010). The sets of individuals are the **classes** of the ontology. Classes may be referred to as types or categories and they can be organized into a taxonomy or hierarchy. A set of common **attributes** can describe a concept such as parts of an object. Attributes can also be other concepts in their own right (i.e. individuals or classes) but they define the context for other concepts. Lastly, **relations** define how pairs of concepts can be related. They can also have specific properties such as symmetry or transitivity. (eSymbiosis, 2012)

2.3 Types of Ontologies

There exist several different categorizations of ontologies, depending on the point of view and intended use.

One categorization by Mizoguchi and colleagues (1995) is as follows:

- Content Ontologies used for knowledge reuse. This category includes task, domain and general ontologies.
- Communication Ontologies used for knowledge sharing.
- Indexing Ontologies used for case retrieval.
- Meta-ontologies also known as Knowledge Representation Ontologies.

Another two-dimensional categorization is provided by Van Heijst and colleagues (1997). The first dimension is the amount and type of the structure and the classification proposed is:

- Terminological Ontologies which specify the terms used for knowledge representation.
- Information Ontologies which specify storage structure data.
- Knowledge Modeling Ontologies which specify the conceptualization of knowledge

The second one is the issue of the conceptualization. The classification proposed is:

- Representation ontologies.
- Generic ontologies.
- Domain ontologies.
- Application ontologies.

A categorization by their dependence on particular tasks or points of view was introduced by Guarino (1998) who identified the following four types:

- Top-level Ontologies which are general ontologies.
- Domain Ontologies which represent knowledge of a specific domain.
- Task Ontologies which are dependent on certain tasks.
- Application Ontologies which are dependent on particular applications.

Finally, a classification of ontologies focused on the design of them was proposed by Gómez-Péréz et al. (2006). They proposed two types of ontologies:

- Lightweight ontologies which include concepts organized in taxonomies, the relationships between those concepts and properties that describe the concepts.
- Heavyweight ontologies which add axioms and constraints to lightweight ontologies.

The Symbiotic Brine Ontology developed is an ontology categorized as a representation, application and domain ontology with knowledge of a specific domain (the domain of Brine Symbiosis) at the same time.

2.4 Methodologies

2.4.1 Types of Methodologies

Many methodologies have been developed in the domain of ontology engineering until today. These methodologies either have been proposed initially or they have emerged from experiences from different projects such as the methodology By Grüninger and Fox that is based on the TOVE project ontology [Grü95] or the approach of Amaya Berneras et al (KACTUS project [KAC96]) (Fernández López, 1999). Although, it is remarkable that the results that came of a survey conducted in 2007 among developers by University of Madeira (Cardoso, 2007), showed that 60% of the respondents do not use any methodology when they develop an ontology. Gómez-Péréz et al. (2006) suggest a general framework for any methodology based on the software development process identified by IEEE. They defined three different kinds of activities, namely (i) managerial activities such as scheduling, control and quality assurance, (ii) development-oriented activities such as implementation and maintenance, and (iii) support activities such as evaluation, documentation and knowledge acquisition (Iqbal et al., 2013).

Over time, several methodologies have been evolved. Below it follows a brief presentation of some of them, depending on their significance:

- CYC Method

CYC Method was one of the early approaches of ontology development methodology suggested by Lenat and Guha (1990) which emerged from the experience of developing the CYC knowledge base. Most of the enabling technologies for ontologies were not in place at the moment when CYC was created and as a result CYC methodology is based on three phases. The first phase requires manual coding, the second one proposes knowledge codification aided by tools, whereas the third phase relies majorly on the tools for work requiring little human intervention (Fernández- López and Gómez-Pérez, 2006 and Iqbal et al., 2013).

- TOVE Method

Grüninger and Fox proposed a methodology related to the domain of business (Gruninger & Fox, 1995 and Iqbal et al., 2013). More specifically, it was proposed on the experience of enterprise ontology (Toronto Virtual Enterprise – TOVE). The key point of TOVE Method is that it first focuses on capturing the ontology requirements by means of informal description.

- METHONTOLOGY

Methontology was introduced for ontology engineering to build domain ontologies from scratch (Fernández-López et al., 2006 and Iqbal et al., 2013). Hence, Methontology focuses on the knowledge level of ontologies. Software development process is the basis of METHONTOLOGY, where processes are divided into three categories (Management, Development and Support), and on knowledge engineering methodologies (e-symbiosis). Management activities include scheduling, control and quality assurance. On the other hand, Development includes activities namely conceptualization, formalisation, specification, implementation and maintenance of the ontology (eSymbiosis, 2012). Finally, Support activities involve knowledge acquisition, evaluation, integration and documentation and configuration management.

- SENSUS METHOD

SENSUS method was developed using various sources of knowledge including PENMAN Upper Model, ONTOS, WordNet and some electronic dictionaries (Swartout et al., 1996 and Iqbal et al., 2013). This method attempts to promote knowledge sharing, by using a base ontology on which new domain ontologies are built.

- ON-TO-KNOWLEDGE METHOD

The methodology focuses on knowledge meta process and knowledge process (Iqbal et al., 2013). It suggests a method for ontology learning which aims to reduce the effort of developing an ontology. In order to serve this purpose, ON-TO-KNOWLEDGE method provides the tools, the methods and the techniques.

Noy and McGuinness (2001) proposed, a combination of all the aforementioned methodologies to be adopted when developing an ontology. They suggest a combination of all these methods in self-explanatory steps:

1. Determine the domain and the scope of the ontology.
2. Consider reusing existing ontologies.
3. Enumerate important terms in the ontology.
4. Define the classes and the class hierarchy (Top-down, Bottom-up, Combination).
5. Create instances.

2.4.2 Criteria of Analysis for ontology Methodologies

The wide range of ontology applications in different sectors has led to the emergence of a need of developing several criteria in order to achieve the evaluation of each ontology engineering methodology. The criteria that were developed cover eight different aspects of any ontology engineering methodology. A brief presentation and description of these criteria follows (Iqbal et al., 2013):

Criterion 1: Type of development

Methodologies can be divided in to three broad categories: stage based model, evolving prototype model and guidelines, depending on the type of development model they follow.

Criterion 2: Support for collaborative construction

Ontologies can be constructed either in isolation or in collaboration as well. Collaborative construction support allows different members of the ontology development team to work on the same ontology, at the same time.

Criterion 3: Support for reusability

Ontology development is a time consuming and tedious task. Consequently, the notion of ontology reusability is a characteristic that gained popularity over the years.

Criterion 4: Support for interoperability

Interoperability is an important factor for ontology engineering. Some methodologies support interoperability between systems. Domain ontologies developed under those methodologies share the same backbone or high level concepts. Hence, systems adopting such ontologies will have a similar knowledge backbone and it would be easier for them to communicate and share knowledge with each other.

Criterion 5: Degree of application dependency

Different methodologies adopt distinct approaches for application dependency, during ontology development. A methodology can opt for one of three scenarios, namely:

- *application dependent:* ontology is developed on the basis of an application knowledge base in mind,
- *application semi-independent*: possible scenarios of ontology use are kept in mind during the specification stage, and
- *application independent*: no assumption is made regarding the uses to which the ontology will be put in knowledge-based systems, agents, etc.

Criterion 6: Life-cycle recommendation

An ontology life cycle is identified as the set of stages through which the ontology moves during its life. Many methodologies do not clearly recommend a life cycle, so it is crucial to distinct them according to this characteristic.

Criterion 7: Strategies for identifying concepts

The process of identification of possible concepts for inclusion in the ontology is of high importance. Some techniques that are used commonly for this purpose are the bottom-up approach, top-down approach and middle-out approach.

Criterion 8: Details of methodology

Every methodology comprises of some activities and techniques to support ontology development. Nonetheless, several methodologies do not provide sufficient details of their employed techniques and activities. Therefore, methodologies are classified into three categories according to the degree of details they provide; methodologies with sufficient details, methodologies with some details and methodologies with insufficient details.

2.5 Ontology development editors

Ontology development editors aid data publishers build their own ontology. These editors are based on RDF(s) and OWL but support other languages and frameworks as well. Most popular editors include but are not limited to:

- Protégé[3]

"Protégé is one of the most commonly used editors because it is free, open-source and provides a suite of tools to construct domain models and knowledge-based applications with ontologies. It can be customized and extended. The significant advantage of Protégé is its scalability and extensibility."

- NeOn Toolkit[4]

"The NeOn Toolkit is an open source, multi-platform ontology editor, which supports the development of ontologies in F-Logic and OWL/RDF. The editor is based on the Eclipse platform and provides a set of plug-ins

[3] https://protege.stanford.edu/
[4] http://neon-toolkit.org/wiki/Main_Page.html
https://en.wikipedia.org/wiki/NeOn_Toolkit

covering a number of ontology engineering activities, including Annotation and Documentation, Modularization and Customization, Reuse, Ontology Evolution, translation and others. "

- TopBraid Composer[5]

"TopBraid Composer is a component of TopBraid Suite and is a professional development tool for semantic models (ontologies). It comes in three editions: Free Edition (FE) is an introductory version with only a core set of features. Standard Edition (SE) that includes all features of FE plus some additional features such as graphical viewers, import facilities, and much more. Maestro Edition (ME) includes all features of SE plus support for TopBraid Live, EVN and Ensemble as well as SPARQLMotion and many other power user features."

- Fluent Editor[6]

"Fluent Editor 2 is a comprehensive tool for editing and manipulating complex ontologies that uses Controlled Natural Language. Fluent editor provides one with a more suitable for human users alternative to XML-based OWL editors. Its main feature is the usage of Controlled English as a knowledge modeling language."

2.6 Ontology Languages

In computer science and artificial intelligence, ontology languages are formal languages used to construct ontologies. They allow the encoding of knowledge about specific domains and often include reasoning rules that support the processing of that knowledge. The most common ones are:

- OWL: Web Ontology Language (OWL)

The W3C Web Ontology Language (OWL) is a Semantic Web language designed to represent rich and complex knowledge about things, groups of things, and relations between things. It is the most common used ontology language. The OWL family contains many species, serializations, syntaxes and specifications with similar names. For example, OWL and OWL2 are used to refer to the 2004 and 2009 specifications.

- XML: eXtensible Markup Language

XML is a general purpose language. The fact that the user can define his own tags classifies it as an extensible language. XML has been the base for development of other later languages such as RDF, DAML-OIL and others (eSymbiosis, 2012).

- RDF: Resource Description Framework

RDF stands for Resource Description Framework. It is a multi-purpose representation model that provides the ability to capture information in the form of directed labelled graphs. It provides concrete syntax that can be

[5] https://www.topquadrant.com/
http://www.ef.uns.ac.rs/mis/archive-pdf/2013%20-%20No2/MIS2013-2-4.pdf
[6] http://www.cognitum.eu/Semantics/FluentEditor/
http://semanticweb.org/wiki/Fluent_Editor.html

used to represent both data and metadata and to describe the semantics of information in a software readable way. RDF comes in many forms of serialization, including RDF/XML that is based on XML and represents resources on the web in a standardised way with the use of IRIs (eSymbiosis, 2012).

- RDF(s)

RDF(s) is a specification of the RDF vocabulary description language. It is the second most common language for ontology development. It defines the classes (e.g. rdfs:Class, rdfs:Resource) and properties (e.g. rdfs:Domain, rdfs:subClassOf) that can be used in RDF in order to describe classes and properties in a machine understandable way (eSymbiosis, 2012).

The language that will be used for SB ontology will be OWL/DL.

2.7 Graph Theory

Graph theory is the study of graphs, which are structures used to model pairwise relations between objects. A graph is made up of vertices, nodes, or points which are connected by edges. In the most common sense of the term, a graph is an ordered pair G = (V, E) comprising a set V of vertices or nodes or points together with a set E of edges, which are 2-element subsets of V (i.e. an edge is associated with two vertices, and that association takes the form of the unordered pair comprising those two vertices).

Ontologies and their data can be modeled as a graph since ontologies explicate the contents, essential properties and relationships between terms in a knowledge base.

3 DEVELOPING SYMBIOTIC BRINE ONTOLOGY (SBO)

3.1 The purpose of ontology

The use of ontologies in the framework of Zero Brine Project aims to capture knowledge in the domain of saline wastewater streams (brines) and material recovery and act as the base that will be used and enriched for further uses on the domain. Ontologies are mainly used in order to represent knowledge in the form of a group of terms. The domain of knowledge is structured hierarchically and enriched with properties and attributes of these models, combined with restrictions on these properties.

An ontology is associated with instances (cases) which represent specific objects of the domain. An advantage of ontologies is that they are flexible to implement, share and reuse. This characteristic of ontologies is very useful especially in conjunction with web technologies and applications.

When users register and edit their profiles in the OBP, they are requested to fill data in the fields that correspond to properties that are connected to the defined concepts. Ontology forms a knowledge model that due to its structure implies or helps build the navigation path that users have to follow during the registration process.

The use of ontologies in the domain of saline wastewater and material recovery provides a standardized vocabulary resulting in elimination of syntactic issues. The creation of a common vocabulary is crucial for the brine domain in order to facilitate communication between the relevant stakeholders. Moreover, ontologies allow to informally express the given knowledge. This characteristic makes them attractive to all audiences no matter the level of coding skills and background (Trokanas et al. 2012). Last but not least, ontologies facilitate the use of synonyms (hence removing the jargon barrier), sharing and reasoning that can automatically generate new knowledge.

The ontology design is compliant with the FAIR data Principles as in order to be findable most (meta)data have a unique identifier and data are described with rich metadata. Also there are (meta)data that are retrievable by their identifier using a standardized communications protocol (USES description). (Meta)Data use a formal, accessible, shared, and broadly applicable language for knowledge representation and they use vocabularies that follow FAIR principles (Dublin Core, GEO ontology, FOAF). Last but not least, (meta)data have a plurality of accurate and relevant attributes in order to make the ontology re-usable.

3.2 Methodology

As mentioned before, most ontology developers do not follow a specific methodology. One main reason is that the methodologies may be too sophisticated for an inexperienced user in software development. Moreover, most of the existing methodologies are highly dependent on the project they are based on. Based on the approach proposed by Noy & McGuinness (2001) the ISB ontology uses a middle-out approach when defining the classes and the class hierarchy, leaving room for re-use of pre-existing ontologies whilst creating new ones.

Most ontology developers do not follow a specific methodology (Cardoso, 2007) because most of them are project based and usually they require some customization and can't be adopted as they are. The methodology used in this project is similar to the one suggested by Noy & McGuinness (2001).

3.2.1 Determine the domain and the scope of the ontology

The ontology purposes on representing the knowledge of the Symbiotic Brine domain that aims the treatment of saline wastewater streams driven by the recovery and use of targeted products. Industrial Symbiosis (IS) is an innovative approach and environmental practice that brings together companies from different business sectors targeting in improving cross industry resource efficiency through the commercial trading of materials, energy and water and additionally sharing expertise, assets and logistics. IS is a key factor for enabling Circular Economy.

This includes the required knowledge of the use of the recovered products derived from the wastewater treatment process as well as details of the participants and their sector of use. It tries to explain their symbiotic relationship and identifies the necessary data and object properties. In order to build the ontology in a way that is theoretically sound, reusable in the domain and extendable it is important to create a set of competency questions in order for them to act as the requirements or specification and make the ontology development easier to comprehend. They are also used as a guide for the validation of the ontology after the stage of the ontology development completion.

Some of these questions that determine the domain and are quite generic can be the following :

1) What is the domain of the ontology?
2) What will be the exact use of the ontology?
3) Who will use the ontology?
4) Is it a standalone ontology or part of a semantic application?

Next, a set of questions that are more specific and have as a purpose the definition of some, if not all, of the requirements of the ontology are:

5) What type of participants are there?
6) Which are the industrial and business sectors of the participants?

7) What kind of information is needed for the establishment of a symbiotic synergy?

This set of seven questions is answered in the next sections.

3.2.2 Reuse of existing ontologies

An ontology that represents the Symbiotic Brine domain doesn't exist. An ontology considered but rejected is the one that represents the United Nations Standard Products and Services Code (UNSPSC). The UNSPSC ontology for products and services is an ontology that consists of more than 10,000 concepts divided into 54 categories (eSymbiosis, 2012). It is way more detailed for the Symbiotic Brine domain and lacked of the necessary specialization at the same time. Thus, it was found best if a new one was developed to be more specific and domain representative. However, an ontology about the industry classification already exists and has been used as a part of our ontology. This is the NACE Economic Activities ontology:

The Statistical Classification of Economic Activities in the European Community is commonly referred to as NACE[7] (the abbreviation derives from the French term Nomenclature statistique des Activités économiques dans la Communauté Européenne) and is the industry standard classification system that the European Union uses.

Other relevant ontologies that represent the units of measurement, the processes and materials could have been used but were found either too detailed or very domain specific allowing no flexibility. If needed in the future they can be imported to the SB ontology. Some of them are:

- http://sweet.jpl.nasa.gov/2.0/chem.owl
- http://sweet.jpl.nasa.gov/2.0/chemElement.owl
- https://sweet.jpl.nasa.gov/2.0/chemCompound.owl
- https://sweet.jpl.nasa.gov/2.3/matr.owl
- https://sweet.jpl.nasa.gov/1.1/substance.owl

Some notary ontologies and vocabularies that are also used are the following:

FOAF[8]

Friend-of-a-friend (FOAF) is an established ontology that is widely used to describe agents (e.g., people, organizations) and relationships between them. In the context of the SB ontology, FOAF will be used to describe agents such as Brine Owners and End-Users.

GEO Ontology[9]

[7] http://ec.europa.eu/eurostat/ramon/ontologies/nace.rdf

[8] http://xmlns.com/foaf/spec/

[9] https://www.w3.org/2003/01/geo/wgs84_pos

GEO Ontology is a vocabulary for representing latitude, longitude and altitude information in the WGS84 geodetic reference datum. (WGS84 Geo Positioning, 2009). The geo:location property will be used for location description.

Dublin Core[10]

A simplified technique of standardizing the most popular domain terms where a set of terms like dc:title, dc:creator, and dc:publisher with agreed meanings are introduced. This gives the ability to attach meaning with resources. (Brickley and Guha, 2004, Dublic Core Metadata Initiative, 2016). Dublin Core vocabulary introduces properties such as the description that will be used in the Symbiotic Brine Ontology.

XML Schema

Datatypes is part 2 of the specification of the XML Schema language. It defines facilities for defining datatypes to be used in XML Schemas as well as other XML specifications. The datatype language, which is itself represented in XML, provides a superset of the capabilities found in XML document type definitions (DTDs) for specifying datatypes on elements and attributes.

xsd: XML Schema Definition Language[11]. For example xsd:double represents that the type of value a resource has is a double number.

RDF Schema

The RDF Schema as described also in the previous section provides a data-modelling vocabulary for RDF data. RDF Schema is an extension of the basic RDF vocabulary.[12]

rdfs:label is used to provide a human-readable version of a resource's name.

The namespace of the Symbiotic Brine ontology is http://www.zerobrine.eu/ontology# and the abbreviated prefix is symbr.

3.2.3 Enumerate important terms in ontology

Existing classifications have been reused for the representation of the industrial sectors (NACE, SU, PC, SBI, AC, TF). However, only NACE has an associated published ontology, which is reused accordingly in SBO. Besides reusing the existing classifications, custom abstract classifications have been developed and are the main core of the SBO.

[10] http://dublincore.org/documents/dcmi-terms/

[11] https://www.w3.org/TR/xmlschema11-2/

[12] https://www.w3.org/TR/rdf-schema/

3.2.4 Define the classes of the Symbiotic Brine Ontology

In the SBO there are two types of agents: (i) the one who owns (BrineOwners) saline wastewater streams (SalineWwStream) and (ii) the one who uses (Enduser) the recovered products (Product) after the treatment (Wwtreatment) of the brine stream. The BrineOwners could be either process industries that produce saline effluents or aggregators. For brine treatment are used the technologies proposed by the ZERO BRINE consortium (SolutionProvider). The saline wastewater streams can be classified using the EWC categorization. The final use (Use) of the recovered products has specific requirements (Requirements) that refer to the recovered product. Moreover, the use of the recovered product can be categorized in six classes: SU, SBI, PC, NACE, AC, TF, WUC. All the classes of the SBO have metadata and other characteristics.

The definition and the characteristics of each class is following.

The Symbiotic Brine ontology’s design is shown in the next figure (figure 1).

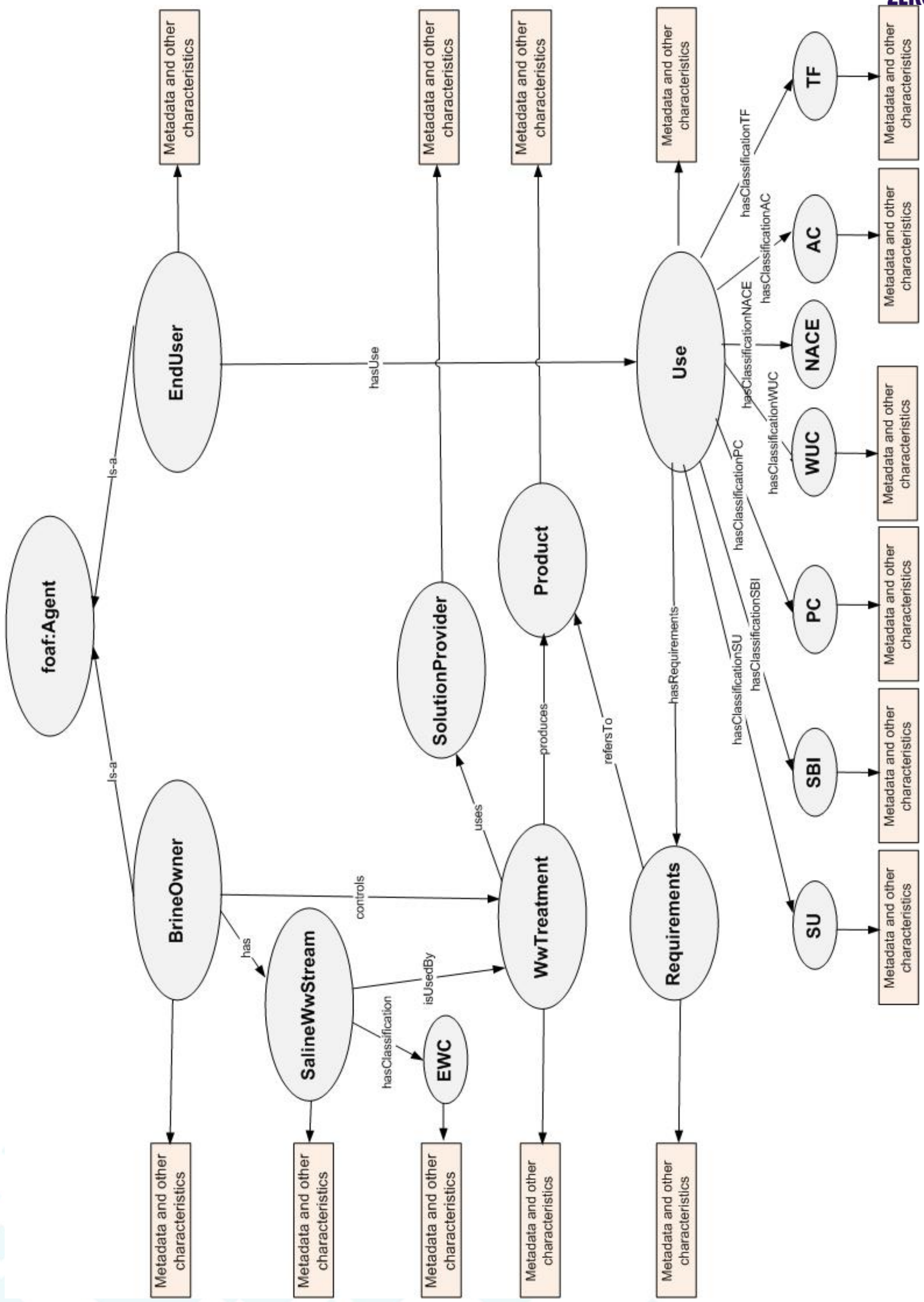

Figure 1: Symbiotic Brine Ontology

Table 1: Classes Definition, SB Ontology

Name	Description
foaf:Agent	This is the class that represents the participants that can be part of the OBP.
BrineOwner	This class represents the type of participant that owns Brine. This type is also a role.
EndUser	This class represents the type of participant that will use the end product. This type is also a role.
SalineWwStream	This class represents the owner of the saline wastewater stream.
EWC	This class represents the saline wastewater stream classification based on the European Waste Catalogue.
SolutionProvider	This class represents the technology used by the wastewater treatment process.
WwTreatment	This class represents the wastewater treatment process and raw material recovery by the brine owner.
Product	This class represents the end product that derives from the wastewater treatment.
Use	This class represents the desired use of the product by the end-user.
Requirements	This class represents the requirements that the end-user sets for the product in the selected use.
SU	This class represents the classification of the Sector of End Use of the product.
SBI	This class represents the classification of economic activities (Netherlands).
PC	This class represents the classification of the chemical product categories.
AC	This class represents the classification of the articles category.
TF	This class represents the classification of the technical functions of the use of the product.
NACE	This class represents the classification of economic activities (EU).
WUC	This class represents the classification of the uses of water.

All classes have each own metadata and characteristics that are defined as properties and are analyzed below.

foaf:Agent

The Agent class of the FOAF ontology is defined in as the class of agents; things that do stuff. It represents a person, a group, a software, an organization etc.

symbr:BrineOwner

A class in the Symbiotic Brine knowledge model that includes the industries that generate saline wastewaters and are interested to recover products by treating this wastewater. It is a subclass of the foaf:agent class.

Properties of this class are presented in table 2.

*Table 2: **symbr:**BrineOwner class properties, SB ontology*

Property Name	Description	Range of Values
foaf:name	The Name of the Brine Owner	xsd:string
geo:location	Term of a basic RDF vocabulary that provides the Semantic Web community with a namespace for representing **lat**itude, **long**itude and other information about spatially-located things, using WGS84 as a reference datum.	geo:SpatialThing
symbr:controls	A property that denotes the relationship between the brine owner and the saline wastewater treatment.	symbr:WwTreatment
symbr:produces	A property that denotes the relationship between the brine owner and the saline wastewater stream.	symbr: SalineWwStream
symbr:is-a	A property that denotes that the BrineOwner is a FOAF Agent.	foaf:Agent

symbr:EndUser

A class in the Symbiotic Brine knowledge model that includes the industries that use the minerals and water and also the salt producers/suppliers who produce salts or supply salts in the industrial market.
Properties of this class are presented in table 3:

*Table 3: **symbr:**EndUser class properties, SB ontology*

Property Name	Description	Range of Values
foaf:name	The Name of the End -ser.	xsd:string
geo:location	Term of a basic RDF vocabulary that provides the Semantic Web community with a namespace for representing **lat**itude, **long**itude and other information about spatially-located things, using WGS84 as a reference datum.	geo:SpatialThing
symbr:hasUse	A property that denotes the relationship between the end-user and the Use class.	symbr:Use
symbr:is-a	A property that denotes that the EndUser is a FOAF Agent.	foaf:Agent

symbr:SalineWwStream

The class **symbr:**SalineWwStream represents the wastewater stream produced by the Brine Owner with its own chemical (e.g. salinity, Na^+, COD e.t.c.) and physical characteristics (e.g. flow). The produced saline wastewater stream has an EWC classification and is used in the wastewater treatment
Properties of this class are presented in table 4.

*Table 4: **symbr:**SalineWwStream class properties, SB ontology*

Property Name	Description	Range of Values
rdfs:label	A name of the Saline wastewater stream	xsd:string
symbr:hasFlowValue	Flow Value	xsd:double
symbr:hasSalinityValue	Salinity Value	xsd:double
symbr:hasElectricConductivityValue	Electric Conductivity Value	xsd:double
symbr:haspHValue	pH Value	xsd:double
symbr:hasDensityValue	Density Value	xsd:double
symbr:hasTDSValue	TDS Value	xsd:double
symbr:hasTSSValue	TSS Value	xsd:double
symbr:hasTSValue	TS Value	xsd:double
symbr:hasSSValue	SS Value	xsd:double
symbr:hasCODValue	COD Value	xsd:double
symbr:hasBODValue	BOD Value	xsd:double
symbr:hasTCValue	TC Value	xsd:double
symbr:hasTOCValue	TOC Value	xsd:double
symbr:hasICValue	IC Value	xsd:double
symbr:hasNaPValue	Na^+ Value	xsd:double
symbr:hasNH4PValue	NH_4^+ Value	xsd:double
symbr:hasKPValue	K^+ Value	xsd:double
symbr:hasCa2PValue	Ca^{2+} Value	xsd:double
symbr:hasMg2PValue	Mg^{2+} Value	xsd:double
symbr:hasZr4PValue	Zr^{4+} Value	xsd:double
symbr:hasCr3PValue	Cr^{3+} Value	xsd:double
symbr:hasClNValue	Cl^- Value	xsd:double
symbr:hasClONValue	ClO^- Value	xsd:double
symbr:hasSiO3NValue	SiO_3^- Value	xsd:double
symbr:hasHSO4NValue	HSO_4^- Value	xsd:double
symbr:hasS2NValue	S^{2-} Value	xsd:double
symbr:hasNO3NValue	NO_3^- Value	xsd:double
symbr:hasHSO3NValue	HSO_3^- Value	xsd:double
symbr:hasCO32NValue	CO_3^{2-} Value	xsd:double
symbr:hasSiF62NValue	SiF_6^{2-} Value	xsd:double
symbr:hasHCO3NValue	HCO_3^- Value	xsd:double
symbr:hasFe2PValue	Fe^{2+} Value	xsd:double
symbr:hasNO2NValue	NO_2^- Value	xsd:double
symbr:hasPO43NValue	PO_4^{3-} Value	xsd:double
symbr:hasS2O3NValue	$S_2O_3^-$ Value	xsd:double
symbr:hasS2O42NValue	$S_2O_4^{2-}$ Value	xsd:double
symbr:hasSO42NValue	SO_4^{2-} Value	xsd:double
symbr:hasSiO42NValue	SiO_4^{2-} Value	xsd:double
symbr:hasHPO42NValue	HPO_4^{2-} Value	xsd:double
symbr:hasPbValue	Pb Value	xsd:double
symbr:hasAsValue	As Value	xsd:double
symbr:hasHgValue	Hg Value	xsd:double
symbr:hasCdValue	Cd Value	xsd:double
symbr:hasAlValue	Al Value	xsd:double
symbr:hasOthermetalsValue	Other metals Value	xsd:double
symbr:hasIValue	I Value	xsd:double
symbr:hasFValue	F Value	xsd:double
symbr:hasAOXValue	AOX Value	xsd:double
symbr: hasTemperature	Temperature	xsd:double
symbr: hasClassification	A property that denotes the relationship between the wastewater stream and the EWC classification.	symbr:EWC
symbr: isUsedBy	A property that denotes the relationship between the wastewater stream and the wastewater treatment process.	symbr:WwTreatment

symbr:EWC [13]

A class that defines the classification of the saline wastewater stream. The EWC classification is a standardized way of describing waste that is used in several reports including quarterly/annual waste data returns to SEPA, waste transfer notes and special waste consignment notes. The EWC is a list of waste types, established by the European Commission Decision 2000/532/EC1, which categorizes wastes based on a combination of what they are, and the process or activity that produces them. It provides a standard framework for the comparison of waste data (statistics) across all member states.

The EWC is divided into 20 chapters, most of which are industry-based, although some are based on materials and processes. Individual waste types are assigned a six-digit code: the first two digits specify the chapter, the next two specify the subchapter, and the last two are specific to the waste type.
Properties of this class are presented in table 5:

*Table 5: **symbr:**EWC class properties, SB ontology*

Property Name	Description	Range of Values
symbr:ewcCode	The category code of the wastewater stream.	xsd:string
rdfs:label	The category name of the wastewater stream.	xsd:string

symbr:WwTreatment

A class that represents the processes that takes place resulting in water and mineral recovery (ZERO BRINE Consortium Technologies).
Properties of this class are presented in table 6.

*Table 6: **symbr:**WwTreatment class properties, SB ontology*

Property Name	Description	Range of Values
rdfs:label	A name (label) of the wastewater Treatment.	xsd:string
symbr:capexValue	CAPEX Value	xsd:double
symbr:opexValue	OPEX Value	xsd:double
symbr:humanToxicityValue	Human Toxicity Value.	xsd:double
symbr:respiratoryEffectsValue	Respiratory effects Value	xsd:double
symbr:ionizingRadiationValue	Ionizing radiation Value	xsd:double
symbr:ozoneLayerDepletionValue	Ozone layer depletion Value	xsd:double
symbr:photochemicalOxidationValue	Photochemical oxidation Value	xsd:double
symbr:aquaticEcotoxicityValue	Aquatic ecotoxicity Value	xsd:double
symbr:terrestialEcotoxicityValue	Terrestial ecotoxicity Value	xsd:double
symbr:aquaticAcidificationValue	Aquatic acidification Value	xsd:double
symbr:aquaticEutrophicationValue	Aquatic eutrophication Value	xsd:double
symbr:terrestialAcidNutrValue	Terrestial acid/nutr Value	xsd:double
symbr:landOccupationValue	Land occupation Value	xsd:double
symbr:globalWarmingValue	Global warming Value	xsd:double
symbr:nonRenewableEnergyValue	Non-renewable energy Value	xsd:double
symbr:mineralExtractionValue	Mineral extraction Value	xsd:double
symbr:humanHealthValue	Human health Value	xsd:double

[13] http://www.nwcpo.ie/forms/EWC_code_book.pdf

symbr:ecosystemQualityValue	Ecosystem quality Value	xsd:double
symbr:climateChangeValue	Climate change Value	xsd:double
symbr:resourcesValue	Resources Value	xsd:double
symbr:uses	A property that denotes the relationship between the wastewater treatment and the solution provider.	symbr:SolutionProvider
symbr:produces	A property that denotes the relationship between the wastewater treatment and the product.	symbr:Product

symbr:SolutionProvider

A class that represents the innovative saline wastewater treatment technologies for water and mineral recovery developed in the framework of ZEROBRINE project.
Properties of this class are presenter in table 7.

*Table 7: **symbr:**SolutionProvider class properties, SB ontology*

Property Name	Description	Range of Values
rdfs:label	The name of the technology used.	xsd:string

symbr:Use

The role of the class **symbr:**Use in the knowledge model is to define the desired use of the product by the **symbr:**EndUser.
Properties of this class are presented in table 8.

*Table 8: **symbr:**Use class properties, SB ontology*

Property Name	Description	Range of Values
rdfs:label	A label for the desired use by the EndUser.	xsd:string
symbr: *UseOfproduct*	The name of the product that the end-user uses.	xsd:string
symbr:hasClassificationSU	A property that denotes the relationship between the desired use and the SU categorization.	symbr:SU
symbr:hasClassificationSBI	A property that denotes the relationship between the desired use and the SBI categorization.	symbr:SBI
symbr:hasClassificationPC	A property that denotes the relationship between the desired use and the PC categorization.	symbr:PC
symbr:hasClassificationNACE	A property that denotes the relationship between the desired use and the NACE categorization.	symbr:NACE
symbr:hasClassificationAC	A property that denotes the relationship between the desired use and the AC categorization.	symbr:AC
symbr:hasClassificationTF	A property that denotes the relationship between the desired use and the TF categorization.	symbr:TF
symbr:hasClassificationWUC	*A property that denotes the relationship between the desired use and the WUC categorization.*	*xsd:string*
symbr:hasRequirements	A property that denotes the relationship between the desired use and the requirements of the end-user.	symbr:Requirements

symbr:SU

A class that represents the categories of the Sector of End-use. This categorization is meant to provide information on the sector of the economy or market area where the use takes place. They therefore indicate types of industries or industry segments where the substance is present.
Properties of this class are presented in table 9.

*Table 9: **symbr:**SU class properties, SB ontology*

Property Name	Description	Range of Values
symbr:suCode	The SU category code.	xsd:string
rdfs:label	The SU category name.	xsd:string

symbr:PC (Product Category)

A class that represents the Chemical Product categorization as defined by REACH. This categorization has two functions:

i) it describes the sectors formulating mixtures by mixture types (information relevant at formulation life-cycle stage). The categories listed help to further structure the uses of the substance along the supply chain based on the product types;
ii) it describes the product types used by the end-users (industrial, professional or consumer end-users). The product type implicitly includes some information on the potential for exposure/release of the substance.
Properties of this class are presented in table 10:

*Table 10: **symbr:**PC class properties, SB ontology*

Property Name	Description	Range of Values
symbr:pcCode	The PC category code.	xsd:string
rdfs:label	The PC category name.	xsd:string
dc:description	The PC description.	xsd:string

symbr:AC (Articles Category)

A class that represents the Articles Categories (AC), a categorization that is designed to describe the types of article in which the substance is contained or on which the substance has been applied.
Properties of this class are presented in table 11.

*Table 11: **symbr:**AC class properties, SB ontology*

Property Name	Description	Range of Values
symbr:acCode	The AC category code.	xsd:string
rdfs:label	The AC category name.	xsd:string
dc:description	The AC description.	xsd:string

symbr:TF (Technical Functions)

A class that represents the Technical Function categorization (TF). This categorization is designed to describe the role that the substance fulfils when it is used (what it actually does as such in a process or what it actually does in a mixture or article).
Properties of this class are presented in table 12.

*Table 12: **symbr:**TF class properties, SB ontology*

Property Name	Description	Range of Values
rdfs:label	The TF name.	xsd:string
dc:description	The TF description.	xsd:string

symbr:SBI (Standaard Bedrijfsindeling)

A class that represents the Dutch Standaard Bedrijfsindeling (SBI 2008). This standard is based upon the activity classification of the European Union (Nomenclature statistique des activités économiques dans la Communauté Européenne, NACE) and on the classification of the United Nations (International Standard Industrial Classification of All Economic Activities, ISIC).
Properties of this class are presented in table 13.

*Table 13: **symbr:**SBI class properties, SB ontology*

Property Name	Description	Range of Values
symbr:sbiCode	The SBI category code.	xsd:string
rdfs:label	The SBI category name.	xsd:string

symbr:WUC (Water Use Category)

Water Use Category (WUC) is a class that represents the categories of the water end-use. This categorization is meant to provide information for the general water uses in industries and agriculture. Properties of this class are presented in table 9.

*Table 14: **symbr:**WUC class properties, SB ontology*

Property Name	Description	Range of Values
rdfs:label	The WUC category name.	xsd:string

NACE

NACE codes for activities statistical classification of economic activities

NACE is the acronym used to designate the various statistical classifications of economic activities developed in the European Union. NACE provides the framework for collecting and presenting a large range of statistical data according to economic activity in the fields of economic statistics (e.g. production, employment, national accounts) and in other statistical domains.

The ontology for NACE exists and has been reused:

NACE Economic Activities ontology: http://ec.europa.eu/eurostat/ramon/ontologies/nace.rdf

symbr: Requirements

A class that represents the requirements set from end-users for a specific desired **USE** of the mineral in question. This class contains the technical specifications and limitations provided by the end-user about the desired product. This class is a subclass of the class symbr:Use.
More specifically the properties of this class are presented in table 14.

*Table 15: Properties of **symbr:**Use class, SB ontology*

Property Name	Description	Range of Values
symbr:hasPurityValue	Purity Value	xsd:double
symbr:hasMoistureValue	Moisture Value	xsd:double
symbr:haspH	pH Value	xsd:string
symbr:hasVolatilematterValue	volatile matter Value	xsd:double
symbr:hasNonvolatilematterValue	nonvolatile matter Value	xsd:double
symbr:hasOrganicmatterValue	organic matter Value	xsd:double
symbr:hasNH4PValue	NH_4^+ Value	xsd:double
symbr:hasNO3NValue	NO_3^- Value	xsd:double
symbr:hasNO2NValue	NO_2^- Value	xsd:double
symbr:hasNH3Value	NH_3 Value	xsd:double
symbr:hasPValue	P Value	xsd:double
symbr:hasPO43NValue	PO_4^{3-} (phosphates) Value	xsd:double
symbr:hasP2O5Value	P_2O_5 Value	xsd:double
symbr:hasClNValue	Cl^- Value	xsd:double
symbr:hasCO32NValue	CO_3^{2-} Value	xsd:double
symbr:hasFeValue	Fe Value	xsd:double
symbr:hasFe2O3Value	Fe_2O_3 Value	xsd:double
symbr:hasCaValue	Ca Value	xsd:double
symbr:hasCaOValue	CaO Value	xsd:double
symbr:hasHeavyMetalsValue	heavy metals Value	xsd:double
symbr:hasPbValue	Pb (Pb) Value	xsd:double
symbr:hasAsValue	As (Arsenic) Value	xsd:double
symbr:hasHgValue	Hg (Mercury) Value	xsd:double
symbr:hasCdValue	Cd (cadmium) Value	xsd:double
symbr:hasCrValue	Cr (Chromium) Value	xsd:double
symbr:hasMnValue	Mn (Manganese) Value	xsd:double
symbr:hasMnO2Value	MnO_2 Value	xsd:double
symbr:hasNiValue	Ni (Nickel) Value	xsd:double
symbr:hasNiOValue	NiO Value	xsd:double
symbr:hasNi2O3Value	Ni_2O_3 Value	xsd:double

symbr:hasCuValue	Cu Value	xsd:double
symbr:hasCuOValue	CuO Value	xsd:double
symbr:hasCu2O3Value	Cu_2O_3 Value	xsd:double
symbr:hasAlValue	Al (Aluminium) Value	xsd:double
symbr:hasAl2O3Value	Al_2O_3 Value	xsd:double
symbr:hasZnValue	Zn (Zinc) Value	xsd:double
symbr:hasZnOValue	ZnO Value	xsd:double
symbr:hasSeValue	Se (Sellenium) Value	xsd:double
symbr:hasSeO2Value	SeO_2 Value	xsd:double
symbr:hasBrValue	Br (Bromide) Value	xsd:double
symbr:hasBr2O3Value	Br_2O_3 Value	xsd:double
symbr:hasBrO2Value	BrO_2 Value	xsd:double
symbr:hasSrValue	Sr (Strontium) Value	xsd:double
symbr:hasSrOValue	SrO Value	xsd:double
symbr:hasZrValue	Zr (Zirconium) Value	xsd:double
symbr:hasZrO2Value	ZrO_2 Value	xsd:double
symbr:hasMoValue	Mo (Molybdenum) Value	xsd:double
symbr:hasMoO3Value	MoO_3 Value	xsd:double
symbr:hasSnValue	Sn (Tin) Value	xsd:double
symbr:hasSnOValue	SnO Value	xsd:double
symbr:hasSnO2Value	SnO_2 Value	xsd:double
symbr:hasSbValue	Sb (Antimony) Value	xsd:double
symbr:hasSb2O3Value	Sb_2O_3 Value	xsd:double
symbr:hasBeValue	Be (Beryllium) Value	xsd:double
symbr:hasBeOValue	BeO Value	xsd:double
symbr:hasVValue	V (Vanadium) Value	xsd:double
symbr:hasVOValue	VO Value	xsd:double
symbr:hasV2O3Value	V_2O_3 Value	xsd:double
symbr:hasTiValue	Ti (Titanium) Value	xsd:double
symbr:hasTiO2Value	TiO_2 Value	xsd:double
symbr:hasBaValue	Ba (barium) Value	xsd:double
symbr:hasBaOValue	BaO Value	xsd:double
symbr:hasSiO2Value	SiO_2 Value	xsd:double
symbr:hasSiValue	Si (Silicon) Value	xsd:double
symbr:hasSValue	S (Sulphur) Value	xsd:double
symbr:hasSO42NValue	SO_4^{2-} (Sulphates) Value	xsd:double
symbr:hasSulphurcompoundsValue	Sulphur compounds Value	xsd:double
symbr:hasS2NValue	S^{2-} (Sulphides) Value	xsd:double
symbr:hasNaPValue	Na^+ (Sodium) Value	xsd:double
symbr:hasMg2PValue	Mg^{2+} (Magnesium) Value	xsd:double
symbr:hasMgOValue	MgO Value	xsd:double
symbr:hasKValue	K (Potassium) Value	xsd:double
symbr:hasK2OValue	K_2O Value	xsd:double
symbr:hasFValue	F (Fluoride) Value	xsd:double
symbr:hasIValue	I (Iodine) Value	xsd:double
symbr:hasNaClValue	NaCl (sodium chloride) Value	xsd:double
symbr:hasNa2SO4Value	Na_2SO_4 (sodium sulphate) Value	xsd:double
symbr:hasNa2CO3Value	Na_2CO_3 (sodium carbonate) Value	xsd:double
symbr:hasNa2SValue	Na_2S (disodium sulphide) Value	xsd:double
symbr:hasK2SO4Value	K_2SO_4 (potassium sulphate) Value	xsd:double
symbr:hasCH3COONaValue	CH_3COONa (sodium acetate) Value	xsd:double
symbr:hasNaNO2Value	$NaNO_2$ (sodium nitrite) Value	xsd:double
symbr:hasH2SO4Value	H_2SO_4 (sulphuric acid) Value	xsd:double
symbr:hasNa2S2O5Value	$Na_2S_2O_5$ (sodium metabisulphite) Value	xsd:double
symbr:hasSO2Value	SO_2 (sulphure dioxide) Value	xsd:double
symbr:hasNa2O7S2Value	$Na_2O_7S_2$ (disodium disulphate) Value	xsd:double
symbr:hasNa2SO3Value	Na_2SO_3 (sodium sulphite) Value	xsd:double

symbr:hasNa2S2O3Value	$Na_2S_2O_3$ (sodium thiosulphate) Value	xsd:double
symbr:hasMgCl2Value	$MgCl_2$ (magnesium chloride) Value	xsd:double
symbr:hasCaSO4Value	$CaSO_4$ (Calcium sulphate) Value	xsd:double
symbr:hasCa(OH)2Value	$Ca(OH)_2$ (Calcium hydroxide) Value	xsd:double
symbr:hasMgSO4Value	$MgSO_4$ (Magnesium sulphate) Value	xsd:double
symbr:hasCaCl2Value	$CaCl_2$ (Calcium Chloride) Value	xsd:double
symbr:hasKClValue	KCl (Potassium Chloride) Value	xsd:double
symbr:hasMgCO3Value	$MgCO_3$ (Magnesium Carbonate) Value	xsd:double
symbr:hasSARValue	SAR Value	*xsd:double*
symbr:hasECValue	EC Value	*xsd:double*
symbr:hasCODValue	COD Value	*xsd:double*
symbr:hasBOD5Value	BOD_5 Value	*xsd:double*
symbr:hasTSSValue	TSS Value	*xsd:double*
symbr:hasTDSValue	TDS Value	*xsd:double*
symbr:hasSSValue	SS Value	*xsd:double*
symbr:hasTurbidityValue	Turbidity Value	*xsd:double*
symbr:hasEcoliValue	Ecoli Value	*xsd:double*
symbr:hasSiO2Value	SiO_2 Value	*xsd:double*
symbr:hasTotalHardnessValue	TotalHardness Value	*xsd:double*
symbr:refersTo	A property that denotes the relationship between the requirements and the Product derived from the wastewater treatment.	symbr:Product

symbr:Product

A class that represents the product produced by the wastewater treatment and/or raw mineral and water recovery. **Product** properties are composed of a chemical components' list and of other characteristics such as purity. These properties in the knowledge model are presented in table:

*Table 16: Properties of **symbr:**Product class, SB ontology*

Property Name	Description	Range of Values
rdfs:label	The name of the product.	xsd:string
symbr:hasQuantityValue	Quantity Value	xsd:double
symbr:hasPurityValue	Purity Value	xsd:double
symbr:hasMoistureValue	Moisture Value	xsd:double
symbr:haspHValue	pH	xsd:string
symbr:hasVolatileMatterValue	volatile matter Value	xsd:double
symbr:hasNonVolatileMatterValue	nonvolatile matter Value	xsd:double
symbr:hasOrganicMatterValue	organic matter Value	xsd:double
symbr:hasNH4PValue	NH_4^+ Value	xsd:double
symbr:hasNO3NValue	NO_3^- Value	xsd:double
symbr:hasNO2NValue	NO_2^- Value	xsd:double
symbr:hasNH3Value	NH_3 Value	xsd:double
symbr:hasPValue	P Value	xsd:double
symbr:hasPO43NValue	PO_4^{3-} (phosphates) Value	xsd:double
symbr:hasP2O5Value	P_2O_5 Value	xsd:double
symbr:hasClNValue	Cl^- Value	xsd:double
symbr:hasCO32NValue	CO_3^{2-} Value	xsd:double
symbr:hasFeValue	Fe Value	xsd:double
symbr:hasFe2O3Value	Fe_2O_3 Value	xsd:double

symbr:hasCaValue	Ca Value	xsd:double
symbr:hasCaOValue	CaO Value	xsd:double
symbr:hasHeavyMetalsValue	heavy metals Value	xsd:double
symbr:hasPbValue	Pb (Pb) Value	xsd:double
symbr:hasAsValue	As (Arsenic) Value	xsd:double
symbr:hasHgValue	Hg (Mercury) Value	xsd:double
symbr:hasCdValue	Cd (cadmium) Value	xsd:double
symbr:hasCrValue	Cr (Chromium) Value	xsd:double
symbr:hasMnValue	Mn (Manganese) Value	xsd:double
symbr:hasMnO2Value	MnO_2 Value	xsd:double
symbr:hasNiValue	Ni (Nickel) Value	xsd:double
symbr:hasNiOValue	NiO Value	xsd:double
symbr:hasNi2O3Value	Ni_2O_3 Value	xsd:double
symbr:hasCuValue	Cu Value	xsd:double
symbr:hasCuOValue	CuO Value	xsd:double
symbr:hasCu2O3Value	Cu_2O_3 Value	xsd:double
symbr:hasAlValue	Al (Aluminium) Value	xsd:double
symbr:hasAl2O3Value	Al_2O_3 Value	xsd:double
symbr:hasZnValue	Zn (Zinc) Value	xsd:double
symbr:hasZnOValue	ZnO Value	xsd:double
symbr:hasSeValue	Se (Sellenium) Value	xsd:double
symbr:hasSeO2Value	SeO_2 Value	xsd:double
symbr:hasBrValue	Br (Bromide) Value	xsd:double
symbr:hasBr2O3Value	Br_2O_3 Value	xsd:double
symbr:hasBrO2Value	BrO_2 Value	xsd:double
symbr:hasSrValue	Sr (Strontium) Value	xsd:double
symbr:hasSrOValue	SrO Value	xsd:double
symbr:hasZrValue	Zr (Zirconium) Value	xsd:double
symbr:hasZrO2Value	ZrO_2 Value	xsd:double
symbr:hasMoValue	Mo (Molybdenum) Value	xsd:double
symbr:hasMoO3Value	MoO_3 Value	xsd:double
symbr:hasSnValue	Sn (Tin) Value	xsd:double
symbr:hasSnOValue	SnO Value	xsd:double
symbr:hasSnO2Value	SnO_2 Value	xsd:double
symbr:hasSbValue	Sb (Antimony) Value	xsd:double
symbr:hasSb2O3Value	Sb_2O_3 Value	xsd:double
symbr:hasBeValue	Be (Beryllium) Value	xsd:double
symbr:hasBeOValue	BeO Value	xsd:double
symbr:hasVValue	V (Vanadium) Value	xsd:double
symbr:hasVOValue	VO Value	xsd:double
symbr:hasV2O3Value	V_2O_3 Value	xsd:double
symbr:hasTiValue	Ti (Titanium) Value	xsd:double
symbr:hasTiO2Value	TiO_2 Value	xsd:double
symbr:hasBaValue	Ba (barium) Value	xsd:double
symbr:hasBaOValue	BaO Value	xsd:double
symbr:hasSiO2Value	SiO_2 Value	xsd:double
symbr:hasSiValue	Si (Silicon) Value	xsd:double
symbr:hasSValue	S (Sulphur) Value	xsd:double
symbr:hasSO42NValue	SO_4^{2-} (Sulphates) Value	xsd:double
symbr:hasSulphurCompoundsValue	Sulphur compounds Value	xsd:double
symbr:hasS2NValue	S^{2-} (Sulphides) Value	xsd:double
symbr:hasNaPValue	Na^+ (Sodium) Value	xsd:double
symbr:hasMg2PValue	Mg^{2+} (Magnesium) Value	xsd:double
symbr:hasMgOValue	MgO Value	xsd:double
symbr:hasKValue	K (Potassium) Value	xsd:double
symbr:hasK2OValue	K_2O Value	xsd:double
symbr:hasFValue	F (Fluoride) Value	xsd:double

symbr:hasIValue	I (Iodine) Value	xsd:double
symbr:hasNaClValue	NaCl (sodium chloride) Value	xsd:double
symbr:hasNa2SO4Value	Na_2SO_4 (sodium sulphate) Value	xsd:double
symbr:hasNa2CO3Value	Na_2CO_3 (sodium carbonate) Value	xsd:double
symbr:hasNa2SValue	Na_2S (disodium sulphide) Value	xsd:double
symbr:hasK2SO4Value	K_2SO_4 (potassium sulphate) Value	xsd:double
symbr:hasCH3COONaValue	CH_3COONa (sodium acetate) Value	xsd:double
symbr:hasNaNO2Value	$NaNO_2$ (sodium nitrite) Value	xsd:double
symbr:hasH2SO4Value	H_2SO_4 (sulphuric acid) Value	xsd:double
symbr:hasNa2S2O5Value	$Na_2S_2O_5$ (sodium metabisulphite) Value	xsd:double
symbr:hasSO2Value	SO_2 (sulphure dioxide) Value	xsd:double
symbr:hasNa2O7S2Value	$Na_2O_7S_2$ (disodium disulphate) Value	xsd:double
symbr:hasNa2SO3Value	Na_2SO_3 (sodium sulphite) Value	xsd:double
symbr:hasNa2S2O3Value	$Na_2S_2O_3$ (sodium thiosulphate) Value	xsd:double
symbr:hasMgCl2Value	$MgCl_2$ (magnesium chloride) Value	xsd:double
symbr:hasCaSO4Value	$CaSO_4$ (Calcium sulphate) Value	xsd:double
symbr:hasCa(OH)2Value	$Ca(OH)_2$ (Calcium hydroxide) Value	xsd:double
symbr:hasMgSO4Value	$MgSO_4$ (Magnesium sulphate) Value	xsd:double
symbr:hasCaCl2Value	$CaCl_2$ (Calcium Chloride) Value	xsd:double
symbr:hasKClValue	KCl (Potassium Chloride) Value	xsd:double
symbr:hasMgCO3Value	$MgCO_3$ (Magnesium Carbonate) Value	xsd:double
symbr:hasSiO3NValue	SiO_3^- Value	xsd:double
symbr:hasHSO4NValue	HSO_4^- Value	xsd:double
symbr:hasHSO3NValue	HSO_3^- Value	xsd:double
symbr:hasCO32NValue	CO_3^{2-} Value	xsd:double
symbr:hasSiF62NValue	SiF_6^{2-} Value	xsd:double
symbr:hasHCO3NValue	HCO_3^- Value	xsd:double
symbr:hasS2O3NValue	$S_2O_3^-$ Value	xsd:double
symbr:hasS2O42NValue	$S_2O_4^{2-}$ Value	xsd:double
symbr:hasSO4N2Value	SO_4^{2-} Value	xsd:double
symbr:hasSiO42NValue	SiO_4^{2-} Value	xsd:double
symbr:hasHPO42NValue	HPO_4^{2-} Value	xsd:double
symbr:hasSARValue	SAR Value	xsd:double
symbr:hasECValue	EC Value	xsd:double
symbr:hasCODValue	COD Value	xsd:double
symbr:hasBOD5Value	BOD_5 Value	xsd:double
symbr:hasTSSValue	TSS Value	xsd:double
symbr:hasTDSValue	TDS Value	xsd:double
symbr:hasSSValue	SS Value	xsd:double
symbr:hasTurbidityValue	Turbidity Value	xsd:double
symbr:hasEcoliValue	E.coli Value	xsd:double
symbr:hasTotalHardnessValue	Total Hardness Value	xsd:double

3.2.5 Create Instances

Instances will be created in the framework of *sub-task 6.1.2: Design and implementation of analysis, feedback and interface tools* and will be presented in *deliverable 6.2: Report on system tools for analysis, feedback and interface*.

3.2.6 Conventions

In order to allow useful information to be assumed from the names of the concepts and properties it has been decided to adopt the following two conventions.

- *Class Names: No whitespaces CamelCase. (e.g. SolutionProvider)*
- *Property Names: No whitespaces, starting with a lower case (usually for the prefix) and capitalising every word after that (e.g. hasUse)*

4 GROUPS OF SB STAKEHOLDERS

4.1 Introduction

"Salinity" is a term used to describe the concentration of inorganic dissolved salts (Cuenca, 2013).According to the classification of Global Water Intelligence (GWI); water bodies can be classified into the following four categories based on their salt content (salinity):

- pure water: less than 500 mg/l,
- river water: 500-3,000 mg/l,
- brackish water: 1,500-15,000 mg/l and,
- seawater: 15,000 – 50,000 mg/l.

Another common classification of water based on the salt content is the following (Wang et al., 2008):

- recycled water with less than 1,500 mg/L TDS,
- slightly saline water with 1,000–3,000 mg/L TDS,
- moderately saline water with 3,000–10,000 mg/L TDS and,
- highly saline water with over 10,000 mg/L TDS.

Several studies also use the term "brine" for water with a salt content greater than 50,000 mg/l. According to WssTP (2012) as brine can be defined a water stream which has almost reached saturation point with dissolved salt content (> 50 g/l). The composition of brines depends on the nature of the water source or on the process producing brine as a waste stream. Many industrial processes produce considerable amounts of wastewater with high salt concentrations. Even though these saline impaired wastewater streams may have salinity less than 50g/l, it is common to characterize them as brines. These saline impaired water streams can be generated mainly from the industrial activities as presented in the following sections.

In the following sections a brief presentation the stakeholders groups engaged to the knowledge model described in chapter 2 is taking place. These stakeholders groups are: (i) brine owners ((ia) Brine waste stream producers, and (ib) Aggregators who collect waste streams from several producers, (ii) solution providers and (iii) end-users of the recovered products. This information is crucial for the knowledge model development procedure, for the creation of the relevant fields of the OBP, and for the simplification of the data procedure. The composition of industrial brines varies from branch to branch and from site to site, making each saline wastewater stream generated in process industries almost unique. To deal with this variety, for brine generators the general information for each sector and the main characteristics of the brine streams produced are provided based mainly on BREF documents in order to obtain broad information about the targeted sectors.

Table 17: NACE codes of brine producers

Section	Division	Group
C **MANUFACTURING**	C10 **Manufacture of food products**	C10.1 Processing and preserving of meat and production of meat products
		C10.2 Processing and preserving of fish, crustaceans and molluscs
		C10.3 Processing and preserving of fruit and vegetables
		C10.5 Manufacture of dairy products
	C13 **Manufacture of textiles**	C13.3 Finishing of textiles
		C13.9 Manufacture of other textiles
	C15 **Manufacture of leather and related products**	C15.1 Tanning and dressing of leather; manufacture of luggage, handbags, saddlery and harness; dressing and dyeing of fur
	C17 **Manufacture of paper and paper products**	C17.1 Manufacture of pulp, paper and paperboard
	C19 **Manufacture of coke and refined petroleum products**	C19.2 Manufacture of refined petroleum products
	C20 **Manufacture of chemicals and chemical products**	C20.13 Manufacture of other inorganic basic chemicals
	C24 **Manufacture of basic metals**	C24.1 Manufacture of basic iron and steel and of ferro-alloys
		C24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel
		C24.3 Manufacture of other products of first processing of steel
		C24.4 Manufacture of basic precious and other non-ferrous metals C24.4.2_*Aluminium production* C24. 4.4 *Copper production*
E **WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES**	E 36 **Water collection, treatment and supply**	E 36.0 Water collection, treatment and supply

4.2 Brine Generators

4.2.1 Food industry –Dairies (NACE code: C10.5)

4.2.1.1 General information about the sector

In the European Union (EU) there are allocated more than 12,000 dairy processing sites where 300,000 direct jobs are involved. Worldwide, five of the ten top dairy companies are European. According to the information provided in the BREF document “Food, Drink and Milk Industries”, the European industry of milk production brings more than 9.3 billion euros to the EU trade. In 2014, in EU-28 there were produced almost 164.8 million tonnes of milk, 96.8% of which was cows’ milk, while a percentage of 3.2% of the total production was derived from ewes, goats and buffalos. Dairy industries were the main receiver of the produced milk while the rest was used on farms. The production of cows’ milk increased by 3.8% between years 2013 and 2014, while the dairy cows increased by 0.4%. The number of cows that produce milk for dairies is 23.6 millions with an average yield of 6,777 kg per head.

As shown in the figure below, in EU-28 Germany holds the first place in the collection of cow’s milk, followed by France and UK.

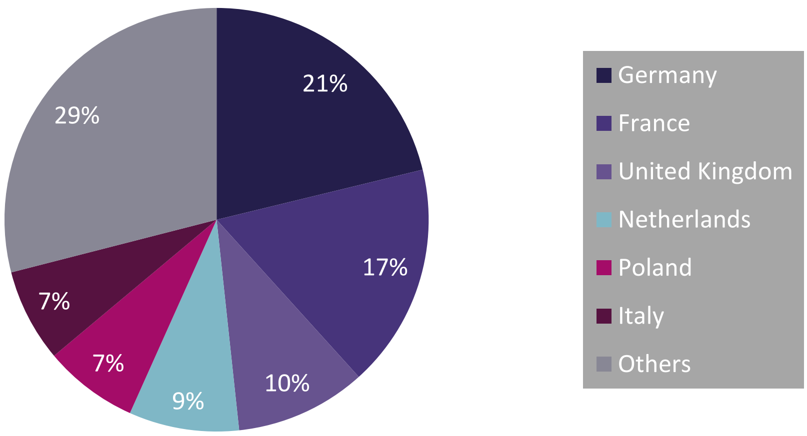

Figure 2: Collection of cows’ milk by dairies in 2014 (% share of EU-28 total) (data taken from Eurostat 2015)

4.2.1.2 Wastewater generation

The main environmental issue in the dairy sector is the generation of a wastewater stream. The high demands of dairies in cleanliness and hygiene lead to the use of vast amounts of water, resulting in the immense production of wastewater (BREF (a) 2017). In UK for example, the dairy sector uses 21% of the UK's fresh water resources (The Water Network, 2018).

The following table shows the water consumption expressed in m^3 per tonne of processed raw material.

Table 18: Water consumption in European dairies (data taken from TWG 2015)

Product	**Water consumption** (m^3/tonne of processed raw material)
Market milk	0.33-8.12
Cheese	0.25-4.12
Powder (e.g. milk, whey)	0.50-3.19

The wastewater generated in dairy industry, like most other agro-industries, is characterized by high Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) concentrations because of their high organic content (Demirel et al., 2004).

Brine effluent in cheese production

The processes of ice-cream, butter, whey and cheese production result all in wastewater generation. However, cheese production is the one, found to generate saline effluents (with the presence of salts and minerals) as a result of the brining process. For that reason, following, the focus will be on the cheese production sector.

Salt brine that is used to cure many different varieties of cheese can end up as a saline wastewater (international Dairy Federation, Dairy Industry Salts IDF Factsheet – February 2012).

The brine used in the brining process of cheese production consists of salts (mainly NaCl or KCl or both) and water in different ratios (Thibaudeau et al., 2015, Madadlou et al., 2007). The salt concentration of brine can reach up to 26% (Fucà et al., 2012, Guinee, 2004). As a result, **in the brine wastewater the K^+, Na^+, Cl^- ions are expected to be found in high concentrations.** When a block of cheese is placed into the brine, there is a net movement of Na^+ and Cl^- ions from the brine into the cheese. Ions such as $Ca^{2+}$and $H_2PO_4^-$ move into the brine if their concentration is higher in the cheese than in the brine (Fucà, et al., 2012). Additionally, it is expected that other cheese components are transferred to the brine. Some parameters to consider in the brine effluent composition are the following: COD, BOD, TSS, SS, VSS, TS, TVS, oils and fats, proteins, alkalinity, pH, EC, sodium, sulphates, potassium, calcium, chlorides, nitrates, magnesium, TKN, Total phosphorous. (Demirel & Yenigun, 2004 and Noorjahan et al., 1970).

It is found that brine wastewater from cheese production can be used in road de-icing: «*When rock salt is combined with cheese brine – a liquid waste product from cheese making – it helps the salt stick to the roadway (rather than flowing into storm drains and waterways beyond) and speeds up melting*» (Conservation law foundation)[14].

As a result of the abovementioned information, in the following table are summarized the key parameters to take into consideration in order to characterize the cheese brine wastewater.

Table 19: Key parameters for cheese brine wastewater characterization

cations	other
Na^+	COD
K^+	BOD
	TSS
Ca^{2+}	VSS
	TVS
anions	TS
Cl^-	Oils and fats
	alkalinity
PO_4^{3-}	pH
	EC
$H_2PO_4^-$	TKN

[14] https://www.clf.org/

4.2.2 Food industry - Meat process (NACE code: C10.1)

4.2.2.1 General information about the sector

The biggest part of EU meat consumption is attributed to processed meat (as canned, cured, cooked etc.). The meat processing sector consists of every activity related to the production of meat preparation and meat products.

In EU-28 more than 24,000 companies exist under the umbrella of meat the processing sector with a total production value of 86 billion EUR. Additionally, a number of more than 421,000 persons are employed in meat processing sector, being one of the largest number for the whole EU food process industry (Clitravi-Avec, 2016).

The majority (90%) of enterprises in EU meat processing is SMEs and is characterized by specialization in operating independently at different stages of the supply chain. This is specifically the case of the beef and pig meat sectors. Larger companies (processing facility storages, owning slaughterhouses) are only a small part of the EU meating process industry and they are mainly in the poultry sector (BREF (a) 2017).

There are many stages in meat processing such as canning, cooking etc. However, according to BREF (a) (2017) and Johnson et al., (2004) the processes that generate brine wastewater are **curing** (Salting, dry salting, vessel salting, injection) and **pickling**. These processes generate wastewaters containing brines and meat juice.

4.2.2.2 Wastewater generation

Curing and pickling

Curing is the process where salt compounds are used for meat preservation and development of characteristic flavor and appearance of meat as well. Two methods of curing meats exist: (a) dry curing, during of which solid salt is rubbed on the surface of meats and (b) immersion method (the most common method) in which meat is submersed into a liquid solution of salts. Pickling is a method in which the injection of pickling solution in the meat takes place. This process is followed by the tumbling of meat with rotating drums in order to aid the distribution. In addition to NaCl, other salts are used for the brine solutions, often substituting the common table salt (NaCl). These salts are potassium nitrate (KNO_3), sodium nitrate ($NaNO_3$) and sodium nitrite ($NaNO_2$). Brines for pickling and curing contain also other substances with properties of enhancing flavor, prevention of discoloration, improvement of water-holding capacity of the meat. Substances with these properties are sugars, ascorbic acid and polyphosphates. The salts used in brines can be introduced in the wastewaters. Johnson et al. (2004) also mentioned that many of the ingredients of pickle solutions represent polluting material in high concentrations and add significantly to the raw waste load from the pickle operation. The large amount of spillage in this operation comes from runoff from the pickle injection, from pickle oozing out of the meat after injection, from dumping of cover pickle, and from dumping of residual pickle from the injection machine at the end of each operating day. These practices contribute substantially to the wastewater and waste load from a meat processing plant (Johnson et al., 2004).

It is necessary for the operators to minimize the over production of brine (BREF (a) 2017). There would be a positive impact as a result of this reduction as the discharge of raw material would be avoided and the detrimental effect of brines on the Waste Water Treatment Plant (WWTP) as well. Chlorides contained in brines are not reduced through a biological WWTP. The chloride concentration is reducing because of the dilution that takes place in WWTP (BREF (a) 2017).

Salt concentration in brines is reported to be in the range of 8-14% (Heinz & Hautzinge, 2007 and Peterson et al., 2017). Other sources mention that brine is usually prepared by dissolving sodium chloride and sodium nitrite in cold water at concentrations of 15-20%. [15]

Taking into consideration the components of brine, it is expected that wastewater from brining and pickling meat will contain ions such as Na^+, Cl^- , K^+, NO_3^-, NO_2^-, phosphates (PO_4^{3-}) and is to be characterized with significant levels of COD and BOD (because of the presence of sugar and ascorbic acid). Additionally, the presence of COD, BOD, NH_4 and phosphorous is expected because of the meat components that are maybe transferred in the brine.

The table that follows summarizes the components and the parameters to consider for the brine wastewater characterization. As there are no data for the concentrations, the ions that are expected to be in the higher concentrations (depending on the salts used in brine) are indicated with bold letters.

Table 20: Key parameters for meat brine wastewater characterization

Anions	Other parameters
NO_3^-	pH
NO_2^-	COD
Cl^-	BOD_5
Cations	TSS
Na^+	TKN
K^+	Alkalinity
Other Compounds	Electric conductivity (due to the presence of salts)
NH_4-N	
Phosphate(P)	

[15] https://condorchem.com/en/brine-treatment/

4.2.3 Food industry - Pickling vegetables (NACE code: C10.3)

4.2.3.1 General information about the sector

The varied climatic and topographic conditions of Europe play a very important role in the production of broad range of fruits and vegetables in the European Union. Typically, southern EU members follow "openair" production, while countries as Belgium and the Netherland have mainly all-season greenhouse production. The two thirds of total production of EU-28 come from Italy and Spain (BREF (a) 2017).

Fruit and vegetable processing includes many different steps accordingly to the final product characteristics. The present study will focus on the pickling process of vegetables as it is found that it is the process generating most of saline wastewater.

Pickling of vegetables

In a typical pickling process, raw vegetables are delivered, washed and then screened to remove extraneous matter such as stones. Depending upon the vegetable, the raw material might be steam cooked and then cooled. The product is then peeled, typically using steam, and reinspected before being cut to the required dimensions, e.g. sliced/diced/shredded, and transported to the filling line. The chopped vegetables are then filled into containers. An acidifying liquor is mixed with spices and transferred to the filling line to be used in the pickling sauce. This liquor typically consists of acetic acid, malt vinegar, spirit vinegar, distilled malt vinegar, liquid sugar and salt, depending upon the formulation. The acidifying liquor is deposited into the container. The container is sealed and typically pasteurised before cooling and packaging.

In a typical pickling process, raw vegetables are delivered, washed and then screened to remove extraneous matter such as stones (BREF (a) 2017).

Table 21: Vegetables submitted in pickling process (data taken from BREF (a) (2017)

Garden vegetables	Processing
Olives, cabbage, artichokes, mushrooms, onions, peppers, carrots and cucumbers	Put in oil, pickling/brining, sulphited

4.2.3.2 Wastewater generation

In the following table the wastewater volume and water pollution per unit of product generated in the processing of some vegetables are shown.

Table 22: Wastewater volume and water pollution per unit of product generated in the processing of some vegetables (data taken from: BREF (a) 2017, FDM)

Pickles	Wastewater volume (m^3/U)	BOD (kg/U)	TSS (kg/Unit of product)
Fresh packed	8.5	9.5	1.9
Process packed	9.6	18	3.3
Salting stations	1.1	8	0.4

Linda et al. (1976), described as the basic characterisation parameters the following: BOD5, TS, SS, Cl^-, TKN, TP, acidity, electric conductivity and pH. Duangsri et al. (2011), presented the following parameters and their values for the wastewater characterization collected from a local pickling factory: of 82 g/l total soluble solid, 11 g/l total sugar, 0.9g/l total acidity, 0.2g/l nitrogen, 1.6g/l phosphorus, 64 g/l NaCl and 10,800 mg/l BOD with a pH of 4.8. The high salinity of this wastewater stream is mainly attributed to the presence of NaCl.

Rosenberg et al. (2013), mention that manufacturers replace NaCl with calcium chloride ($CaCl_2$), as it is more environmental friendly. Traditionally, the production of pickles used to take place with the use of NaCl and although manufacturers of pickles recycle brines before discharge, the generation of effluents with high NaCl concentration is inevitable. In addition, Wilson et al. (2015), mention also that the use of $CaCl_2$ instead of NaCl for brining in pickling process is a good alternative choice in order to avoid the environmental impact of discharging an effluent with high NaCl concentration. Concluding, replacing NaCl with $CaCl_2$ can lead to the presence of Ca^{2+}, in pickling effluent. In the present study there are not available data for the concentration of calcium in the effluent of pickling process.

Taking into account the above mentioned information, the key parameters for the characterization of pickling wastewater are summarized in the following table:

Table 23: Main characteristics of the wastewater stream from pickling process

Parameters	Tankyard Brines from cucumbers (Little et al., 1974)	Cauliflower (Little et al., 1974)	Pepper (Little et al., 1974)	Onion (Little et al., 1974)	Pickling Vegetables (Duangsri et al., 2011)	Pickling cucumber (Rosenberg et al., 2013 and Wilson et al., 2015)
pH	3.4	4	4.2	3.9	4.8	n.a.
TOC (mg/l)	3,400	6,200	6,300	<100	n.a.	n.a.
SS (mg/l)	330	219	310	620	n.a.	n.a..
TKN (mg/l)	732	233	95	20	n.a.	n.a
TP (mg/l)	87	142	80	9.6	1,600	n.a.
BOD (mg/l)	2,000	>2,700	>2,700	630	10,800	n.a
Na^+	***	***	***	***	25,200	n.a
Cl^- (g/l)	111	79	184	113	38.4	✓
Acidity (mg/l)	2,324	1,850	800	170	900	n.a

Conductivity (mmhos)	159	138	202	172	-	n.a.
Ca^{2+}	n.a.	n.a.	n.a.	n.a.	n.a.	✓
Total sugar (g/l)	n.a.	n.a.	n.a.	n.a.	11	n.a.
Total nitrogen (mg/l)	n.a.	n.a.	n.a.	n.a.	200	n.a.

***: the presence of NaCl is mentioned, but there are only data for chloride concentration
N.A.: Non available, there are only information about the use of $CaCl_2$ in brining, and it is concluded its presence in the brine wastewater.
✓ The presence is mentioned, but there are no concentration data.

The ingredients that are presented in the table are the ingredients that are possible in the wastewater. That does not necessarily mean that all these ingredients are present in the vegetable brining wastewater.

Due to the high concentration of NaCl or/and $CaCl_2$ in the pickling liquid, the recovery of NaCl and $CaCl_2$ can be proposed.

Table 24: Key parameters for pickling vegetables effluent characterization

Anions	Other parameters
Cl^-	pH
	TOC
	SS
Cations	Total nitrogen
	TP
Na^+	BOD
	Acidity
Ca^{2+}	Conductivity
	TSS
	Total sugar

4.2.4 Food industry - fish and shellfish industry (NACE code: C10.2)

4.2.4.1 General information about the sector

The sector of fish processing is widely spread and is characterized by big variability. Fish processing includes the processing of white or pelagic fish, fatty fish, shellfish and fresh water fish. There are also species of fish that are mass processed as cod, herring, tuna, mackerel, pollock, haddock ect (BREF (a) 2017).

A **preliminary processing** of fish aiming at the partial, or full, separation of the edible and the inedible parts of fish usually precedes the main fishing processing. Modern preliminary process is mainly mechanized and is supported by special machines for the following:

- Freezing/Thawing.
- Grading.
- Scaling.
- Deheading and gutting.
- Filleting and skinning.

Fish preservation methods include canning, salting/pickling, smoking and drying (BREF (a) 2017). The present study focuses on salting/pickling method as these methods result in generation of high salinity wastewater.

Salting/pickling

The salting process is applied in order to lower the moisture or the water content of fish or other fishery products. The moisture is reduced to such a level that microorganism growth will be inhibited. Sodium chloride (NaCl) improves fish texture as it firms up the fish (BREF (a) 2017). The role of salt addition is the dehydration of fish combined with elimination of bacteria growth as well.

There are three basic methods of salt applying for fish preserving (BREF (a) 2017):

- *Pickle salting*: the fish is covered with salt and packed in layers in watertight containers. This forms the pickle that serves as the saturated brine solution that covers the fish completely.
- *Brine salting*: the fish is immersed in a saturated solution made up of 25 parts of salt and 100 parts of water. Brine salting is done only as a temporary way to preserve fish before they are dried, smoked, or processed;
- *Dry salting*: the fish is run granular by salt. The proportion of salt to fish varies from 10 % to 35 % of the fish weight.

4.2.4.2 Water consumption and wastewater generation

The vast water consumption in fish processing industry combined with the generation of wastewater with high pollution load are matters of great concern about the sector. Huge amounts of water are consumed and a big part ends up as wastewater. Wastewater is generated during different processing steps of the fish industry such as thawing, washing, skinning and trimming, filleting, cleaning and salting. In the table below are presented the volumes and some main characteristics of the wastewater that is generated during different fish production in Germany (BREF (a) 2017).

Table 25: Typical wastewater production rates and characteristics for fish processing in Germany (data taken from ATV 2000)

Production	Wastewater production (m^3/t)	TSS (mg/l)	BOD_5 (mg/l)
Herring	17-40	220-1520	2300-4000
Fresh fish	About 8	170-3650	1000-6250
Smoking of fish	About 8	14-845	1000-1700
Salting of salmon	**About 35**	**NI**	**NI**
Deep frozen fish	2-15	NI	NI
Thawing	NI	0-70	30-1800
NI= No information provided			

Brine characteristics

When the fish is processed in brine, there is a high salt concentration in the wastewater ((BREF (a) 2017).). Industrial production of salted fish products is based on fish pickling in concentrated NaCl brines. The waste brine generated after the fish pickling is a complex biochemical system consisting of concentrated NaCl solution, salt-soluble proteins, tissular and bacterial enzymes.[16]

Instead of NaCl, other salts such as KCl, $CaCl_2$ and $MgCl_2$ can be also used in fish brining (Martínez-Alvarez, & Gómez-Guillén, 2005). From these salts, NaCl and KCl are the main salts used in brining while $MgCl_2$ and $CaCl_2$ are added in portions of less than 1% of salt content. The total salt concentration is possible to have different values and can reach levels up to 25% (saturated brines) (Martínez-Alvarez & Gómez-Guillén, 2005).

Summarizing the abovementioned data, the parameters of interest in brines from fish processing are presented in the following table.

[16] http://hydropark.ru/projects.en.htm

Table 26: Key parameters for the brine wastewater from fish processing characterization

Anions	Other parameters
Chlorides (Cl^-)	pH
Sulphates SO_4^{2-}	Total Nitrogen
Total phosphates	Oil and grease (and fats)
Cations	COD
Na^+	BOD_5
K^+	Total Suspended Solids
Ca^{2+}	
Mg^{2+}	

The salts that could be recovered are NaCl and KCl that are used in brining in high concentrations (up to 25%).

As mentioned by Afonso & Bórquez (2002) it was investigated the treatment of this brine (used during the salting of herring) with the use of RO and UF in order to reuse the permeate in the final herring products.

4.2.5 Textile industries (NACE codes: C13.3, C13.9)

4.2.5.1 General information about the sector

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The textile industry is probably one of the most complicated industrial branch chain of the manufacturing industry. This sector is characterized by fragmentation and heterogeneity and is dominated mainly by Small and Medium Enterprises (SMEs). Clothing, home furnishing and industrial use are the predominant end-users of textile products. Textile industry's activities are distributed all over EU, but only in a few EU states textile industries are concentrated. In textile industry, the leading producers are Italy, France, the United Kingdom, Germany and Spain. These countries together account for about three quarters of EU production. (EU, 2018d). The following table presents the percentages of textile and clothing production for each of EU-15 countries in 2000: (BREF (c), 2003)

Table 27: Country breakdown of the EU-15 textile and clothing industry in 2000 (Data taken from EURATEX 2000)

Country	Share of Textile (%) in 2000	Share of Clothing (%) in 2000	Share of Textile & Clothing (%)in 2002
Germany	14.4	13.1	13.8
France	13.1	13.0	12.9
Italy	29.7	30.8	30.1
Netherlands	2.0	0.8	1.5
Belgium	5.6	2.2	4.2
United Kingdom	12.5	14.3	13.4
Ireland	0.7	0.5	0.6
Denmark	1.0	1.1	1.1
Spain	8.4	11.4	9.6
Greece	2.1	2.5	2.3
Portugal	6.1	7.9	6.9
Austria	2.8	1.2	2.1
Finland	0.8	1.0	0.9
Sweden	0.8	0.2	0.6
Luxembourg	0	0	0
EU-15	100	100	100

The textile industry can be classified into three main categories taking into consideration the kind of processed fibres (Ghaly et al., 2014):

- cellulose fibres (cotton, rayon, linen, ramie, hemp and lyocell),
- protein fibres (wool, angora, mohair, cashmere and silk) and ,
- synthetic fibres (polyester, nylon, spandex, acetate, acrylic, ingeo and polypropylene).

The major environmental issues emerging from the textile industry's activities are related mainly to water and air emissions and to energy consumption. Water is the most crucial concern, as the textile industry uses water for applying dyes and finishing agents, for removing impurities, and for steam generation.

Water losses to the product are not important and only a small part of water used is evaporated during drying. The major amount of water used ends up as an aqueous effluent and consequently the main important issue of the process is the volume of water discharged and the chemical load it carries.

In the table below an overview of the environmental loads of wastewater generated by textile industries is presented. The reported data have been extrapolated to European level.

Table 28: Mail charging loads from Textile Industry in Europe (data taken from EURATEX, 2000)

Substances	Environmental load (t/yr)
Salts	**200,000 – 250,000**
Natural fibre impurities (including biocides) and associated material (e.g. lignin, sericine, wax, etc.)	50,000 – 100,000
Sixing agents (mainly starch, starch derivatives, but also polyacrylates, polyvinylalcohol, carboxymethylcellulose and galactomannans)	80,000 – 100,000
Preparation agents (mainly mineral oils, but also ester oils)	25,000 – 30,000
Surfactants (dispersing agents, emulsifiers, detergents and wetting agents)	20,000 – 25,000
Carboxylic acids (mainly acetic acid)	15,000 – 20,000
Thickeners	10,000 – 15,000
Urea	5,000 – 10,000
Complexing agents	<5,000
Organic solvents	n.d.
Special auxiliaries with more or less ecotoxicological	<5,000

It can be seen that salt contained in the wastewater from textile industry is a significant part of the wastewater load in Europe. From the reported data, it is also indicated that a considerable percentage of the total wastewater load from textile processing is due to substances used as raw materials prior to the finishing process sequence. Typically, these raw materials are:

-preparation agents

-sizing agents

-natural fibres impurities and associated material

Although dyestuffs do not represent a significant load in comparison to other raw materials used in textile processing, they play an adverse role in the effluent produced. Not only as an aesthetic problem, but also as an environmental problem since color in natural water is responsible for the reduction of light transmission to aquatic plants. In addition substances included in colors are related with other environmental problems such as organic load, AOX and metal elimination (BREF (c), 2003).

Textile processing includes many different steps in most of which wastewater is generated. The volume of the wastewater and the composition depend on many different factors such as the type of process applied and the processed fabric (Bisschops & Spanjers, 2003).

The dyeing process can be separated in two categories:

a. Dry process

The dry process comprises of (i) opening, blending and mixing, (ii) carding, (iii) combing, (iv) spinning, (v) weaving and (vi) knitting. Generally in dry processing the amount of water used is negligible.

b. Wet process

The wet process comprises of (i) singeing, (ii) desizing, (iii) kiering, (iv) bleaching, (v) mercerizing and (vi) dyeing. The wet process consists of a series of operations and requires vast amounts of water at each stage.

In the following figure is presented a flowchart for the processes that take place in textile manufacturing industry.

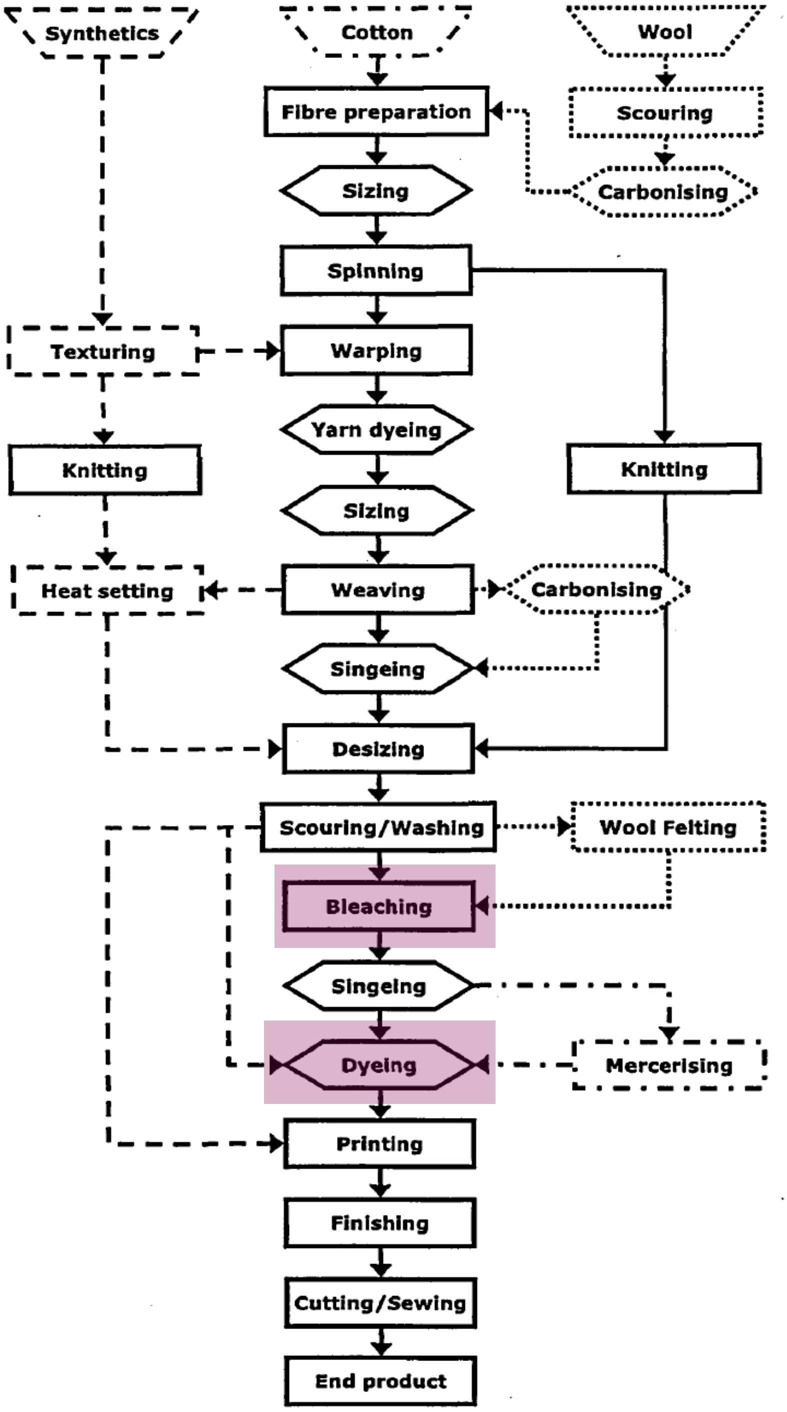


Figure 3: General flowchart for processes taking place in textile manufacturing. (Taken from: Bisschops & Spanjers, 2003)

Note: Square boxes are processes that always take place in that order, and "diamond" shaped boxes are processes that can occur at different places in the chain. The line style indicates if the process is only used for a certain fabric type: (- - -) for synthetic fibres, (- . -) for cotton and (….) for wool.

The following three tables contain data of pollutants resulting from processes used in textile industry. By reviewing this information it can be clearly concluded that the **dyeing** process is the one generating wastewater with significant presence of salts (figure 3: purple color). The wastewater resulting from **bleaching** process seems to also contain salts (figure 3: purple color). In fact, inorganic ions are present in all wastewaters resulting from wet processes. However this report will concentrate on the dyeing and bleaching process as they are the processes generating saline wastewater.

Table 29: Wastewater generation in textile production processes (Data taken from Ghal et al., 2014)

Process	**Wastewater**
Fibre preparation	Little or none
Yarn spinning	Little or none
Slashing/sizing	BOD, COD, metals, cleaning waste, size
Weaving	Little or none
Knitting	Little or none
Tufting	Little or none
Desizing	BOD from sizes lubricants, biocides anti-static compounds
Scouring	Disinfectants, insecticide residues, NaOH, detergent oils, knitting lubricants, spin finishes, spent solvents
Bleaching	**H_2O_2, stabilizers, high pH**
Singeing	Little or none
Mercerizing	High pH, NaOH
Heat setting	Little or none
Dyeing	**Metals, salts, surfactants, organic processing assistants, cationic materials, color, BOD, COD sulphide, acidity/alkalinity, spent solvents.**
Printing	Suspended solvents, urea, solvents, color, metals, heat, BOD, foam.
Finishing	COD, suspended solids, toxic materials, spent solvents.

Table 30: List of some of the pollutant generated at each level of textile wet processing (Data taken from: Holkar et al., 2016

<table>
<tr><td colspan="8">Deszing</td></tr>
<tr><td colspan="2">Sizes</td><td colspan="2">Enzymes</td><td colspan="2">Starch</td><td colspan="2">Waxes</td></tr>
<tr><td colspan="8">Scouring</td></tr>
<tr><td>NaOH</td><td>Surfactants</td><td>Soaps</td><td>Fats</td><td>Pectin</td><td>Oils</td><td>Sizes</td><td>Waxes</td></tr>
<tr><td colspan="8">Bleaching</td></tr>
<tr><td colspan="2">H_2O_2</td><td colspan="2">Sodium Silicate</td><td colspan="2">Organic Stabilizer</td><td colspan="2">Alkalanie pH</td></tr>
<tr><td colspan="8">Dying</td></tr>
<tr><td colspan="2">Color</td><td>Metals</td><td colspan="2">Salts</td><td>Surfactant</td><td colspan="2">Alkaline/Acidic</td></tr>
<tr><td colspan="8">Printing</td></tr>
<tr><td colspan="2">Color</td><td>Metals</td><td colspan="2">Urea</td><td>Formaldeyde</td><td colspan="2">Solvents</td></tr>
<tr><td colspan="8">Finishing</td></tr>
<tr><td colspan="2">Softeners</td><td colspan="2">Solvents</td><td colspan="2">Resins</td><td colspan="2">Waxes</td></tr>
</table>

Table 31: Effluent characteristics in textile production processes (Data taken from PATEL & VASHI, 2015

Process	Effluent Composition	Nature
Sizing	Starch, waxes, carboxymethyl, cellulose (CMC), polyvilyl alcohol (PVA), wetting agents	High in BOD, COD
Desizing	Starch, CMC, PVA, fats, waxes, pectin	High in BOD, COD, SS, DS
Bleaching	Sodium hypochlorite, Cl_2, NaOH, H_2O_2, acids, surfactant, $NaSiO_3$, sodium phosphate, cotton fiber	High alkalinity, high SS (suspended solid)
Mercerizing	Sodium hydroxide, cotton wax	High pH, low BOD, high DS
Dyeing	Dyestuffs urea, reducing agents, oxidizing agents, acetic acid, detergents, wetting agents	Strong colored, high BOD, high DS, low SS, low heavy metals
Printing	Pastes, urea, starches, gums, oils, binders, acids, thickeners, cross-linkers, reducing agents, alkali	Highly colored, high BOD, oily appearance, High Suspended Solid, slightly alkaline, low BOD

4.2.5.2 Bleaching process: salts as raw materials and wastewater generation

Bleaching process aims at increasing the whiteness of cotton and other fibres by removing the natural yellowish coloring. The bleaching process is typically necessary if the finished fabric is to be white or dyed a light color (Correia et al., 1994).

After the scouring process, the fabric is treated with bleach liquor. Bleaching is actually an oxidation process that takes place with the use of hydrogen peroxide, sodium hypochlorite or sodium chlorite (Correia et al., 1994). Other chemicals used in this process are formic acid, caustic soda, sodium bisulphite, surfactants and chelating agents (Vashi, 2015). A percentage of 10-20% of the total pollution load of textile processing comes from the bleaching process. Bleaching wastewater is characterized by a high solids content and low to moderate BOD levels. This effluent has uncommonly significant dissolved oxygen content due to the decomposition of hydrogen peroxide.

Nevertheless, chloride or hydrogen peroxide can cause toxicity problems in biological treatment processes (6). The wastewaters from this unit contain soap and optical whitening agents. (Vashi, 2015).

The most frequently used for cellulosic fibres oxidative bleaches are namely:
_ hydrogen peroxide (H_2O_2),
_ sodium hypochlorite (NaClO) and,
_ sodium chlorite ($NaClO_2$).

Typical recipes for bleaching are included in the following table (BREF (c), 2003).

Table 32: Standard recipe for bleaching with hydrogen peroxide of knit fabric

Chemicals	g Telquel/kg textile substrate	
	Continuous and optimized process	Discontinuous process
H_2O_2 (100%)	5-15	5-15
NaOH (100%)	4-10	4-30
Complexing agents	0-2	0-2
Organic stabilizer	0-10	0-20
Surfactant	2-5	2-10
Sodium Silicate	8-20	0-20
Water Consumption (1/kg textile substrate)	n.d.	n.d.

Table 33: Standard recipe for reductive bleaching and optical brightening of polyamide

Chemicals	(g Telquel/kg textile substrate)
Sodium dithionite containing formulation	10-30
Optical brightener	5-15
Surfactant	1-2
Water Consumption (1/kg textile substrate)	n.d.

Table 34: Standard recipe for bleaching of Polyester (PES) and Polyacrylic (PAN) with sodium chlorite

Chemicals	(g Telquel/kg textile substrate)
$NaClO_2$ (100%)	5-15
Formic acid pH 2.5-3.5 or oxalic acid pH 2.5	n.d
Corrosion inhibitor	10-20
Water Consumption (1/kg textile substrate)	n.d.

Depending on the recipe applied some salts can be in higher concentrations. For example, when bleaching with hydrogen peroxide, sodium silicate is one of the main components of the recipe, while when bleaching PES or PAN sodium chlorite is one of the main components.

Information concerning bleaching processes retrieved from the different literature sources is integrated in the following table.

Table 35: Bleaching process characteristics

Process	Effluent composition	Nature
Bleaching	Sodium hypochlorite, Cl_2, NaOH, H_2O_2, acids, surfactant, $NaSiO_3$, sodium phosphate, cotton fiber, COD, BOD	High alkalinity, high SS (suspended solid), low BOD

Several studies mention that $NaSiO_3$ can be inserted as raw material in bleaching solution in concentration up to 10g/l. That means that $NaSiO_3$ may present in high concentration in bleaching wastewater [17]. For environmental reasons the use of sodium hypochlorite is now limited in Europe to just a few particular cases, connected with knitted fabric and, in some cases, bleaching of yarn when a high degree of whiteness is required (BREF (c), 2003).

Table 36: Salts as raw materials- salts in wastewaters

Salt name	Raw material in bleaching	Presence in wastewater
NaCl	+	+
$NaSiO_3$	maybe	+
$NaHSO_4$	+	+
NaClO	+	+
Sodium Phosphates	Maybe	+

Table 37: Key parameters for brine from bleaching process (in textile industries) characterization

Pollutants	Parameters
ClO	BOD
ClO_2^-	pH
O_2^{2-}	EC
Cl^-	DS
PO_4^{3-}	SS
Na^+	
F^-	
SiO_3^{2-}	

As mentioned before, some salts can be used in large amounts in bleaching process and consequently it is expected to be found in higher concentrations in the wastewater. The ions written with bold letters are the ones expected to be found in higher concentrations.

4.2.5.3 Dyeing process: salts as raw materials and wastewater generation

During dyeing process the textile material is given the desired color according to its final use. A dyestuff is a molecule containing a chromophoric group (conjugated system) capable of interacting with light, thus giving the impression of color (BREF (c), 2003)

The predominant pollution problem of dyeing process is the color. Color, as mentioned also before, can cause several problems in water as it decreases its transparency combined with the fact that some of dyes and of their degradation products are toxic to aquatic organisms.

[17] http://textilelearner.blogspot.com/2014/09/bleaching-recipe-of-hydrogen-peroxide.html

Dyeing processing requires large amounts of water. Water is used in the dyeing process and in the rinsing processes of the dyed products. Water use depends on the process characteristics (the equipment, fabric and dyestuff used). Except for the dyes, the different auxiliary chemicals that are used, end up in the wastewater (BTTG, 1999). Typical pollutants generated in the dyeing step are colour and different auxiliary chemicals, such as organic acids, fixing agents, defoamers, oxidising/reducing agents, and diluents. A large amount of dyes end up in wastewater in an unfixed state. The amounts and adverse effects pollution depend on the dyes and process employed (EPA Office of Compliance, 1997).

(Dyeing contributes most of the metals and almost all of the salts and colour present in textile effluents (US EPA, 1996). For some dyeing processes, about 75% of the salts end up in the wastewater (Danish Environmental Protection Agency, 1997), (Bisschops & Spanjers, 2003).

Table 38: Classification of dyes in textile processes (adapted from: BREF (c),2003.)

Dyes	Applicability
Acid dyes	polyamide (70 – 75 %) and wool (25 – 30 %). They are also used for silk and some modified acrylic fibres.
Basic (cationic) dyes	Basic dyes were initially used to dye silk and wool (using a mordant), but they exhibited poor fastness properties. Nowadays these dyestuffs are almost exclusively used on acrylic fibres, modified polyamide fibres, and blends.
Direct (substantive) dyes	Direct dyes are used for dyeing cotton, rayon, linen, jute, silk and polyamide fibres.
Disperse dyes	Disperse dyes are used mainly for polyester, but also for cellulose (acetate and triacetate), polyamide and acrylic fibres.
Metal-complex dyes	Metal-complex dyes (also called pre-metallised dyes) have great affinity for protein fibres. Among metal-complex dyes, 1:2 metal-complex dyes are also suitable for polyamide fibres. More than 65 % of wool is today dyed with chrome dyes (see next section) or metal-complex dyes and about 30 % of PA is dyed with 1:2 metal-complex dyes.
Mordant dyes (chrome dyes)	Mordant dyestuffs are generally used for protein (wool and silk). They are practically no longer used for polyamide fibres or for printing.
Naphthol dyes (azoic dyes developed on the fibre)	Azoic dyes, also known as naphthol dyes, are used for cellulosic fibres (particularly cotton), but may also be applied to viscose, cellulose acetate, linen and sometimes polyester.
Reactive dyes	Reactive dyes are mainly used for dyeing cellulose fibres such as cotton and viscose, but they are also increasingly gaining importance for wool and polyamide.
Sulphur dyes	Sulphur dyes are mainly used for cotton and viscose substrates. They may also be used for dyeing blends of cellulose and synthetic fibres, including polyamides and polyesters. They are occasionally used for dyeing silk. Apart from black shades, sulphur dyes play almost no part in textile printing.
Vat dyes	Vat dyes are used most often in dyeing and printing of cotton and cellulose fibres. They can also be applied for dyeing polyamide and polyester blends with cellulose fibres.
Pigments	Pigments are widely used in printing processes (pigment printing).

Dyeing processes require also the use of auxiliary chemicals. These sometimes are contained in the dyestuff are usually added to the dye liquor.

A table that summarizes the different salts that are used during the dyeing process according to dye category follows.

Table 39: Salts used in dyeing process (Adapted from: (BREF (c), 2003)

Dye	Substance name	Molecular form	Role in the dyeing process
Acid dyes	sodium sulphate	Na_2SO_4	for level dyeing & fast acid
	sodium acetate	CH_3COONa	for acid milling dyes
	ammonium sulphate	$(NH_4)_2SO_4$	for acid milling dyes
	ammonium salt, ammonium chloride	NH_4Cl	pH regulator
Direct dyes	sodium chloride	NaCl	electrolytes
	sodium sulphate	Na_2SO_4	electrolytes
Disperse dyes	sodium hydrosulphite	NaHS	reducing agent
Metal-complex dyes	ammonium acetate	$NH_4C_2H_3O_2$	chemicals and auxiliaries
	ammonium sulphate	$(NH_4)_2SO_4$	chemicals and auxiliaries
	sodium sulphate	Na_2SO_4	chemicals and auxiliaries
Mordant dyes (chrome dyes)	sodium sulphate	Na_2SO_4	chemicals and auxiliaries
	ammonium sulphate	$(NH_4)_2SO_4$	chemicals and auxiliaries
	Dichromate salt	contain the dichromate anion, $Cr_2O_2^{-7}$	chemicals and auxiliaries
Naphthol dyes	**sodium nitrite**	$NaNO_3$	chemicals and auxiliaries
Reactive dyes	**sodium carbonate**	Na_2CO_3	chemicals and auxiliaries
	sodium chloride NaCl	NaCl	chemicals and auxiliaries
	sodium sulphate	Na_2SO_4	chemicals and auxiliaries
	ammonium sulphate	$(NH_4)_2SO_4$	chemicals and auxiliaries
	sodium silicate	Na_2SiO_3	sodium silicate
Reactive dyes (printing)	**sodium carbonate**	Na_2CO_3	chemicals and auxiliaries
Sulphur dyes	**sodium hydrosulphite or Sodium dithionite**	$NaHSO_3$	chemicals and auxiliaries
	Sodium hydrosulfide	NaHS	chemicals and auxiliaries
	sodium chloride NaCl	NaCl	chemicals and auxiliaries
	sodium sulphate	Na_2SO_4	chemicals and auxiliaries
Vat dyes	**Sodium dithionite**	$Na_2S_2O_4$	reducing agent
	sodium sulphate	Na_2SO_4	chemicals and auxiliaries
	potassium carbonate	K_2CO_3	chemicals and auxiliaries
	sodium carbonate	Na_2CO_3	chemicals and auxiliaries

Dyeing process wastewater

Some common auxiliaries used in dyeing process are organic acids, fixing agents, defoamers, oxidizing/reducing agents and diluents. A significant number of dyes used in dyeing process leaves the process in an unfixed state. The exact amounts of these pollutants depend on the dyes and the process used (EPA Office of Compliance, 1997).

Dyeing wastewater contribute most of the metals and almost all of the salts and color present in the overall textile effluent. For some dyeing processes, about 75% of the salts used end up in the wastewater (Bisschops & Spanjers, 2003).

However, dyeing wastewater characteristics shows a very high variability in composition because of the different dyes, auxiliary chemicals and processes employed. The salinity depends on the process and on the chemicals used. There are no available data for the concentrations of salts of the dyeing effluent wastewater, but information on the inorganic ions present in the dyeing effluent is summarized in the following table.

Table 40 List of pollutants in dyeing process (Correia et al., 1994).

Process/Fibres Dyeing	Substances		
	Inorganic		Organic
	Cations	Anions	
Cotton Viscose Linen	Na^+	Cl^-	-Naphthol (A), Acetate (B), Amides of naphtholic acid (B), Anionic surfactants (A), Cationic fixing agents (NB), Anionic dispersing agents (NB), Chloro amines (SB), formaldehyde (A), Formate (B), Nitro amines (SB), Non-anionic surfactants, residual dyes (NB), Soaps (A), Soluble oils (SB), Sulphated oils (A), tannic acid (A), tartrate (B), Urea (B)
	Cr^{3+}	CO_3^{2-}	
	Cu^{2+}	CO_4^{2-}	
	Sb^{3+}	F^-	
	K^+	NO_2-	
	NH_4^+	O_2^{2-}	
		S_2^-	
		$S_2O_3^{2-}$	
		SO_3^{2-}	
		SO_4^{2-}	
Wool	Na^+	SO_4^{2-} ,SO_3^{2-}	Acetate (B), dispersing agents (U), Formate (B), Lactate (B), residual dyes (NB), sulphonated oils (A), Tartrate (B)
	K^+, NH_4^+	$S_2O_4^-$, CO_3^{2-}	
	Cr^{3+}, Cu^{2+}	Cl^-	
	Al^{3+}, Sb^{3+}		
Polyamide	Na^+	Cl^-	Acetate (B), Formate (B), Polyamide oligeines (U), residual dyes (NB), sulphonated oils (A)
		CO_3^{2-}	
Acrylic	Na^+	SO_4^{2-}	Acetate (B), aromatic amines (A), formate (B), levelling agents (U), phenolic compounds (A), residual dyes (NB), retardants (U), surfactants, thioreia dioxide (A)
	Cu^{2+}		
	NH_4^+		
Polyester	Na^+	$S_4O_6^{2-}$	Acetate (B), anionic surfactants (A), Antistatic agents (NB), dispersing agents (A), dye carriers (SB), EDTA (NB), Ethylene oxide condensates (U), formate (B), mineral oils (SB), non-ionic surfactants (A), residual dyes (NB), soaps (A), solvents (A)
	NH_4^+	ClO^-	
		NO_3^-	
		Cl^-	
		SO_3^{2-}	

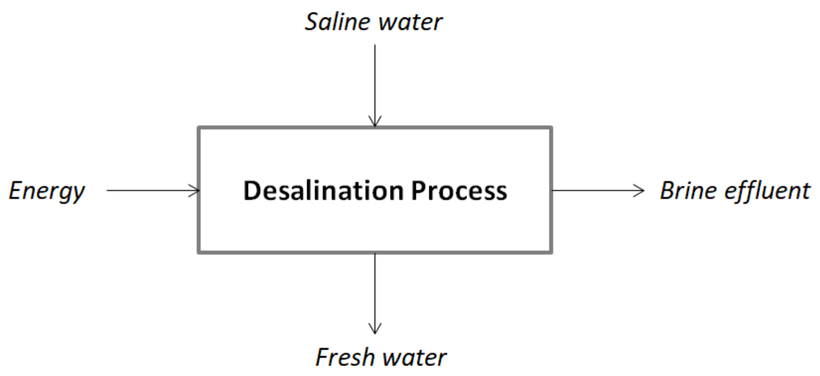
Table 41: list of pollutants in dyeing process (data taken from Correia, et al., 1994).

Dye	Fibre	Color ADMI[1]	BOD (mg l^{-1})	TOC (mg l^{-1})	SS (mg l^{-1})	DS (mg l^{-1})	pH
Acid	Polyamide	4000	240	315	14	2028	5.1
Acid/Chrome	Wool	3200	135	210	9	1086	4.0
1:2 Metal Complex	Polyamide	370	570	400	5	3945	6.8
Basic	Acrylic	5600	210	255	13	1469	4.5
Basic	Polyester	1300	1470	1120	4	1360	5.0
Direct developed	Viscose	2730	12	55	13	918	3.2
Direct	Viscose	12500	15	140	26	2669	6.6
Direct after cooperable	Cotton	525	87	135	41	2763	5.0
Reactive (batch)	Cotton	3890	0	150	32	12500	11.2
Reactive (continuous)	Cotton	1390	102	230	9	691	9.1
Naphtols	Cotton	2415	200	170	387	10900	9.3
Sulphur (Continuous)	Cotton	450	990	400	34	2000	3.7
Vat	Cotton	1910	294	265	41	3945	11.8
Disperse	Polyester	1245	198	360	76	1700	10.2
Disperse	Polyester	315	234	300	39	914	7.8
Disperse	Polyester (carpet)	215	159	240	101	771	7.1
Disperse	Polyamide (carpet)	100	78	130	14	396	8.3
Disperse/Acid/Basic (continuous)	Polyamide (carpet)	<50	130	160	49	258	6.5
Disperse/Acid/basic (batch)	Polyamide (carpet)	210	42	130	8	450	6.7
Disperse/Vat	Cotton & polyester	365	360	350	9	691	9.1

4.2.6 Water treatment (NACE code: E36.0)

4.2.6.1 General information about the sector

The predominant water treatment method resulting in a high salinity waste stream is desalination. A desalination plant separates saline water into two streams, as shown in the figure below: (i) one with a low concentration of dissolved salts (the fresh water stream) and (ii) another containing the remaining dissolved salts (the concentrate or brine stream). The desalination process requires energy to operate and can use a number of different technologies for the separation (Buros, 2000).



Adapted from Buros (2000)

Production of treated water with desalination techniques is a widely used practice. In general, desalination refers to the process of removing salts from waters of different qualities (Cooley et al., 2006)).

4.2.6.2 Desalination for the production of drinking water from saline ore brackish water

Production of drinking water form brackish water sources by desalination processes is a common practice in Mediterranean Region Countries but not in Western Europe. In addition to drinking water, desalination process produces vast amounts of brine as a waste stream. Also, several industries around the world use water processed to a high quality by desalination techniques that result in a concentrate stream with a high salt content (WssTP,2012).

Worldwide, the total volume of desalinated water produced is approximately 83 million m^3/day derived from 14,220 plants (Alvarado-Revilla et al., 2015). As shown in Figure 5, the vast majority of desalination plants work in order to produce drinking water for municipalities. Another significant end-user of desalinated water is the industrial and power sector. As shown in figure 6, the total capacity of desalinated water is served mainly by seawater and brackish water.

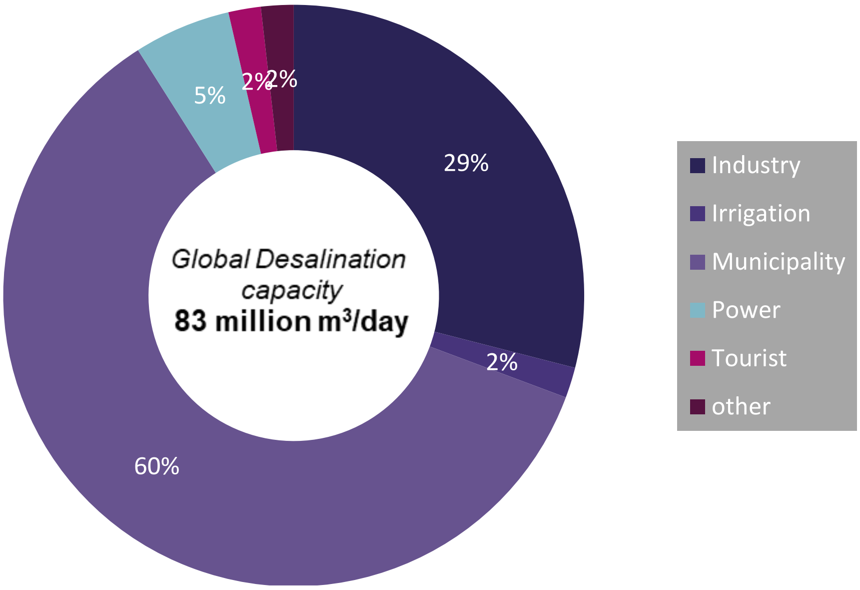


Figure 4: Global desalination capacity by end-user (based on Alvarado-Revilla et al., 2015)

The composition of brine effluent from desalination technologies depends mainly on the feed water type and on the technology applied.

Desalination techniques

A variety of desalination technologies exist today. These technologies remove salts effectively from saline water (or extract fresh water from salty water), producing a water stream with a low concentration of salt (the product stream) and another with a high concentration of remaining salts (the brine or concentrate). Most of industrial desalination technologies use either phase change or involve semipermeable membranes to separate the solvent or some solutes (Xevgenos et al., 2018). The final selection of the proper desalination process depends on conditions of the installation site, including the salt content of the feed water, economic issues, the quality of water needed by the end-user, and on the local engineering experience and available techniques (Berkün, 2016).

Desalination techniques may be classified into the following categories (Xevgenos et al.,2016):

- phase-change or thermal processes,
- membrane or single-phase processes; and
- hybrid processes.

The principal processes that fall into the first two categories are presented below. As reported in many sources, Reverse Osmosis (RO) is the most widespread technology applied. The brine solution resulting by RO desalination systems is typically between 10% to 50% of the feed water depending on the salinity and pressure of the feed water (Clayton, 2015).

Table 42: Principal processes applied for water desalination

Phase-change or thermal processes	Multistage flash evaporation/distillation (MSF)
	Multiple-effect evaporation/distillation (MED)
	Vapor Compression (VC)
	Solar Distillation (SD)
	Eutetic Freeze Crystallization
Membrane or single-phase processes	Reverse Osmosis (RO)
	Electrodialysis (ED)
	Forward Osmosis (FO)

Feed water type

Different source water types are used in desalination plants depending on the availability of water as well as on different quality demands of the end-user. The most common feed water sources are:

- Seawater,
- Brackish water,
- Tap water,
- River water and,
- Wastewater

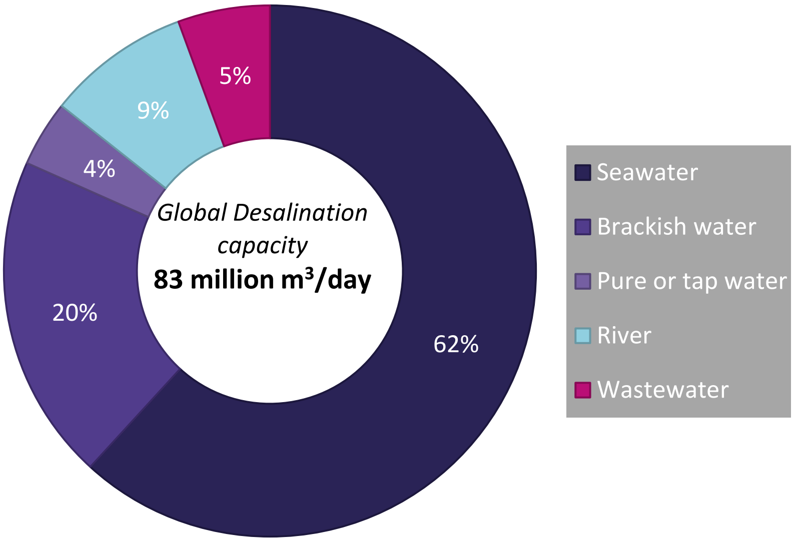


Figure 5: Global Desalination Capacity by feed water type (based on Alvarado-Revilla et al.,2015)

Brine Composition

The characteristics of the concentrate resulting in desalination plants reflect the chemical constituents of the feedwater. The MSF effluents are approximately 1.1 times more concentrated than the original feedwater (Alameddine & El-Fadel 2007). On the other hand, RO desalination effluents can be 2 times more concentrated than the original feedwater (Alameddine & El-Fadel 2007). Brine stream contains 2 or 4-5 folds the salinity of the feed water in case of seawater and brackish water respectively (Elsaid et al., 2012). Brine derived from desalination processes, along with diluted salts existing in the feed water, can contain residues of pretreatment and cleaning chemicals, their reaction byproducts and heavy metals occurred originating from corrosion as indicated and explained in the table 41.

As shown in figure 5 seawater represents worldwide the most common feed water in desalination plants. Seawater comprises a complex solution of water containing nearly all elements of the periodic table in varying amounts (Geertman, 2000). However it can be characterized sufficiently by the following six elements, since these represent more than 99% of the dissolved solids: chloride (Cl^-), sodium (Na^+), sulfate (SO_4^{2-}), magnesium (Mg^{2+}), calcium (Ca^{2+}), and potassium (K^+). The composition of seawater is illustrated in Figure 6.

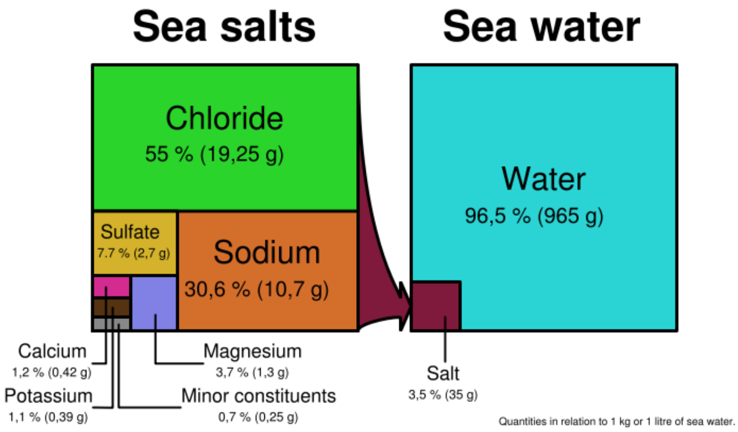


Figure 6: Chemical composition of seawater with salinity of 35% (Illustrated in 1kg of seawater)

In the following table the mineral composition of seawater is shown.

Table 43: Indicative composition of important minerals in seawater (data taken from: Hultman, 2011)

Species	Concentration (g l^{-1})
NaCl	27.319
$MgCl_2$	4.176
$MgSO_4$	1.668
$MgBr_2$	0.076
$CaSO_4$	1.268
$Ca(HCO_3)_2$	0.178
K_2SO_4	0.869
B_2O_3	0.029
SiO_2	0.008
Iron/Alumina	0.022

Alameddine, & El-Fadel (2007) made a comparison between source feed water (seawater) and brine effluent from different desalination plants as shown in table 41.

Table 44: Comparison between the chemical characteristics of the feed and brine water (adapted from: Alameddine, & El-Fadel, 2007)

Parameter	Plant 1		Plant 2		Plant 3		Plant 4	
	Intake Water	Brine Water	Intake Water	Brine Water	Intake Water	Brine Water	Intake Water	Brine Water
Cations								
Magnesium (mg/l)	1,612	3,625	1,655	3,500	1,821	3,606	N.R.	N.R.
Sodium (mgl)	11,806	21,750	13,250	26,142	12,103	22,437	N.R.	N.R.
Potassium (mg/l)	574	870	610	830	542	845	N.R.	N.R.
Calcium (mg/l)	516	1,850	659	1,775	563	1,818	N.R.	N.R.
Iron (ppb)	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	19.0	25.0
Copper (ppb)	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	4.3	8.0
Anions								
Chloride (mg/l)	26,921	37,223	28,113	38,821	27,135	37,779	25,134	41.748
Sulfate (mg/l)	3,723	4,560	3,227	4,319	3,115	4,321	N.R.	N.R.
Bicarbonate (mg/l)	115	190	131	187	126	185	N.R.	N.R.
TDS (mg/l)	45,340	70,278	47,738	71,689	45,490	71,204	46,710	79,226
pH	8.1	8.9	8.3	8.8	8.2	8.9	8.25	8.93
N.R.: Not Reported								

Brackish or inland water is the second most often used source of feed water in desalination plants worldwide. Inland waters vary greatly in terms of composition. Solute concentrations in aquatic systems are linked to abundance and solubility of ions in source. Moreover, biological processes can incorporate some ions and reduce their relative abudance in aquatic systems. As a result brine streams derived from inland desalination plan vary a lot in terms of salinity and composition and cannot be easily characterized. In the table below table the major ions present in inland waters are indicated.

Table 45: Major ions presented in inland waters

Cations	Anions
Ca^{2+}	HCO_3^-
Mg^{2+}	CO_3^{2-}
Na^+	SO_4^{2-}
K^+	Cl^-

However, as mentioned before, the concentrate produced by desalination techniques contains also multiple chemical constituents in addition to natural source water components, related to the applied desalination process. The principal contaminants found in brine desalination effluents are briefly presented in the following table.

Table 46: Brine constituents resulted by desalination process.

Contaminant	Characteristics	Type	Reference
Antiscalling additives	Used to remove the scales formations	Polymeric substances such as polyphosphates, phosphonates and polycarbonic acids, orthophosphates Membrane desalination plants	Lattemann &Höpner (2003)
Antifouling additives	Used to hinder the potential of bacterial, algal and other marine organisms to foul the desalination plant	Chlorine, hypochlorite, sodium hypochlorite, calcium hypochlorite, ozone	Alameddine & El-Fadel (2007)
Coagulatnts/ Flocculants	Used to bind together particulate and colloidal matter so they may be filtered from the feed before the membrane process. Prevents Fouling and Clogging of the Membranes	Ferric chloride, ferric sulphate, polyelectrolytes	Lattemann &Höpner (2003) Ladewig, B., & Asquith (2012)
Antifoaming additives	Used to prevent foam formation in MSF units	Polyglycol blends	Lattemann &Höpner (2003)
Corrosion products (heavy metals)	Resulted mainly in MSF plants from the corrosion of copper alloy tubing. The copper concentration increases under high operation temperatures in thermal desalination plants.	Copper (the most significant heavy metal discharged from desalination plants) , iron, nickel, chromium, zinc, molybdenum	Alameddine & El-Fadel (2007)
Acids in pretreatment – pH adjustment	Used mainly as an antiscalant and can produce effluents with significant low pH values	Sulphuric acid, hydrochloric acid	Lattemann &Höpner (2003) Ladewig & Asquith (2012)
pH Adjustment to 7 at post-treatment	Prevent Corrosion in Distribution System, Protect Aquatic Life in case of Surface Discharge Increase sodium level in produced water and brine concentrate	Caustic soda, soda ash, lime	Lattemann &Höpner (2003)

Summarizing all the above mentioned information regarding brine effluents generated at desalination plants, the key parameters for the characterization of these streams are presented in the following table.

Table 47: Key parameters for desalination wastewater characterization

Anions	Other parameters
SO_4^{2-}	TDS / electric conductivity
Cl^-	
Cations	pH
Ca^{2+}	Temperature
Mg^{2+}	Other impurities
Na^+	Contaminants/impurities
K^+	

4.2.6.3 Industrial water production

Several industries use water processed to high quality resulting to a concentrate stream with a high salt content.

As indicated in figure 5 the second end-user of desalinated water after municipalities (for drinking water purposes) are industries. According to WssTP (2012), the principal end-users of desalinated water for industrial use are:

-food industry,
-agriculture for green house irrigation and,
-chemical industry.

The feed water type in the industrial water production can be saline (seawater or brackish water) but also tap water, if the process demands water of high quality.

The raw water is softened and/or demineralised using techniques like RO, nano-filtration or ion exchange (IE). The resulted brine stream can be characterized by the parameters described in the previous section for drinking water desalination (see table 25).

4.2.6.4 Water softening - Ion exchange re generation

The ion exchange is a process mainly applied for hard waters softening. Hardwater is softened (for domestic users), so as to reduce the amount of soap used, increase the life of water heaters, and reduce encrustation of pipes (cementing together the individual filter media grains). The reduction of hardness is a common process in water treatment sector. Chemical precipitation and ion exchange are the two predominant softening processes. (Spellman, 2013)

The principal benefit of the ion exchange process is the production of a softer water in comparison with the water softened by chemical precipitation. Moreover, an ion exchange process does not produce large quantity of sludge as does the traditional lime–soda process. However, the major disadvantage of the process is the production of a concentrated brine effluent. (Cheremisinoff, 2011)

In ion exchange processes, water passes through a bed of resin that adsorbs undesirable ions from the water, replacing them with less undesired ions. The available ion exchange resins are natural and synthetic. Salt brine is flushed through the resins and the sodium ions attach to the resin. Once the resin is charged, water passes through the resin, and the resin exchanges the sodium ions attached to the resin with the undesired ions, thus removing them from the water (Spellman, 2013).

When the resin has given up all of its donor ions, it is regenerated with strong salt brine (sodium chloride); the sodium ions from the brine replace the adsorbed ions and restore the ion exchange capabilities. (Cheremisinoff, 2011)

To be more specific, when hardness-causing cations such as calcium and magnesium ions replace the sodium ions in the ion-exchange resin, the resin can no longer remove the hardness ions from the water. At this stage, a concentrated solution (10 to 14% sodium chloride solution) is pumped on the resin in order to regenerate it. When the resin is completely recharged with sodium ions, it is ready for softening again. The needed salt dosage to prepare the brine solution ranges from 80 to 240 kg of $NaCl/m^3$ resin (Spellman, 2013). The typical concentration of brine solution used to regenerate the resins containing 10-15% of NaCl.

Characteristics of spent brine depend on the components adsorbed by the resins and also the initial salt concentration (Ariono et al., 2016). In general, spent brine is characterized by high salinity (about 50g/l or higher), hardness and in some cases organic compound content (Gryta et al., 2005). In the table below is presented in the concentration of the major components in saline wastewater resulting from ion exchange processes.

Table 48: Concentration in saline wastewaters resulted from ion exchange processes.

	Concentration (ppm)			
	Wastewater from cationic ion exchanger		Mixed wastewater from anion and cation exchangers regeneration	
Ions	Gryta et al., 2005	Gryta et al., 2016	Gryta et al., 2005	Ghasemipanah et al., 2013
Ca^{2+}	2,030	4,040	953	150
Mg^{2+}	1,380	1,730	310	20
Na^{+}	2,250	2,560	6,700	2,300
K^{+}	834	*n.a.*	187	6.5
Si^{-}	73.3	112	40.7	1.5
Cl^{-}	34,500	65,500	9,300	1,900
SO_4^{2-}	119.5	37.1	1,010	2,600

The spent brine regenerant from the ion-exchange softening process, contains multivalent ions (Ariono et al., 2016). The discharge of the spent brine regenerant into a disposal well requires attention to the scaling tendencies in plumbing systems. Anti-scaling agent should be incorporated during the injection of the brine, which increases the cost of discharge. In the case of organic matter contained in the spent brine Barranco et al. (2001) mention that cannot be easily treated in conventional sewage systems. Since, the high concentration of salts inhibits biological activities. For this reason salt tolerant microorganisms are required to digest the organic substances.

4.2.6.5 Solar ponds

Solar ponds or solar salterns are traditionally applied for the production of salt (mainly NaCl) from seawater. During water evaporation in solar ponds, various salts are precipitated in different stages. By this process, the brine remaining in the ponds mainly contains magnesium chloride ($MgCl_2$) after NaCl precipitation. (Ariono et al., 2016) The remaining brine (known as bittern salt) is usually considered a byproduct. The disposal of the bittern brine is not considered a serious environmental issue as it can be easily treated to recover valuable components (Ahmad & Baddour, 2014). Further treatment of this brine stream can result in the recovery of magnesium, potassium, bromide, boron, and other constituents as valuable products (Nayaka & Pandab. 2014).

4.2.6.6 Landfill Leachate

Municipal solid waste (MSW) landfill sites generate leachate effluents that must be treated in order to be discharged properly. It is common, after the application of various processes, that the treated effluent is subjected to a reverse osmosis process unit in order to obtain a pure water flow that can be reused or discharged and a smaller flow containing the concentrated contaminants. This effluent has a high salt content as it contains all the salts originally present in the leachates.

4.2.7 Oil - Petroleum refinery (NACE code: C19.2)

4.2.7.1 General Information about the sector

Crude oil and natural gas as natural raw materials need to be treated in order to obtain the necessary characteristics to turn to useful saleable products. For this reason, refining process is carried out. Both crude oil and natural gas are natural hydrocarbons and are found in many and different areas of the world, in a variety of composition and quantities. These hydrocarbons are transformed into different products in refineries. Some examples are the following:

1) Fuels for different means of transport (cars, ships, airplanes etc.)
2) Combustion fuels for heat and power generation for industrial, commercial and domestic use.
3) Raw materials for chemical and petrochemical industries.
4) Other products as paraffins/waxes, bitumen and lubricating oils.
5) Energy as by-product in the form of the heat (steam) and power (electricity).

The manufacturing of the aforementioned products requires the handling and processing of these raw materials in a number of different refining facilities, either alone or as a mixture with biofuels. Refinery is the combination of the processing units whose purpose is to convert natural gas and crude oil into products. The size, the configuration and the complexity of a refinery is defined by the desirable characteristics of the final product, the available crude oil quality and the requirements set by authorities. Consequently and as the factors mentioned before vary from location to location, there are no identical refineries (BREF (b), 2015).

The total capacity of **oil refineries** is around 4,400 million tonnes per year while the number of refineries worldwide is 655 (year of reference 2012). The world's largest refining region is Asia (25 %), followed by North America and Europe (around 20 % each). The top refining countries in the world are the US, followed by China, Russia and Japan (O&Gas Journal, 2011 and BREF (b), 2015).

General overview of refinery processes

In order to convert crude oil to usable petroleum products, refining is necessary and can be separated into two phases and a number of supporting operations.

The first phase includes the desalting of the crude oil and the subsequent distillation into its various components. A further distillation of the lighter components and naphtha is carried out to recover methane and ethane for use as refinery fuel, LPG (propane and butane), gasoline-blending components and petrochemical feedstocks. This light product separation is done in every refinery.

The second phase consists of three different types of 'downstream' process and includes: (i) breaking, (ii) combining and (iii) reshaping fractions.

The above processes change the molecular structure of hydrocarbon molecules either by breaking them into smaller molecules, combining them to form larger molecules, or reshaping them into higher quality molecules. The aim of these processes is to convert some of the distillation fractions into marketable petroleum products through a combination of downstream processes.

Desalting process description

Desalting units are used for the removal of contaminants as water inorganic salts, sand, water-soluble trace metals, silt, rust and other suspended solids from crude oil. These impurities are characterized as bottom sediment (BREF (b), 2015, Pak & Mohammadi, 2008).

The crude oil salts are in the form of dissolved or suspended salt crystals in water emulsified with the crude. The crude oil impurities and especially salts, can cause fouling and corrosion of heat exchangers and especially in the crude distillation unit overhead system. Salts also can damage the activity of many catalysts used in the downstream conversion processes, while sodium salts stimulate coke formation (BREF (b), 2015).

Desalting aims to wash the crude oil or heavy residues with water at high temperature and pressure in order to dissolve, separate and remove the salts and other water extractable components. The feed of the desalter is crude oil and/or heavy residues and reused and fresh water, while the output of the desalting process are the stream of the desalted crude oil and the stream of contaminated water (brine). The water phase from the crude distillation unit overhead and other used water streams are normally fed to the desalter as wash water. The design of the desalter and the crude source play a very important role in the concentrations of inorganic impurities in the cleaned stream.

There are two predominant methods of crude-oil desalting: (i) chemical separation and (ii) electrostatic separation. For both methods, the extraction agent is hot water. The steps followed at a typical desalting/dehydration plant operation are: separation of gravity settling, chemical injection, heating, adding of fresh water, mixing and electrical coalescing (Al-Otaibi et al., 2005 and Pak, & Mohammadi, 2008).

In chemical desalting, water and chemical surfactants (demulsifiers) are added to the crude oil, then they are heated so that salts and other impurities dissolve into the water or are attached to the water. At the end, they settle out. Electrical desalting refers to the application of high-voltage electrostatic charges to concentrate on suspended water globules in the bottom of the settling tank. When the crude oil has a large amount of suspended solids are also added surfactants (Pak & Mohammadi, 2008)

4.2.7.2 Water consumption and wastewater volume in petroleum desalting process

In the crude oil desalting process, the water that is used is either untreated or partially treated from other refining processes. In the following table the typical operating conditions and the water consumption in the desalters, depending on the type of crude oil used are presented.

Table 49: Typical operating conditions of the desalting process (data taken from: (BREF (b), 2015)

Crude oil density (kg/m^3 at 15 °C)	Water wash (% v/v)	Temperature (°C)
<825	3 - 4	115 - 125
825 - 875	4 - 7	125 - 140
>875	7 - 10	140 - 150

The output wastewater of the desalter contributes a high percent to the total process wastewater (30 – 100 litres/tonne feedstock desalted) (BREF (b), 2015).

Brine Wastewater characteristics from desalting process

The wastewater generated from desalting process is an oily desalter sludge characterized by high temperature and high salinity level. Typically, this wastewater is possibly the most polluted in the refinery and has awide variety of pollutants in considerable amounts. This wastewater stream cannot be discharged without proper treatment (BREF (b), 2015).

EPA[18] states that the major salts that contribute to the salinity of brine from oil production contain mainly ions of Na^+, Ca^{2+}, Cl^-, Mg^{2+}, HCO_3^- and SO_4^{2-}. Additionally, Pak & Mohammadi (2008) mention sodium, calcium and magnesium chlorides ($NaCl$, $CaCl_2$ and $MgCl_2$) are the main salts found in the wastewater generated from desalting process.

The table below summarizes the key parameters and their approximate values based on different references.

Table 50: Composition of the wastewater generated in the desalting process

Water pollutants (mg/l)	BREF (b) (2015)	EPA (1997)	Pak & Mohammadi (2008)
Suspended solids	50 – 100*	N.A.	N.A.
Oil/oil emulsions	High	N.A.	N.A.
Dissolved hydrocarbons	50 – 300*	N.A.	N.A.
Phenols	5 – 30*	N.A.	N.A.
Benzene	30 – 100*	N.A.	N.A.
BOD	High*	N.A.	N.A.
COD	500 – 2000*	N.A.	N.A.
Ammonia	50 – 100*	N.A.	N.A.
Nitrogen compounds (N-Kj)	15 – 20*	N.A.	N.A.
Sulphides (as H_2S)	10*	N.A.	N.A.

[18] https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=50000HE9.TXT

Na^+	N.A.	12 000 – 150 000	65 633
Mg^{2+}	N.A.	500 – 25 000	1 000
Ca^{2+}	N.A.	1 000 – 120 000	8 350
Cl^-	N.A.	20 000 – 250 000	118 925
SO_4^2	N.A.	0 – 3 600	216
HCO_3^-	N.A.	0 – 1 200	153
K^+	N.A.	30 – 4 000	N.A
Br^-	N.A.	50 – 5 000	N.A.
I^-	N.A.	1 - 300	N.A
Temperature (°C)	115 – 150*	N.A.	N.A.
**N.A. : Not applicable*			

4.2.8 Paper and Pulp Industry (NACE code: C17.1)

4.2.8.1 General Information about the sector

The pulp and paper industry is one of the most important industrial sectors worldwide because of the economic benefits that arise from this activity. At the same time, pulp and paper is one of the predominant contributors of industrial water pollution. Additionally, pulp and paper industry is increasing rapidly. There is a strong correlation between the increase in the consumption of paper products and the growth in the gross national product (GNP). This means that the consumption of paper and board products is related to the standards of living and the economic situation of the user populations. (BREF (d), 2015)

Europe's role in global pulp and pare industry is very important, as Europe is the second largest producer after North America (as indicated also in the following figure) and the third largest consumer of paper and board. The production of wood pulp in Europe is about 41.8 million tonnes per year, which corresponds to 22% of the world's total pulp production (192.4 million tonnes) (BREF (d), 2015)

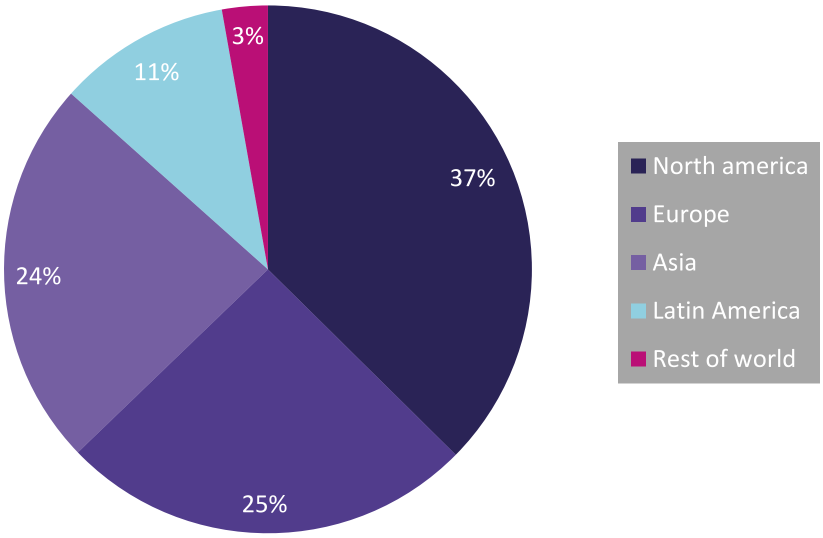


Figure 7: Pulp production per region in 2008 (Data taken from: CEPI (2009))

The principal types of pulp and paper mills are the following:

- kraft pulp mills,
- sulphite pulp mills,
- mechanical and semi-mechanical pulp and paper mills,
- mills processing paper for recycling, and,
- non-integrated paper mills including specialty paper mills.

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From the aforementioned groups of papermaking the most common in Europe is sulphate pulping covering a percentage of 60% of total pulp production, followed by semi-chemical pulp that represents the 32% of total pulp production and sulphite pulp that represents the 5% of the total pulp production.

In Europe, 192 pulp mills (of all kinds) are operating. Most mills (77 mills in total) use sulphate pulping. Mechanical pulp is produced by 72 mills in Europe which are located in Finland (20), Germany (14), Sweden (9), Norway (7), France (6), Italy (4) and Austria (4). The main producers of semi-chemical pulp (a total of 18 mills) are Sweden (7), Finland (3), Italy (2) and the Netherlands (2) with single mills operating in some other countries (BREF (d), 2015).

4.2.8.2 Wastewater generation from kraft pulp process

<u>The sulphate or kraft process</u>

The present report will focus on the sulphate process (or kraft process), as it is the most applied process in Europe. Worldwide approximately 80% of the world pulp production arise from sulphate processes. On the other hand, sulphite process has decreased and today only a 10% of the global production is obtained by this method. In both techniques, the wood chips are cooked under pressure with a mixture of sodium sulphide (Na_2S) and caustic soda (NaOH) in order to break various ether bonds in the lignin. The inorganic chemicals that are existing in the black liquor are recovered. The process stages of the sulphate (kraft) pulp processes are the following:

- Reception and storage of wood
- Debarking
- Wood chipping and screening
- Cooking and delignification
- Washing and screening
- Oxygen delignification
- Bleaching

An overview of the input (raw materials and energy) and the output (products and major releases such as emissions, waste, etc.) of the production of kraft pulp is presented in the following figure.

The way of delignification and bleaching defines the use of some chemicals. The release of these chemicals to the environment is depended on the process design and operation (recirculation flows, recovery system e.t.c.) and the wastewater treatment plant.

As it is shown in the figure below, the emissions to water coming from kraft pulp mills are generated from different process stages.

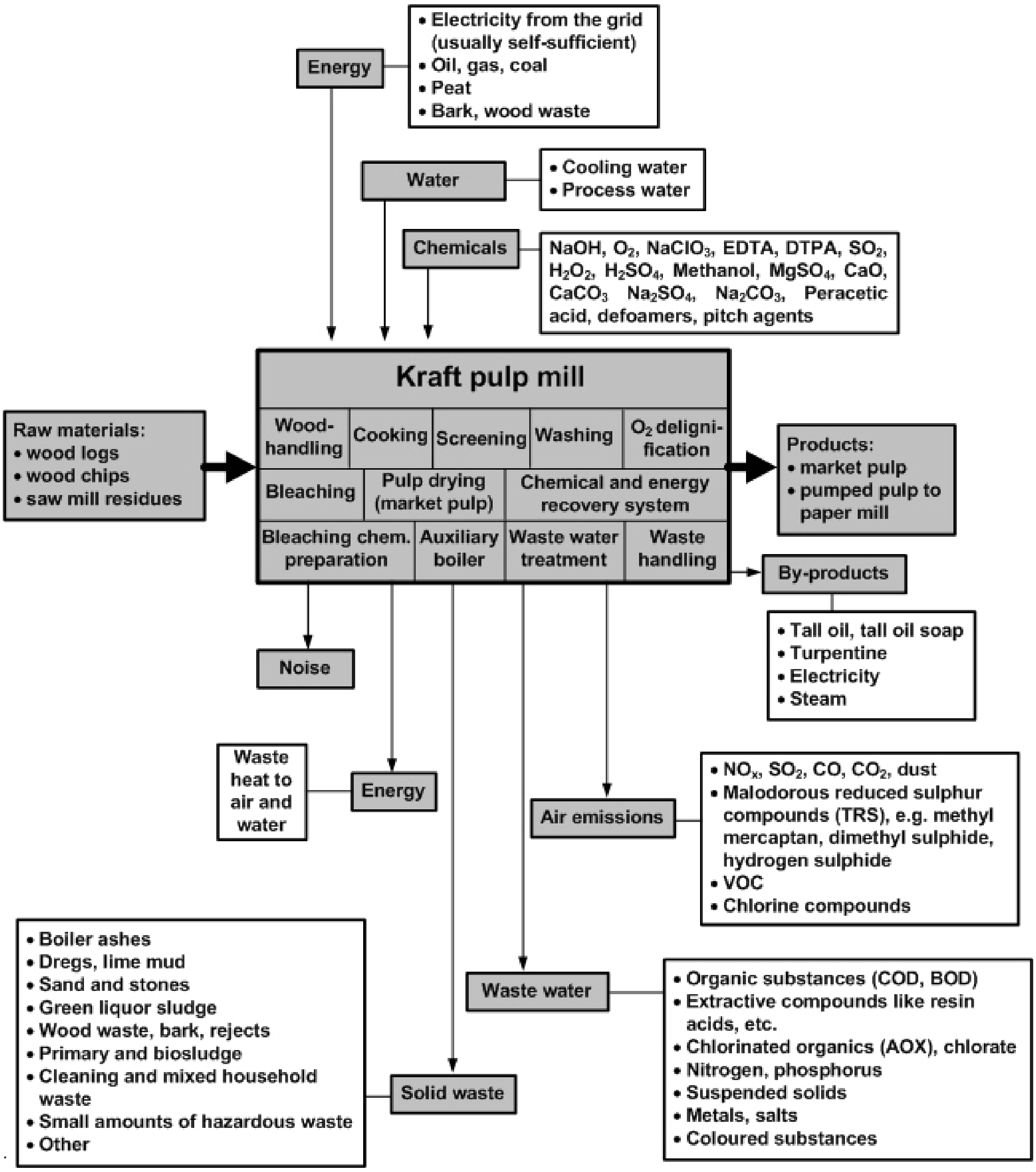

Figure 8: Mass stream overview of input and output of a kraft pulp mill (taken from BREF (d), 2015)

The oxygen-consuming organic substances (measured as BOD, COD and/or TOC) are predominant in the effluent concentration. The bleach plant effluent (use of bleaching chemicals) contain AOX and chlorate. Additionally, kraft pulp mill effluent contains substances with toxic effects on aquatic organisms when treated, while emissions can affect the living species negatively, by decreasing the water transparency. Nitrogen and phosphorous (nutrients) can cause eutrophication. Finally, metals extracted from the wood can end-up in the effluents.

As noticed in the previous figure the two process stages that produce wastewaster including salts are (i) white liquor preparation and (ii) bleaching. Description of the chemicals used and the wastewater generated from the bleaching process follows. Bleaching process is a process with very large volume with high concentration of pollutants. Almost 60-65% of wastewater is contributed to this section. Bleach effluent contains dissolved organic substances, chlorinated substances, chlorate, phosphorous, nitrogen and salts. Bleaching chemical can end-up as pollutants (e.g. NaOH) in bleaching effluent.

Bleaching Process description

After the removal of spent cooking and dissolved wood organics, the pulp is produced as slurry. Then bleaching process takes place in order to remove further lignin and to make the pulp whiter. Usually, bleaching is done in different steps by the use of a combination of chlorine dioxide and oxygen-based chemicals. According to EPA (2006) the vast majority of pulp is bleached. The number of stages for the bleaching of kraft pulp is usually four to five, while recently the "three stage bleaching" is reaching ground. The chemicals that are commonly used are oxygen (O_2), sodium hydroxide (NaOH), chlorine dioxide (ClO_2), hydrogen peroxide (H_2O_2) and sometimes ozon (O_3). In recent years paracetic oxide (CH_3CO_3H) is also available in market as a bleaching chemical. In EU, hypochlorite (e.g. NaOCl) and chlorine (Cl_2) have been phased out as primary bleaching chemicals. The chemicals that are used for bleaching are summarized in the tables below (BREF (d) 2015, EPA 2009).

Table 51: The most common used bleaching chemicals (CEPI 1997 & EPA 2009)

Bleaching Chemicals
NaOH
O_2
NaOCl
$NaClO_3$
EDTA
SO_2
$MgSO_4$
CaO
$Ca(OCl)_2$
H_2SO_4

<u>**Discharges from the bleach plant**</u>

The effluent of the bleach plant is the most polluted wastewater in a pulp mill. The bleach plant could be partly or entirely a closed process, resulting to a substantial further reduction in discharge of nutrients, metals and organic substances.

<u>*Chlorinated organic substances (AOX)*</u>

The mills in the EU have stopped the use of molecular chlorine for the bleaching and bleaching takes place with chlorine dioxide bleaching sequences. There are also mills that have been adapted to market demands and have completely eliminated the use of bleaching chemicals that contain chlorinated compounds by combining oxygen delignification with an ozone stage and/or a peroxide stage (TCF pulp).

<u>*Chelating agents (EDTA/DTPA)*</u>

In order to achieve metal removal in bleaching process, a chelating treatment or an acid wash of the pulps takes place. Chelating agents such as EDTA or DTPA are poorly biodegradable in normal conditions.

Organic substances (COD or TOC)

The bleach plant is the main contributor of organic discharges (COD or TOC) in the pulp paper mills, as mentioned before. Other processes that conclude to high organic load are wood handling, condensates, spillage and washing losses.

Discharges of nutrients (nitrogen and phosphorous)

Normally, wood is a source of nutrients but sometimes it is necessary for the biological effluent to add nutrients if deficient. Studies about nutrient issues show that in kraft pulp mills nitrogen discharges derive mainly from the unbleached part of the process, while phosphorous discharges come from the bleach plant. In general, the emissions from unbleached pulp production are lower than from bleached pulp mills.

Discharges of metals

In the bleach wastewater, metals from the wood are contained which come from the wood. The following table shows typical discharges of metals coming from pulp mills. By increasing the degree of process closure, a reduction in discharges of metals is possible.

Table 52: Typical discharges of metals from kraft pulp mills (BREF (d), 2015)

	Concentration (g/ADt)					
Process	**Cd**	**Pb**	**Cu**	**Cr**	**Ni**	**Zn**
Unbleached pulp	0.03	0.3	0.5	0.2	0.4	5
Bleached pulp	0.1	0.4	1	0.7	0.9	15

The key parameters to consider for the bleaching effluent characterization are presented in the following table.

Table 53: Key parameters for bleaching effluent characterization

Chemical elements (anions & cations)	Other parameters
Na^+	pH
Ca^{2+}	Electric conductivity
Mg^{2+}	COD
SO_4^{2-}	SS
OCl^-	Color
ClO_3^-	AOX
Pb	VOCs
Ni	
Cu	
Cd	
Zn	
Nitrogen	
Phosphorous	

4.2.9 Leather industry (NACE code: C15.1)

4.2.9.1 General information about the sector

The activity of leather making consists of converting the skin or raw hide (which is a very putrscrible material) into a stable material called leather. Leather is involved in the manufacturing of a wide range of products. The process of leather manufacturing consists of both mechanical processes and complex chemical reactions. Amongst these, the process stage that gives leather its stability and essential character is tanning. There is a variety of desirable leather characteristics, such as: appearance, stability, water and temperature resistance, permeability and elasticity, ect. These properties are achieved by tanning (preservation of hides and skins) and by performing various steps of preparation and finishing.

As leather is a material that is used in the manufacturing of a wide range of products, different types of leather are required to meet the standards for each application. Some of the sectors where leather is used are the folowing: clothing, shoes, leather goods, upholstery for cars, boats and aircraft, furniture and many other items in daily use.

The recent years, there is a continuous decrease of tanneries in EU. Comparatively to 1998 there were over 3,000 tanneries and almost 50,000 workers in the EU-15, in EU-27 the leather sector has shrunk to fewer than 3,000 enterprises and less than 50,000 workers. The following table shows the distridution of leather manufacturing in European countries in 2007.

Table 54: Structure of the European leather Industry, 2007 (data taken from BREF (h) 2013)

Country	Employees	Companies	Turnover (thousand EUR)	Exports (%)	Production (thousand m^2)	
					Cattle/calf	Sheep/goat
Belgium	124	1	21742	94.70	492	
Finland	147	12	19000	80.00		
France	1721	62	296000	41.00	3490	3247
Germany	2125	30	440000	60.00	12000	500
Greece	476	68				
Hungary	65	3	4200	67.20		
Italy	17175	1496	5435578	67.00	126742	40603
Netherlands	380	15	85000	75.00	3500	
Portugal						
Slovenia						
Spain	3974	140	851407	39.90	20950	11792
Sweden	430	4	76500	90.00	2400	80
UK	1300	25	220000	75.00	3890	2170
Lithuania	200	4	15000	90.00	750	
Bulgaria		19				
EU Total	28117	1879	7464427	70.90	170714	58392
Norway	102	2	19000	95.00	431	
Switzerland						
EU + EFTA	28219	1881	7483427		171145	58392

Environmental relevance of the leather industry

Most of the processes in tanneries are carried out in water. Therefore, wastewater generation must be taken into account in tanneries. Wastewater generated from tanneries is characterized by high chemical and biochemical oxygen demand (COD and BOD), high salt and specific chemical used in tanning processes.

Applied processes and techniques

The following figure shows schematically the possible steps involved in leather production. It must be mentioned that there is a high variation between tanneries as far as the process steps are concerned, reliant on the type of leather that is produced.

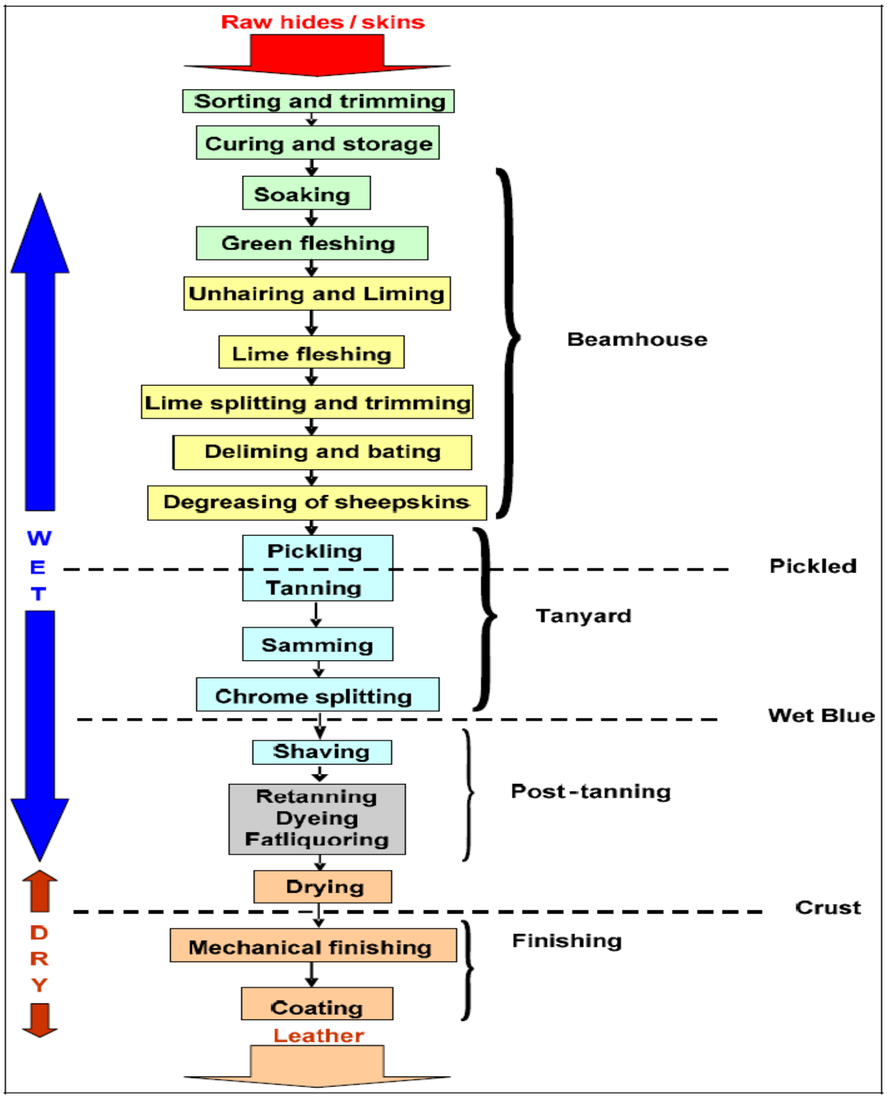

Figure 9: Process steps in leather making (chromium tanning) (taken from: BREF (h) 2013)

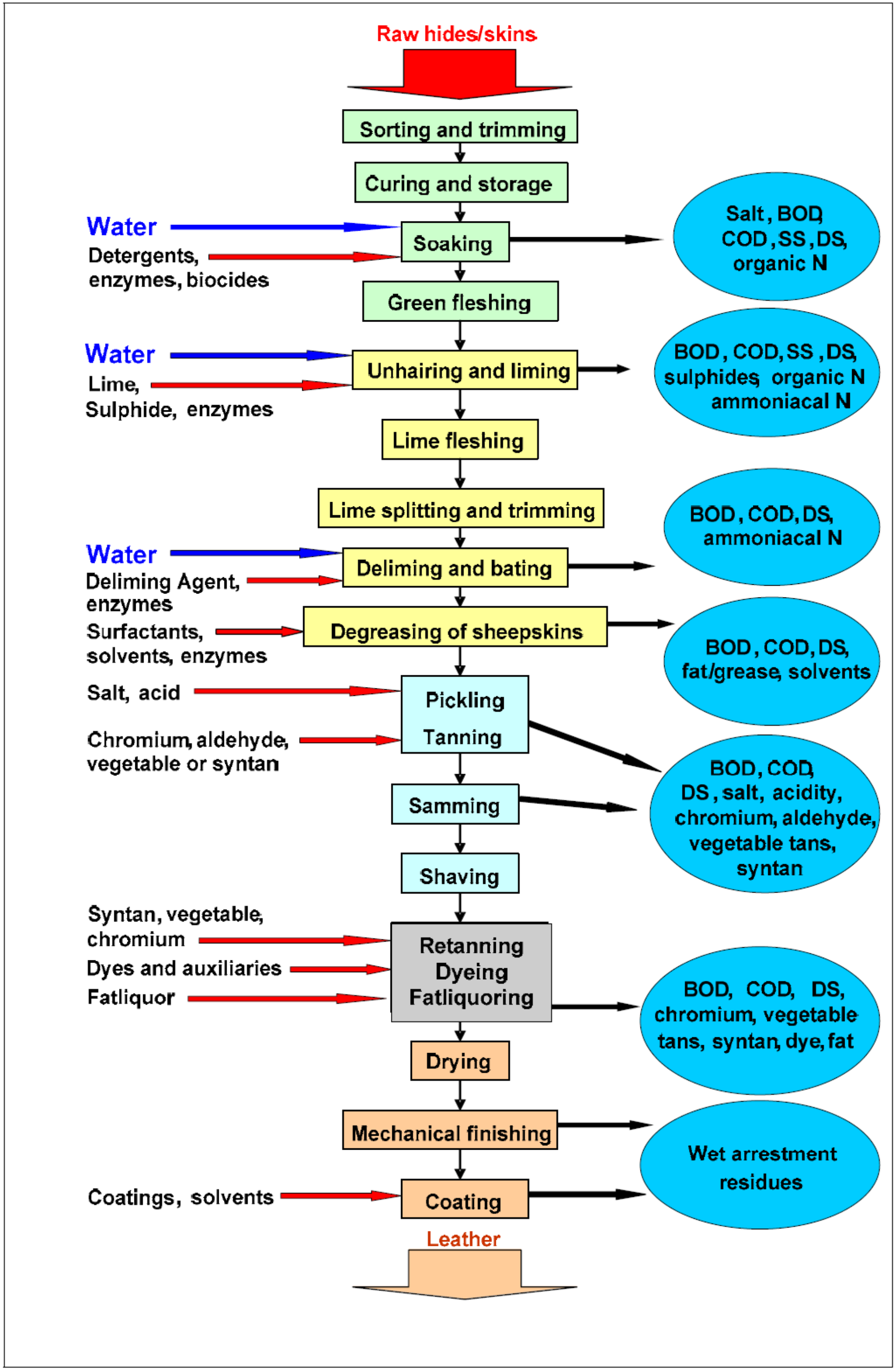

Figure 10: Main inputs and aqueous effluents (taken from: BREF (h) 2013)

As it is shown in the figure above, in the beamhouse, the tanyard and the post-tanning areas are the ones that generate wastewaters. Consequently, the present research will be focused in the wet processes that are responsible for saline wastewater generation.

4.2.9.2 Main pollutants in leather manufacturing effluents

- **Salt (NaCl)**

Sodium chloride (common salt) is a pollutant that is found in tannery effluents and mainly in the effluents coming from the soaking and the tanning process. Sodium chloride arises usually in the effluent from soaking process, if hides or skin. Additionally, it can be found in the effluent from the tanyard because of the use of salt in pickling processes. The following figure shows the salt loads in effluents from various stages of processing:

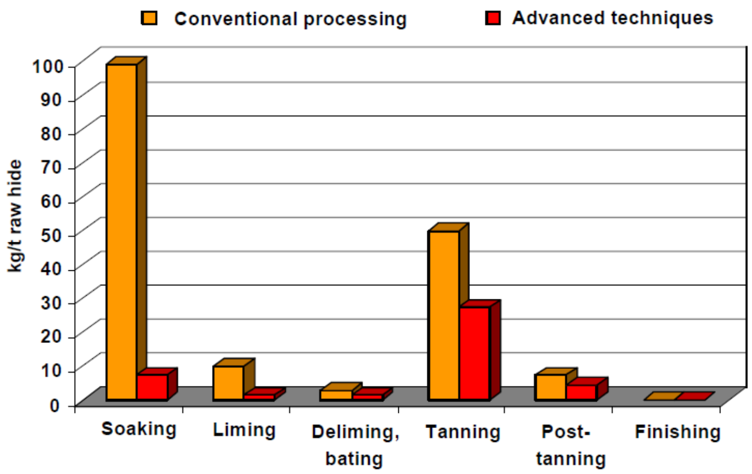

Figure 11: Comparison of the mean chloride loads (taken from: Ludvik, 2000).

- **Sulphates (SO_4^{2-})**

The deliming process is the main source of sulphate in tanneries. Additionally, sulphates come from other processes as tanning and post-tanning. The oxidation of sulphides in the wastewater leads in formation of sulphates.

The use of sulphuric acid, ammonium sulphate or products with high sodium sulphate contentin these processes results in the presence of sulphates in the effluents. It has to be mentioned that many process chemicals contain sodium sulphate. The following figure shows the sulphate loads in effluents from various stages of processing.

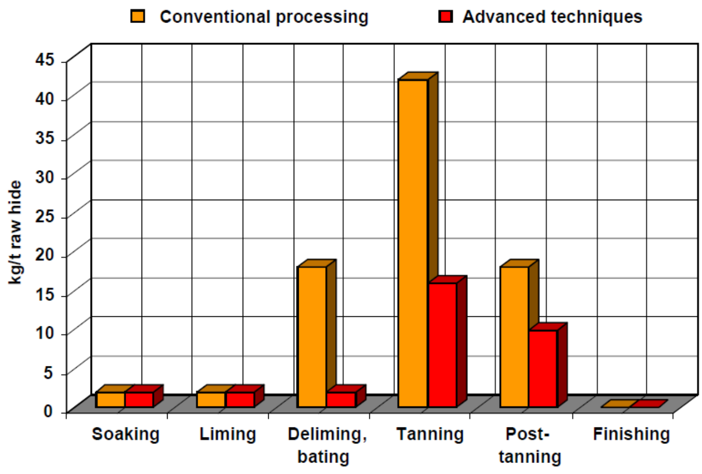

Figure 12: Comparison of the mean sulphate loads (taken from: Ludvik, 2000)

- **Sulphides (S^{2-})**

Due to the use of sodium sulphide and hydrosulphide in the unhairing process, sulphides are found in tannery effluents. The following figure shows the sulphide loads in effluents from various stages of processing:

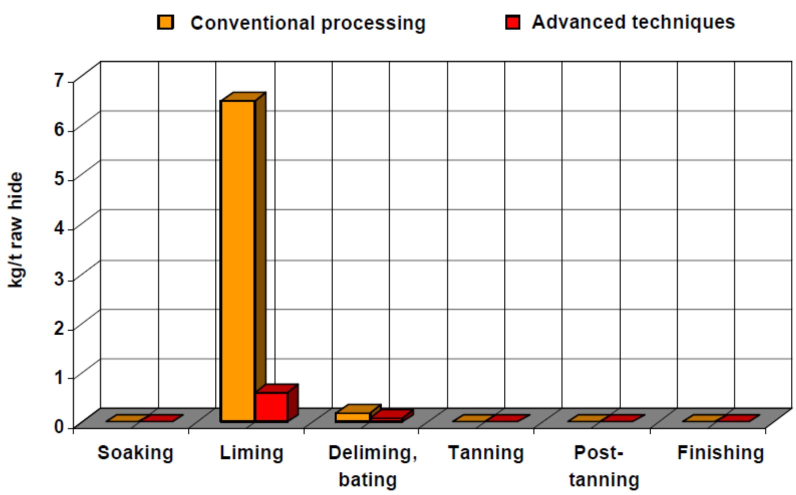

Figure 13: Comparison of the mean sulphide loads (taken from: Ludvik, 2000)

- **Nitrogen (N)**

Tannery wastewaters contain nitrogenous compounds which come mainly from ammonium salts used for deliming and the breakdown products of proiteins that are removed from skins and hides during the unhairing and liming process.

- **Ammonium (NH_4^+)**

Deliming process is responsible for the ammonium in the wastewater from tanneries. The following figure shows the ammonium loads resulting from various stages of processing.

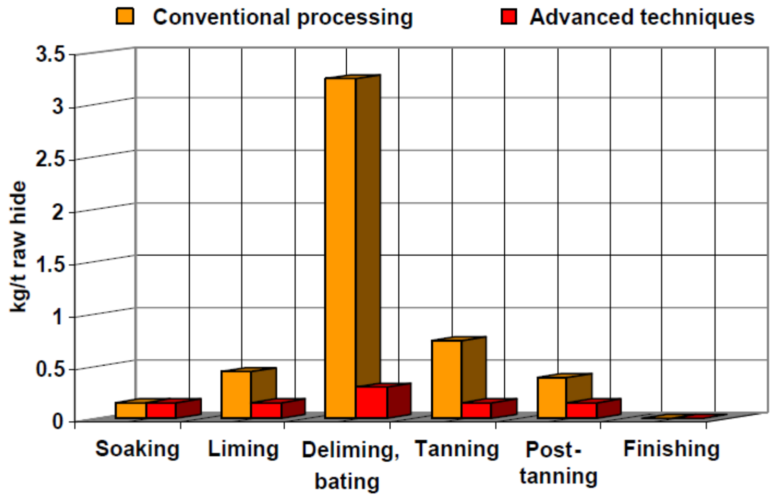

Figure 14: Comparison of the mean ammonium loads (taken from: Ludvik, 2000)

- **Chromium(III) salts (tanning agent)**

Tanning process is the main source of chromium in water effluents. However, when chromium retanning takes place, chromium is also contained in effluents generated from post-tanning processes. Additionally, leaching of chromium (wet process steps following chromium tanning and retanning) is a source of chromium. The following figure shows the chromium loads in effluents from various stages of processing.

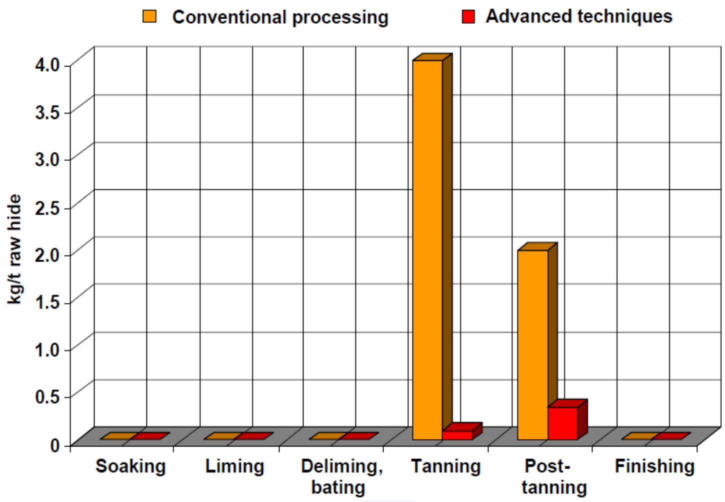

Figure 15: Comparison of the mean chromium loads (taken from: Ludvik , 2000)

- **pH regulators**

Acids, organic acids, buffering salts, or mixtures of these chemicals

4.2.9.3 Tannery Wastewater generation

The composition of wastewater effluents varies a lot between tanneries. The most common parameters to consider in order to set the requirements for waste effluents are COD , BOD_5, SS, N-tot (total nitrogen), TKN (total Kjeldahl nitrogen), NH4-N (ammoniacal nitrogen), P-total (phosphorus), sulphide (S^{2-}), chromium (total), grease and fat content, pH and temperature. Other parameters are Cl^- (chlorides), SO_4^{2-} (sulphates), TDS (Total Dissolved Solids), AOX (adsorbable organic halogenated compounds), pesticides, surfactants, fish toxicity and phenols but are not as common. The following table shows the wastewater loads (before treatment) per tonne of raw hide:

Table 55: Wastewater loads (before treatment) per tonne of raw hide achieved by good practice (data taken from: BREF (h) 2013)

	Unit	Soaking	Unhairing	Deliming -bating	Pickling-tanning	Wet after treatments	Various	Total
Water consumption	(m^3/t)	2	5	2.5	0.5	2	3	15
Total solids	(kg/t)	35	70	20	80	30	10	245
Suspended solids	(kg/t)	10	19	6	7	7	1	50
BOD	(kg/t)	12	20	5	3	6	0	46
COD	(kg/t)	23	45	12	8	13	1	102
Total Kjeldahl Nitrogen	(kg/t)	2	2.5	1.1	0.5	0.1	0	6.2
Ammonia Nitrogen	(kg/t)	0	0.3	0.2	0.1	0.1	0	0.7
Sulphide	(kg/t)		0.7	0.03				0.7
Chromium	(kg/t)				0.1	0.15		0.25
Chloride	(kg/t)	5	3	1	28	3	2	42
Sulphate	(kg/t)			2	16	4	1	23
Grease and oil	(kg/t)			5	1.5	2	0.1	8

The following table shows the water consumption in different process stages.

Table 56: Wastewater discharge in individual processing operations (data taken from: Ludvik, 2000)

Process stage	Wastewater volume (m^3 per tonne of raw hide)
Soaking	2
Liming	4.5
Deliming, bating	2
Tanning	0.5
Post-tanning	3
Finishing	0
Total	12

In the present research, the focus will be in soaking, liming, deliming-bating, tanning and post tanning processes as they generate the effluents with possible high concentrations of ions such as Na^{+}, Cl^{-}, NH_4^{+}, CO_3^{2-}, Ca^{2+}, SO_4^{2-}, OCl^{-}, S^{2-}, HSO_3^{-} and Cr^{6+} .

4.2.9.4 Salts as raw materials in different process and operation stages

Leather industry consumes different salts in their process. Basing on BREFs the salts that are used in leather industries for different processes and operations are the following:

Table 57: Salts and their use in leather industry (data taken from: BREF (h) 2013)

Salt name	Formula	Process stage	Operation	Use
Sodium chloride	$NaCl$	curing	beamhouse	biostat
		pickling		
		Chromium tanning	tanyard	
Sodium silicofluorade	Na_2SiF_6	curing	Post-tanning	biocide
		bleaching		
Sodium hypochlorite	$NaOCl$	soaking	beamhouse	
Sodium bisulphite	$NaHSO_3$	soaking	beamhouse	
		Deliming & Bating	beamhouse	
		neutralisation	Post-tanning	
Sodium carbonate	Na_2CO_3	soaking	beamhouse	
		bleaching	Post-tanning	
		neutralisation	Post-tanning	
		Liming & unhairing	beamhouse	Sharpening agents
		tanning	tanyard	
Sodium sulphide	Na_2S	Liming & unhairing	beamhouse	
		Painting		
		Chrome tanning	tanyard	
Sodium hydrogen sulphide	$NaHSO_3$	Liming & unhairing	beamhouse	
		Painting		
Calcium Chloride	$CaCl_2$	Liming & unhairing	beamhouse	Sharpening agents
Ammonium Chloride	NH_4Cl	Deliming & Bating	beamhouse	
Ammonium Sulphate	$(NH_4)_2SO_4$	Deliming & Bating	beamhouse	
Sodium sulphate	Na_2SO_4	pickling	beamhouse	
Potassium chloride	KCl	pickling	beamhouse	
Sodium bicarbonate	$NaHCO_3$	Chrome tanning	tanyard	
		bleaching	Post-tanning	
		neutralisation	Post-tanning	
Aluminium salts		Mineral tanning	tanyard	
Zirconium sulphate	$Zr(SO_4)_2$	Mineral tanning	tanyard	
Chromium sulphate	$Cr_2(SO_4)_3$	Chrome tanning	tanyard	
Ammonium bicarbonate	NH_4HCO_3	neutralisation	Post-tanning	
Sodium triosulphate	$Na_2S_2O_3$	neutralisation	Post-tanning	

Curing

Curing is a preservation process where salting of hides and skins takes place. Typically the sodium chloride used is 15% of the salted hide weight. Another preservation technique is brining which is mainly used in US and involves dragging the hides through a salt solution. Sometimes, the salts may include biocides (e.g. sodium silicofluoride) to prevent the growth of salt tolerant bacteria but this is not very common in Europe.

Soaking

Soaking is a process where the skins and hides are soaked in processing water filled vessels. The water consumption may be between 200% and 3000% of the hides and skin. In certain cases, biocides are used so as to minimize the bacterial damage to the hides and the production of foul odours. The biocides are added particularly if the soaking is taking place at an elevated temperature, at a rate about 0.1% of the hide weight (Sharphouse, 1983). Additionally, other substances such as surfactants, enzymes and alkali may be added in order to achieve higher efficiency in the soaking process. Sodium hypochlorite (Rydin & Frendrup, 1993) is added, although it can cause problems with the presence of AOX in wastewater effluents. Instead of sodium hypochlorite (Rydin & Frendrup, 1993), weak acids (e.g. formic acid or sodium bisulphite) can be used. In general, alkali, biocides for example sodium carbonate or caustic soda, surfactants and enzymes are added each in amounts of less than 1% of the weight of the salted hides and skins. If the hides and skins were preserved, the effluent contains most of the salt and biocides which were on the hides. The salinity of the soak liquor varies from 11 200 to 23600 mg/l (as Cl).

The following table shows the main pollutants and parameters to consider (based on the research of BREF (h) 2013 & Cooman et al. 2002) for wastewater generated from soaking process:

Table 58: Key parameters for soaking process wastewater characterization

Anions	Other Parameters
Cl^-	pH
OCl^-	Electric conductivity
CO_3^{2-}	COD
SiF_6^{2-}	BOD
HSO_3^-	TS
Cations	TDS
Na^+	Organic nitrogen
	AOX
	Emulsifiers, sufractants, biocides

Liming and unhairing

The incoming raw material will affect the environmental impact of the liming and unhairing process of hides and skins. Generally, the unhairing and liming of hides takes place in the same float. The use of alkali and sharpening agents is required in order to attack the hairs. The most common recipe is the following: 150-400% water, 1-5 % Na_2S (or plus NaHS), 3-6% hydrated lime. Water consumption, including the rinsing afterwards, is considerable (almost a quarter of overall consumption in the tannery). The following table shows the main parameters and pollutants to consider for the liming and unhairing process.

Table 59: Key parameters for liming and unhairing process wastewater characterization

Anions	Other Parameters
S^{2-}	pH
Cl^-	EC
CO_3^{2-}	TDS
Cations	TS
Ca^{2+}	SS
Na^+	BOD
	COD
NH_4^+	Grease and oil
	TKN

Sodium hydroxide, sodium carbonate and calcium chloride can also be used as 'sharpening' agents. The concentration of chemicals varies greatly depending on the type of raw stock processed. For example, small calfskins will require higher chemical concentrations to achieve successful hair removal.

The wastewater generated from liming and unhairing is characterized by high COD and sulphide concentration values. Additionally, high suspended solids loading is observed in this wastewater and it is estimated that the effluent coming from the liming process contains more than 50% of total suspended solids and more than 70% of BOD loading comes from the beamhouse (preparation area) (Rydin & Frendrup, 1993).

Deliming and bating

Deliming agents and a combination of washes is used to reduce the alkalinity and to remove the calcium from limed hides. Washing can remove the calcium held on the surface of the hides. Also, deliming salts (e.g. ammonium chloride, ammonium sulphate and organic ammonium salts) can further reduce pH (BASF 1997). The amount that is added is about 2-3% of the weight of raw hides (Spain 1997, Frendrup 1999), but also a use of 2.5-4% has also been reported reported (Pearson et al. 1999).

Emissions

If the pH is adequately low, sulphides carried over with the hides from the liming give rise to free hydrogen sulphide in the drum. This happens in the case of deliming with the use of CO_2. Additionally, there is a large contribution of the ammonium salts to the total NH_4-N release (Frendrup 1999).

The following table presents the key parameters and pollutants to consider (based on the research of BREF (h) 2013, Abdallh et al., 2016 , Das et al., 2008) for the deliming – bating process:

Table 60: Key parameters for deliming-bating process wastewater characterization

Anions	Other Parameters
Cl^-	pH
S^{2-}	Electric Conductivity
SO_4^{2-}	TS
HSO_3^-	SS
Cations	TDS
Ca^{2+}	COD
	BOD
	AOX
	NH_4-N

Tanyard operations

Pickling

Several quality requirements exist for the leathers such as softness, strength and suppleness. For this purpose, the pickling of hides and certain skins with acid and salt is necessary for their preparation and for the tanning process. Usually, during the pickling process sulphuric acid and sodium chloride (NaCl) are added to the delimed pelts. In general, there are different combinations of acids added to the pickle, the choice depending on the type of tanning employed and the desired properties of the tanned leather. As mentioned before, the most used acid is sulphuric formic acid. There also other acids used in pickling process including hydrochloric acid, boric acid and other weak organic acids.

The quantities of acids used are a 0.5% - 3% of the weight of the raw materials, while the quantities of salts are used in concentrations from 6% (bovine hides) to 14% (mainly pickled pelt skins). Instead of sodium chloride, potassium chloride and sodium sulphate can be used.

4.2.9.5 Wastewater from pickling process

The wastewater generated from pickling is acidic with a pH value at about to 2 (pH=2) and has a very high salt concentration. This wastewater stream has the second higher salinity level after the soaking effluent, in the tannery. The following table shows the pollutants/parameters to consider (based on the research of Galiana-Aleixandre, 2005 and BREF(h), 2013) for the wastewater characterization.

Table 61: Key parameters for pickling effluent characterization

Anions	Other Parameters
Cl^-	BOD
SO_4^{2-}	COD
Cations	pH
Na^+	TDS
	SS
K^+	TSS
	EC

Tanning

Tanning is a process where hides and skin are converted into non-putrescible material. This process includes the introduction of tanning agents to the pelts. Depending on the quantity and the type of the tanning agent that are added to the pelts, different leathers are produced. The following table shows the types of tannage,main tanning agents and auxiliaries.

Table 62: Types of tannage, main tanning agents and auxiliaries (taken from: BREF (h) 2013)

Types of tannage	Tanning agents used	Auxiliaries used
Chrome tannage	Basic sulphate complex of trivalent chromium	Salt, basifying (magnesium oxide, sodium carbonate, or sodium bicarbonate), fungicides, masking agents (e.g. formic acid, sodium diphthalate, oxalic acid, sodium sulphite), fatliquors, syntans, resins.
Other mineral tannages	Aluminium, zirconium and titanium salts	Masking agents, basifying agents, fatliquors, salts, syntans, resins, etc.
Vegetable tannage	Polyphenolic compounds leached from vegetable material (e.g. quebracho, mimosa, oak)	Pretanning agents, bleaching and sequesting agents, fatliquors, formic acid, syntans, resins, etc.
Synthetic tannage (resin-syntans)	Sulphonated products of phenol, cresol, naphthalene, cresylics, polyacrylates, melamine resins, etc.	Fixing agents, either acid or alkali, fatliquors
Aldehyde tannage	Glutaraldehyde and modified aldehydes	Alkali, bleaching agents, tanning agent carrier
Oil tannage	Cod oil and marine oils	Catalysts such as manganese, copper, or chromium. Sodium bicarbonate or other alkali, aldehydes, emulsifiers.

The following table summarizes the parameters/pollutants (collected from different sources) to consider for the characterization of tannery wastewaters (BREF (h) 2013, Tahiri et al. 2013, Cooman et al. 2003).

Table 63: Key parameters for tanning wastewater characterization

Anions	**Other Parameters**
SO_4^{2-}	pH
Cl^-	Electric conductivity (EC)
Cations	Turbidity (NTU)
Cr^{6+}	TS
Na^+	VSS
	COD
	BOD
	TDS
	TKN
	NH_4-N
	SS

It has to be mentioned that these parameters are the same for the post tanning effluent characterization.

4.2.10 Non-ferrous metal production (NACE codes: C24.4.2, C24.4.4)

4.2.10.1 General information about the sector

As reported by the European Commission, non-ferrous metals are important for EU's manufacturing industries, economic growth and sustainability. Non-ferrous metals have unique characteristics that allow their wide use. These characteristics are: (i) low weight (aluminium) (ii) high conductivity (copper), (iii) resistance to corrosion and (iv) non-magnetic property (zinc). Because of the last two properties, they are recognized from ferrous materials. Non-ferrous metal are utilized in mechanical engineering, transport, aerospace, construction, packaging, electricity and energy sector, electronics, and medical devices. (EU, 2018a)

Table 64: Kinds of non-ferrous metals

Copper (Cu) and its alloys
Aluminium (Al)
Lead (Pb)
Tin (Sn)
Zinc (Zn)
Cadmium (Cd)
Precious metals
Ferro-alloys
Nickel (Ni)
Cobalt (Co)
Carbon and graphite

4.2.10.2 Wastewater generation

Copper & its Alloys Production

The wastewater generated from primary copper production contains dissolved and suspended solids. These suspended solids may include copper, lead, cadmium, zinc, arsenic, and mercury and also residues from mold release agents (lime or aluminum oxides). In some cases fluoride is presented, leading to a low pH of the effluent. Typically, the smelting process does not result in a liquid effluent other than cooling water, wastewaters that come from scrubbers, wet electrostatic precipitators and cooling of copper cathodes. Sources of wastewater include spent electrolytic baths, slimes recovery, spent acid from hydrometallurgy processes, cooling water, air scrubbers washdowns, stormwater, and sludges from wastewater treatment processes that require reuse/recovery or appropriate disposal. (WBG, 1998b)

In the BREF (BREF (e),2017) document for the Non-Ferrous Metals Industries, is reported that the wastewater treatment is environmental beneficial if suspended and coarse particles, metals, acids, sulphates and fluorides are removed, rendering it suitable for discharge or reuse.

In an example industry described in BREF (e),2017, during the water treatment process weak acid from the acid plant, bleed from the electrolytic refining, and wet scrubber water from the smelter secondary gas cleaning and some surface water are collected together. The combined stream is processed in a central multistage chemical water treatment plant consisting of three stages:

1) clean gypsum precipitation (treatment with lime milk, pH 1–1.3, flocculant, precipitation of clean gypsum);
2) metal precipitation (treatment with lime milk, $FeCl_3$, H_2O_2, flocculant and increase of pH to 9–10; capture of metals by precipitation);
3) arsenic removal (treatment with lime milk, $FeCl_3$ and H_2O_2 to capture the remaining arsenic, pH 6–8). The inlet water composition varies depending on the concentrate quality, the off-gas properties and the operation of the wet gas cleaning systems.

The inlet water composition varies depending on the quality of the concentrate, the off-gas properties and the operation of the wet gas cleaning systems. The sludge produced is 6-7 t/h, with a moisture level of 40-50% and a composition as shown in the below table.

Table 65: Sludge composition of copper production (based on BREF (e),2017)

Component	Concentration (%)
$CaSO_4$	30-35
As	1
Cu	1
Fe	1-2
Pb	1
Ni	0.1
Cd	0.1

Aluminium Production

The processes included in Aluminium production are in general dry processes. By melting light metals, salt slag is generated. There are different ways to minimise the amount of salt flux used, as well as different treatment techniques for salt and metal recovery. The output of a typical salt slag recycling process is NaCl and KCl that can be used for internal valorization in secondary Al melter. When a "partial recycling process" takes place the product resulting from the process is KCl (95% purity) that could be sold in fertilizer industry.

Table 66: Key parameters for non-ferrous metals wastewater characterisation

Anions	Cations
SO_4^{2-}	Ca^{2+}
Cl^-	Na^+
Heavy metals	K^+
As	**Other parameters**
Cu	pH
Fe	TDS
Pb	SS
Ni	Conductivity
Cd	

4.2.11 Iron & Steel Production (NACE codes: C24.1, C24.2, C24.3)

4.2.11.1 General Information about the sector

The steel industry has long held a strategic place in the EU economy, fostering innovation, growth, and employment (EU, 2018b). Iron and steel have found uses in agriculture, construction, in the generation and distribution of power, in the manufacturing of machinery and equipment, in household and in medicinal uses. In 2006 steel production increased up to a world total of more than 1200 million tonnes (figure below) (BREF(f), 2013).

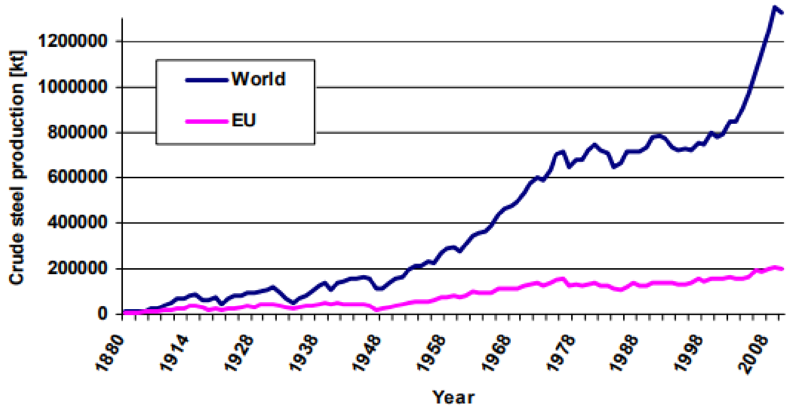

Figure 16: Crude steel production in Europe and worldwide since 1870 (Stahl, 2008)

According to BREF(f), 2013 document, there are four routes that are currently used worldwide for the steel production:

- Classic blast furnace/basic oxygen furnace route
- Direct melting of scrap (electric arc furnace)
- Smelting reduction
- Direct reduction

Integrated steelworks consist of networks of interdependent material and energy flows between the various production units:

- sinter plants
- pelletisation plants
- coke oven plants
- blast furnaces and basic oxygen steelmaking plants with Iron and Steel Production subsequent casting.

4.2.11.2 Wastewater generation

Coke Oven Plant

The cokemaking process involves carbonization of coals to high temperatures (1100 °C) in an oxygen deficient atmosphere in order to concentrate the carbon. The commercial cokemaking process can be categorized as: a) By-product Cokemaking and b) Non – Recovery/Heat Recovery Cokemaking.

The majority of coke produced in the United States comes from wet-charge, by-product coke oven batteries. In the cokemaking operation, before carbonization, the selected coals from specific mines are blended, pulverized and oiled for proper bulk density control. The blended coal is charged into a number of slot type ovens wherein each oven shares a common heating flue with the adjacent oven. Coal is carbonized in a reducing atmosphere and the off-gas is collected and sent to the by-product. In this stage, various by-products are recovered. (BREF(f), 2013)

Wastewater from wet oxidative desulphurisation processes is commonly treated separately because of the presence of compounds that have a detrimental effect on the biological wastewater treatment plant. Table 67 shows a representing wastewater composition of a desulphurisation processes. The application of one of the other wet oxidative techniques is possible to lead to water emissions with arsenic compounds (Thylox process), 1,4-naphthoquinone-2-sulphonic acid (Takahax process), picric acid and thiocyanides. BREF(f), 2013

Table 67: Composition of wastewater of two wet oxidative desulphurization processes (adapted from BREF(f), 2013)

Component	**Composition (g/l)**
NH_3 (free)	0.1
Na_2CO_3	5.7-65
SCN^-	80-300
$S_2O_3^{2-}$	50
SO_4^{2-}	12.2
Vanadate (VO_3^-)	1.2
Antharaquine	1.9

Table 68: Key parameters for iron and steel metals production wastewater characterization

Anions	**Cations**
SO_4^{2-}	Na^+
CO_3^-	
$S_2O_3^{2-}$	
Other parameters	
pH TDS SS Conductivity Arsenic compounds	

4.2.12 Inorganic Chemical Industry (NACE codes: C 20.13)

4.2.12.1 General information about the sector

The EU chemical industry, is a dynamic sector of the European economy, as it has an average growth rate of about 50 % higher than that of the EU economy and has also a growth rate about 75 % higher than the average of the total EU industry (CEFIC, 2004).

The European chemical industry is second after China (along with United States) in total sales of chemicals with a percentage of 15.1%. By including both EU and non-EU countries in Europe, total sales reached billion 597€ in 2016. As shown in the figure below, Germany and France are the two largest chemicals producers in Europe, followed by Italy and the Netherlands (CEFIC, 2017).

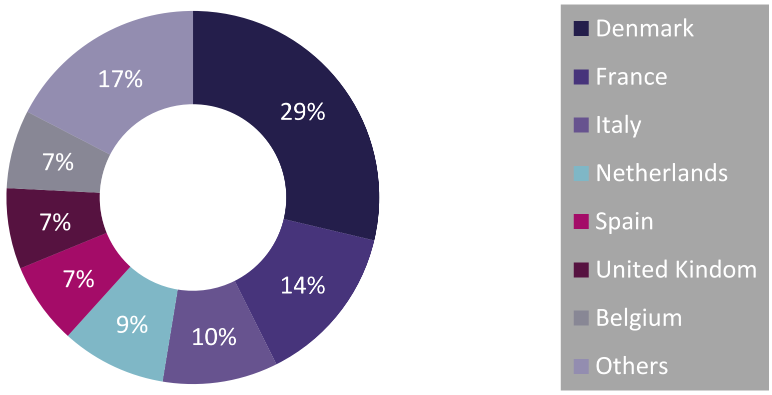

Figure 17: EU Chemical Industry sales by geographic breakdown (data taken from CEFI, 2017)

Chemical industry is one of the largest and most diversified industries. The European chemical industry supplies in a way all the economic sectors and provides innovative and sustainable economic and environmental solutions. Moreover, it plays a vital role in providing all manufacturing sectors, including the construction, health and agricultural sectors, with essential products and services. In the European Union, in terms of value added per employee, the chemical industry is the leading manufacturing sector (EU, 2018c).

The output of the chemical industry covers a wide range of chemical products and supplies virtually all sectors of the economy. The extent to which chemical processes and products penetrate other sectors of the economy is in fact a measure of the significance of the chemical industry in economic development. The well-developed EU chemical industry is both its own principal supplier and best customer. This is due to the processing chains that involve many intermediate steps in the transformation of chemicals. A very large internal market and a high degree of export-oriented production, favor development of the EU chemical industry (BREF(g), 2007).

4.2.12.2 Wastewater generation – Soda Ash Production

Soda ash is a raw material of great importance for the glass, detergent and chemical industries and consequently is of strategic importance in the European and global manufacturing framework (BREF(g), 2007). The present European soda ash capacity is over 15 million tonnes per year, and of that approximately 7.7 million tonnes per year are produced in the EU-25 (CEFIC-ESAPA, 2004).

The major industrial process for the production of sodium carbonate (soda ash) is the Solvay process or ammonia-soda (Kostick Dennis, 2006). The Solvay process is the process used in almost all European soda ash plants. The typical plant capacity ranges from 160 to 1200 kt per year. The production of soda ash in Europe by the Solvay process has been developing for over 140 years (BREF(g), 2007).

The large production capacity of the salts results in huge requirements of primary raw materials and also energy, cooling water and a range of secondary raw materials, including ammonia are also required (BREF(g), 2007).

Use of raw materials

Sodium chloride (NaCl), Limestone ($CaCO_3$) and Brine (NaCl with impurities) are the principal raw materials of the Solvay process. Ammonia, is also used in the process and is principally totally regenerated and recycled. Essentially, a high content of $CaCO_3$ in the limestone used plays and an important role in order to avoid problems associated to the limestone calcination and also to improve production efficiency.

As far as the raw brine is concerned, the basic selection criteria are (CEFIC-ESAPA, 2005):

- maximum purity of salt, to avoid excessive purification costs and,
- appropriate thickness of the deposit, allowing technically viable extraction and economic exploitation.

In the Solvay process, the NaCl reacts in a liquid phase. This is known as brine which has reached saturation point (around 300 g NaCl/l). This brine contains impurities, mainly magnesium, calcium and sulphate. Purified brine is produced during the brine purification procedure on the Solvay process.

A typical composition of raw and purified brine is given in the following table.

Table 69: Raw and purified brines (typical composition ranges) (CEFIC-ESAPA, 2004 &(BREF(g), 2007)).

Component	Raw brine composition (g/l)	Purified brine composition (g/l)
Na^+	120-125	115-125
Cl^-	186-192	180-190
SO_4^{2-}	2.4-10	2.6-8.5
Ca^{2+}	0.8-1.7	0-0.2
Mg^{2+}	0-1.5	0-0.1
CO_3^{2-}		0.4-0.9
OH^-		0-0.3

It should be noted that raw brine also contains heavy metals, however the importance of heavy metals in raw brine is relatively low, at about 6 % of the total heavy metals entering the soda ash plant. Also, the heavy metals content in raw brine varies over time.

The principal environmental impacts caused by the Slovay process are the atmospheric and aqueous emissions associated with the calcination of limestone, carbonation of ammoniated brine and, predominantly, with the wastewaters from the 'distillation' stage of the process In several EU-25 locations, the disposal of the post-distillation liquid effluent without a proper post treatment is a significant environmental issue, because of the the volume and composition of the post-distillation slurry (inorganic chlorides, carbonates, sulphates, alkali, ammonia and suspended solids, including heavy metals). The discharge of wastewaters into a local low flowrate water source is normally only possible after removal of suspended solids and possible pH adjustment, if required by the local conditions. The solids (usually $CaCl_2$) are then disposed off in settling ponds, a normal practice in the EU-25 soda ash industry, provided that the measures prescribed for liquid effluent discharge management are adopted and observed, to avoid the contamination of groundwaters by the leaking of chloride solutions drained from settling ponds

The main sources of liquid effluent from the soda ash process are typically:

i. wastewater from the distillation (after treatment) and,
ii. wastewater from the brine purification.

Wastewater from distillation

Flowrates and concentrations of the major components present in the liquid outlet distillation are given in the following table. These indicative ranges represent distiller effluent prior to any form of treatment and should not necessarily be considered as levels or concentrations emitted to the environment.

Table 70: Wastewater from distillation (CEFIC-ESAPA, 2004).

Component	Quantity (kg/t soda ash)	Concentration (kg/m^3 post-distillation liquid)
Cl^-	850-1100	99-115
OH^-	9-30	1-2.7
SO_4^{2-}	1-11	0.1-1.2
Ca^{2+}	340-400	39-45
Na^+	160-220	18-25
NH_4^+	0.3-2.0	0.03-0.24
$CaCO_3$	30-110	3.8-11
SO_4 as $CaSO_4$	15-90	1.7-7.1

Wastewater from brine purification

Wastewater from brine purification is basically brine with suspended precipitated $CaCO_3$ and $Mg(OH)_2$ in variable proportions according to the nature of the salt deposits (calcium and magnesium ions coming naturally from the original seawater).

Table 71: Effluent from brine purification (typical composition) (CEFIC-ESAPA, 2004).

Component	Concentration (% w/w)
$CaSO_4 \cdot 2H_2O$	0-8
$Mg(OH)_2$	1-6
$CaCO_3$	5-15
NaCl (Brine)	By difference

Co-products

The manufacturing of soda ash by the Solvay process enables two main co-products to be produced:

i. Calcium chloride ($CaCl_2$)

Outlet liquor from the distillation unit contains primarily $CaCl_2$ in solution in quantities corresponding to production of sodium carbonate. By treating this liquid to remove suspended solids and dissolved sodium chloride, a pure solution of calcium chloride can be obtained (BREF(g), 2007)).

ii. Refined sodium bicarbonate ($NaHCO_3$)

The refined sodium bicarbonate is mostly produced from a solution of sodium carbonate that may also contain small amounts of dissolved sodium bicarbonate. Refined sodium bicarbonate plants are typically integrated with the soda ash plants. The degree of integration in the EU is quite high, with 10 sites currently producing refined sodium bicarbonate out of the total of 14 soda ash producing sites. However, the size of the refined sodium bicarbonate plants in relation to the soda ash capacity is variable from the smallest representing just 3 to 4 % of the total plant output compared with the largest accounting for 17 % (CEFIC-ESAPA, 2004).

4.2.12.3 Wastewater generation -Synthetic Amorphous Silica

Synthetic amorphous silica and silicates are used in a wide range of industrial applications. Due to their physico-chemical properties, they are employed in synthetic resins, plastics, rubbers, cosmetics, nutritional products and drugs, for example as fillers or anti-caking agents. Synthetic amorphous silica and silicates are produced either **i)** by a wet process – precipitation of a water glass solution with acids (precipitated silicas, silica gels, silicates) – or **ii)** by a high temperature process – hydrolysis of chlorosilanes (pyrogenic silicas).

In the wet process of the production of the synthetic amorphous precipitated silica and silica gel, the main emissions are by products of the process, normally aqueous Na_2SO_4 along with small amounts of other materials, for example, particulates, pollutants characterized by COD, and in some cases, chlorides. Sulphate, normally as a sodium sulphate content in the wastewater, is up to 588 kg/t silica as it is generated during the silica synthesis as a by-product (CEFIC-ASASP, 2002).

In the pyrogenic silica process of the production process of the amorphous pyrogenic silica, emissions to water are low. The wastewater consists mainly of aqueous NaCl solutions generated by the hypochlorite treatment with small amounts of other materials, giving minor particulates and **COD** contributions to the effluent (BREF(g), 2007)).

A detailed characterization of the wastewater produced in the production process of precipitated silica was carried out in the framework of the deliverable 4.1 of ZERO BRINE project. The results showed that the main ions in solution were sulphate and sodium, which come from the reagents used in the production process. The presence of Al, Fe and Si as well as the high turbidity of the effluents are inhibiting for the treatment of the wastewater by nanofiltration.

4.2.12.4 Wastewater generation - Magnesium Compounds Production

Magnesium is the eighth most frequent element in the earth's crust and the third most frequent element in seawater. In industry, the most important magnesium minerals that are used are magnesium carbonate ($MgCO_3$, magnesite), calcium magnesium carbonate ($CaCO_3 \cdot MgCO_3$, dolomite), magnesium chloride ($MgCl_2$) and its double salt with potassium chloride ($KCl \cdot MgCl_2 \cdot 6H_2O$, carnallite), magnesium sulphate ($MgSO_4 \cdot H_2O$, kieserite) and magnesium silicates such as asbestos or olivine. Magnesium compounds are widely used to produce metallic magnesium, refractories and insulating compounds, and find applications in the rubber, printing ink, pharmaceutical and toilet industries (Ashton Acton, 2013).

As described in the BREF(g), (2007) document for an industry in the Netherlands used as an example, approximately, 3 million m^3 of wastewater are discharged every year by a pipeline to surface waters. Calcium chloride brine from the magnesium hydroxide thickener has the largest concentration in this effluent. The other effluent streams come from the purification of magnesium chloride, from the boron/sulphate reduction and spent wash-water from the magnesium hydroxide washing process. The effluent contains ions of Mg^{2+}, Ca^{2+}, K^+, Na^+, Cl^-, SO_4^{2-}, B^{3+} and also chromium (Cr) and zinc (Zn). Chromium and zinc come from the raw materials used, and the other elements from the dolime magnesium chloride brine. The suspended solids content is normally below 0.01 kg/m^3 (BREF(g), 2007).

In the following table the mean concentrations and mean yearly load based on the average concentration and flow in the magnesia plant of the Netherlands for the year 2002 are presented. In 2002 the magnesia plant in the Netherlands discharged 3329400 m^3/yr of which 340000 m^3 was from a neighboring company. As mentioned before, the load of wastewaters from MgO production is estimated to about 3 million m^3/year. (BREF(g), 2007)

Table 72: Emissions to water – mean concentrations and mean yearly load (the Netherlands) (InfoMil, 2004)

	Mg^{2+}	Ca^{2+}	K^+	Na^+	Cl^-	SO_4^{2-}	B^{3+}	Cr	Zn
Conc. mg/l							2.5	0.064	0.032
Load kg/yr								213.5	105.5
Conc. g/l	0.33	21.11	0.54	2.21	41.99	0.37			
Load tonne/yr	1099	70285	1785	7359	139807	1163	8.6		

Table 73: Key parameters for chemical industry wastewater characterization

Anions	Cations
SO_4^{2-}	Ca^{2+}
Cl^-	Na^+
OH^-	K^+
CO_3^{2-}	Mg^{2+}
Other parameters	NH_4^+
pH	**Other elements**
TDS	Cr
SS	Zn
Conductivity	Al
COD	Fe
Turbidity	Si

4.3 Solution Providers

As defend also in the SBO, the solution providers will consist of the technologies for treating saline wastewater proposed in ZERO BRINE project.

As described in *Deliverable 5.1 " Plans for shared use of the BEC modules by project partners"*, the methods applied for brine processing as it regards the technologies to be adopted are grouped in the following four (4) categories:

- ORganics (OR)
- Brine Purification (BP)
- Brine Concentration (BC)
- Brine CRystallization (BCR)

Table 74: Technology toolbox of ZERO BRINE project

Technology Groups	Technologies
Organics	Adsorption with electrochemical destruction
	Advanced oxidation (ozone/ hydrogen peroxide)
Brine purification / Ion Separation	Nanofiltration
	Regeneration of membranes
	Electrodialysis
	Electrodialysis Metathesis/ ED with bipolar membranes
	Ion exchange
Brine Concentration	Electrodialysis
	Electrodialysis Metathesis
	Membrane Distillation
	Reverse Osmosis / UF / MF
	Forward-feed MED evaporator*
Brine Crystallization	Eutectic Freeze Crystallization (EFC)*
	Crystallization with Ion Exchange Membranes (CrIEM)*

The information regarding the solution providers will be enriched at the time that the BECs and the case study will be operational.

4.4 End-users

Activity sectors using salts as raw material or water for different purposes and companies producing or supplying salts or water in market are possible end-users interested in the Symbiotic Brine Ontology. The two categories (salts/minerals and water) are going to be examined apart in the present report.

4.4.1 End-users of Minerals

Each chemical substance used in industries has certain technical specifications according to its use taking into consideration the recipe of the process, environmental parameters etc.

Under REACH (EC1907/2006)[19] regulation, "*each manufacturer and importer of a substance is obliged to provide a brief general description of the identified uses in his registration dossier. A use in this context means any utilisation of a substance as such or in a mixture. Article 3(24) of the REACH legal text includes a definition of use: " use: means any processing, formulation, consumption, storage, keeping, treatment, filling into containers, transfer from one container to another, mixing, production of an article or any other utilisation". This includes for example: formulation of mixtures, or production of an article*" . (Guidance on Information Requirements and Chemical Safety Assessment, Chapter R.12: Use description, Version 3.0, December 2015)[20].

REACH also refers to the recovered substances and points out the following in the Guidance on waste and recovered substances (ECHA, 2010):

"As soon as a material 'ceases to be waste', REACH requirements apply in principle in the same way as to any other material, with a number of exceptions granted conditionally. The point at which waste 'ceases to be waste' has been the subject of long debates. According to Article 6 (1) and (2) of the new Waste Framework Directive, certain specified waste shall cease to be waste when it has undergone a recovery operation and complies with specific criteria to be developed in line with certain legal conditions, in particular:
(a) the substance or object is commonly used for specific purposes;
(b) a market or demand exists for such a substance or object;
(c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and
(d) the use of the substance or object will not lead to overall adverse environmental or human health impacts."

In this context, it is clear that the technical characteristics (for specific uses) in the material recovery process are of high importance. A recovered substance must be "useful" in market and consequently this implies that it must have specific technical characteristics.

[19] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006R1907
[20] https://echa.europa.eu/documents/10162/13632/information_requirements_r12_en.pdf

Moreover, as each manufacturer of a substance must create a dossier in REACH providing information for the suitability of specific uses of the substance, it is of high importance for brine owners who would like to recover a material to know the required characteristics for its final use**.** For this reason, OBP aims to contribute in the recovery process for raw materials, by giving to the brine owners a general idea about the technical characteristics that are demanded in the market in different sectors and for different uses of the recovered materials. At this point is very important to be clarified the meaning of use. REACH sets key elements to describe a use as follows:

- Life cycle stage
- Use name and further description of use
- Identification of the markets in which the substance is used
- Description of the different activities contributing to the uses (from human health and environment perspectives)
- Technical function of the substance in the use.

Table 75: Use descriptor category-related key elements according to REACH

Use descriptor category	Related key element(s)
Life cycle stage (LCS)	Life cycle stage
Sector of use (SU)	Market description (sector of economy where the use takes place)
Product category (PC)	Market description (type of product), Contributing activities (consumers)
Product category (PROC)	Contributing activities (workers)
Environmental release category (ERC)	Contributing activities (environment)
Article category (AC)	Market description (type of article), Contributing activities (service life)
Technical function (TF)	Technical function of the substance

For the SBO there will be used the key elements that have to do with market (SU, PC and AC) and the key element TF, as it is assumed to be important to find out who are the users of the salts (SU), for which reason they use them (AC and PC) and which are the technical functions (TF) of these salts. This information is useful for those who recover raw material because it will be necessary to define the suitability of these materials for specific uses as they are obligated by REACH. End-users set their technical specifications/restrictions according the use of the mineral (SU, AC, TF, PC) and this way brine owners will have the possibility to know in advance which characteristics must have the desirable recovery materials.

A brief description of the key elements (according REACH) follows:

SU: Sector of End-use

The categories for Sector of use are meant to provide information on the sector of the economy or market area where the use takes place. Therefore, they indicate types of industries or industry segments where the substance is present.

PC: Product Category

The Chemical Product Categories as defined by REACH have two functions:

i) they describe the sectors formulating mixtures by mixture types (information relevant at formulation life-cycle stage). The categories listed help to further structure the uses of the substance along the supply chain based on the product types;

ii) they describe the product types used by the end-users (industrial, professional or consumer end-users). The product type implicitly includes some information on the potential for exposure/release of the substance.

AC: Articles Category

The Articles Categories (AC) are designed to describe the types of article in which the substance is contained or on which the substance has been applied.

TF: Technical Functions

The Technical Function categories (TF) are designed to describe the role that the substance fulfils when it is used (what it actually does as such in a process or what it actually does in a mixture or article).

Requirements/Restrictions

As mentioned before, end-users could define the salt use taking into consideration the criteria of SU, TF, PC, and AC as set by REACH. Subsequently, they will be asked to give information for the requirements/restrictions they set for the use for the salt. The restrictions have to do with properties such as purity and chemical characteristics of impurities. The Technical Specifications Sheets for the salts that are of concern in Symbiotic Brine domain have been reviewed and all the parameters set are collected and presented in the table 88 of the ANNEX.

4.4.2 Water end-users and water recovery

The recovery of water from brine streams is very important. Although water is used for many purposes (such as domestic use, for agricultural and industrial purposes etc), in the building of SBO we will focus on the use in agriculture and in industry. These sectors are the ones to be considered as end-users and the principal quality requirements are examined below.

4.4.2.1 Water used for irrigation

In EU on average 44 % of total water abstraction is used for agriculture (EU, 2017)

Water quality denotes the characteristics of a water supply that will define if it is suitable for a specific use, i.e. how well the quality meets the standards set for the need of the user. In order to define the quality, physical, chemical and biological characteristics are taken into consideration (FAO, 1985). Application of low quality water for irrigation purposes may result in accumulation of salts in the root zone, leading in loss of permeability of the soil because of the excess sodium or calcium leaching, or in contaminants which are directly toxic to plants or to those who consume them. In addition, if contaminants are accumulated in the soil, the soil will be unsuitable for irrigation after years. If pesticides or pathogenic organisms are present in irrigation water, they may not affect the growth of the plants, but will affect the suitability of agricultural products for consumption. Food and Agriculture Organization of the United Nations (FAO) has published criteria for irrigation water, but many countries have published their own criteria. From country to country, differences in the criteria can be found because of the different annual application rates of irrigation water and local characteristics. (WHO, 2016)

The quality irrigation water used varies greatly depending on the type and the quantity of dissolved salts. Salts concentration of irrigation water is quite low but significant. Salts in the water come from the dissolution or weathering of the rocks and soil, including dissolution of gypsum, lime and other soil mineral that are slowly dissolved. The salts are applied with the water and remain behind in the soil as the water evaporates or is used by the crop. Except of the quantity of salts that defines the suitability of irrigation of water, the kind of salts present plays also an important role. As the salt content increases, various soil and cropping problems arise. The water suitability for use and quality are judged on the potential severity of problems that can be expected to be developed during long-term use. (FAO, 1985)

Four problem categories are used for evaluation:

- Salinity,
- Infiltration,
- Toxicity, and
- Miscellaneous

The following table presents the guidelines for the evaluation of irrigation water quality. The guidelines emphasize the long-term influence of water quality on soil conditions, crop production and farm management

Table 76: Guidelines for interpretations of water quality for irrigation adapted from FAO 1985 and JRC 2017)

Potential Irrigation Problem	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Salinity (affects crop water availability)				
EC_w	dS/m	< 0.7	0.7 – 3.0	> 3.0
(or)				
TDS	mg/l	< 450	450 – 2000	> 2000
Infiltration (affects infiltration rate of water into the soil. Evaluate using ECw and SAR together)				
SAR = 0 – 3 and EC_w (dS/m) =		> 0.7	0.7 – 0.2	< 0.2
SAR = 3 – 6 and EC_w (dS/m) =		> 1.2	1.2 – 0.3	< 0.3
SAR = 6 – 12 and EC_w (dS/m) =		> 1.9	1.9 – 0.5	< 0.5
SAR = 12 – 20 and EC_w (dS/m) =		> 2.9	2.9 – 1.3	< 1.3
SAR = 20 – 40 and EC_w (dS/m) =		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity *(affects sensitive crops)*				
Sodium (Na)				
surface irrigation	SAR	< 3	3 – 9	> 9
sprinkler irrigation	me/l	< 3	> 3	
Chloride (Cl)				
surface irrigation	me/l	< 4	4 – 10	> 10
sprinkler irrigation	me/l	< 3	> 3	
Boron (B)	mg/l	< 0.7	0.7 – 3.0	> 3.0
Miscellaneous Effects *(affects susceptible crops)*				
Nitrogen (NO_3 - N)	mg/l	< 5	5 – 30	> 30
Bicarbonate (HCO_3)				
(overhead sprinkling only)	me/l	< 1.5	1.5 – 8.5	> 8.5
pH	Normal Range 6.5 – 8.4			

The following table shows the parameters for determinations and calculations needed to use the guidelines, along with the symbols used.

Table 77: Laboratory determinations needed to evaluate common irrigation water quality problems (FAO, 1985)

Water parameter	Symbol	Unit	Usual range in irrigation water
Salinity-Salt content			
Electrical Conductivity	EC_w	dS/m	0 – 3
(or)			
Total Dissolved Solids	TDS	mg/l	0 – 2000
Cations and Anions			
Calcium	Ca^{2+}	me/l	0 – 20
Magnesium	Mg^{2+}	me/l	0 – 5
Sodium	Na^{+}	me/l	0 – 40
Carbonate	CO^{2-}_3	me/l	0 – .1
Bicarbonate	HCO_3^-	me/l	0 – 10
Chloride	Cl^-	me/l	0 – 30
Sulphate	SO_4^{2-}	me/l	0 – 20
Nutrients			
Nitrate-Nitrogen	NO_3-N	mg/l	0 – 10
Ammonium-Nitrogen	NH_4-N	mg/l	0 – 5
Phosphate-Phosphorus	PO_4-P	mg/l	0 – 2
Potassium	K^+	mg/l	0 – 2
Miscellaneous			
Boron	B	mg/l	0 – 2
Acid/Basicity	pH	1–14	6.0 – 8.5
Sodium Adsorption Ratio	SAR	(me/l)	0 – 15

The presence of phytotoxic trace elements such as, heavy metals, boron and pesticides may inhibit the growth of plants or make the crop unsuitable for human consumption or other uses.

Table 78: Selected water quality criteria for irrigational waters (mg l-1) (FAO, 1985 WHO 2006;)

Element	Concentration (mg/l)
Aluminium	5.0
Arsenic	0.1
Cadmium	0.01
Chromium	0.1
Copper	0.2
Manganese	0.2
Nickel	0.2
Zinc	2.0

Moreover, according to the report of the JRC (2017) the Joint Research Centre (JRC) was asked by the European Commission to develop and set the minimum quality requirements for water reuse in groundwater discharge and agricultural irrigation. The purpose of this action was to foster water reuse as a core element in the framework of Circular Economy. The core water quality requirements for water reuse in agricultural irrigation that were proposed by JRC report are summarized in the following table:

Table 79: Minimum quality requirements for reclaimed water in agricultural irrigation (JRC, 2017)

Reclaimed water quality	Indicative technology target	Quality criteria				
		E. coli (cfu/100 ml)	**BOD_5 (mg/l)**	**TSS (mg/l)**	**Turbidity (NTU)**	**Additional criteria**
Class A	Secondary treatment, filtration and disinfenction (advanced water treatments)	≤ 10	≤ 10	≤ 10	≤ 5	Legionella spp.: <1,000 cfu/l when there is risk of aerosolization in greenhouses. Intestinal nematodes (helminth eggs): ≤ egg/l when irrigation of pastures or fodder for livestock.
Class B	Secondary treatment, and disinfection	≤ 100	According to Directive 91/271/EEC	According to Directive 91/271/EEC	-	
Class C	Secondary treatment and disinfection	≤ 1,000	According to Directive 91/271/EEC	According to Directive 91/271/EEC	-	
Class D	Secondary treatment and disinfection	≤ 10,000	According to Directive 91/271/EEC	According to Directive 91/271/EEC	-	

4.4.2.2 Water Use in Industry sector

Industries can be considered as systems whose operation demands water for different uses. The suitability of water in different industrial uses is defined by the parameters below (IWA, 1996)

- the potential for causing damage to equipment (e.g. abrasion, corrosion)
- problems that can be caused in the manufacturing process (e.g. color changes, precipitates)
- damage of product quality (e.g. discoloration, taste)
- complexity of waste handling as a result of using water of the quality available.

The following table presents *the potential water-related problems associated with various* industrial processes.

Table 80: Potential water-related problems associated with various industrial processes (IWA, 1996)

Water Use	Equipment damage	Process problems	Product problems	Waste disposal
Cooling water	Corrosion Scaling Fouling Blockages	Foaming Sediments Gas production Odours HE impairment		pH TDS COD SS
Water for steam generation	Resin film Resin poison Corrosion Scaling	Resin impairment Competition	Inadequate treatment	pH TDS
Process water	Corrosion Scaling Fouling Blockages Abrasion embrittlement Discoloration	Precipitates Foaming Color effects Gas production Interference	Sediment Foam Color Taste/odour Tarnish	SS Fe/Mn TDS
Product water	Corrosion Scaling Fouling Blockages	Precipitates Foaming Gas production Interference	Sediment Turbidity Foam Color Taste/odor Coagulation	
Utility water	Corrosion Scaling Fouling Blockages Abrasion		Sediment Turbidity Foam Color Taste/odour Intestinal irritation Breath hazards	pH TDS SS Fe/Mn COD
Wash water	Corrosion Scaling Fouling Blockages Abrasion	contamination	Contamination blemishes Sediment Process solutions	pH TDS SS Fe/Mn COD

The water quality problems listed in the table above can be identified with constituents that contribute to them. Frequently, water quality problems are associated not only with the presence of a variable but with the interaction between variables, as is the case with corrosion and scaling. The table below indicates the constituents which may be associated with water-related problems in industrial processes.

Table 81: Constituents which may be associated with water-related problems in industrial processes (indicated with blue color) (IWA, 1996)

Problem	pH	Conductivity	Total Hardness	Fe	Mn	Alkalinity	SO_4	Cl^-	SiO_2	SS	COD
Corrosion											
Scaling											
Fouling											
Blockage											
Abrasion											
Embrittlement											
Discoloration											
Resin blinding											
Foaming											
Sediment											
Gas production											
Taste/odours											
Precipitates											
Turbidity											
Color											
Biological growth											

4.4.3 Targeted products for the SB domain

Targeted products for the SB domain are the **salts and minerals** presented in the following table and **water** as described in the previous section.

During the procedure of developing the SBO a research took place for the sectors that generate saline wastewater. Most of them are also users of the salt that end up as pollutants. Additionally, studying ECHA (European Chemical Agency) some information about the salts that are widely used was retrieved. This research resulted in a list of targeted salts which includes salts that have been found in saline wastewaters, and salts that are widely used.

Table 82: Targeted salts and minerals for the SB domain

Formula	Name
$NaCl$	Sodium chloride
$NaSiO_3$	Sodium silicate
Na_2CO_3	Sodium carbonate
Na_2SO_4	Sodium sulphate
$NaClO$	Sodium hypochlorite
$NaHSO_4$	Sodium bisulfate, Sodium hydrogen sulfate
NH_4Cl	Ammonium chloride
$(NH_4)_2SO_4$	Ammonium sulphate
$NaNO_3$	Sodium nitrate
$NaHSO_3$	Sodium hydrogensulfite
$Na_2S_2O_4$	Sodium dithionite
K_2CO_3	Potassium carbonate
Na_2SiF_6	Disodium hexafluorosilicate
Na_2S	Disodium sulfide
$CaCl_2$	Calcium chloride
KCl	Potassium chloride
$NaHCO_3$	Sodium hydrogencarbonate
$Na_2S_2O_3$	Sodium thiosulphate
$Zr(SO_4)_2$	Zirconium sulphate
$Cr_2(SO_4)_3$	Chromium sulphate
$MgCl_2$	Magnesium chloride
$CaSO_4$	Calcium sulphate
$MgSO_4$	magnesium sulphate
$Mg(OH)_2$	Magnesium hydroxide
$Ca(OH)_2$	Calcium dihydroxide
$CaHPO_4$	Calcium hydrogenorthophosphate
$Ca_3(PO_4)_2$	Tricalcium bis(orthophosphate)
NH_4NO_3	Ammonium nitrate
$CaSiO_4$	Silicic acid, calcium salt
$CaCO_3$	Calcium carbonate
NH_4HCO_3	Ammonium bicarbonate
$NaNO_2$	Sodium nitrite

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6 ANNEX

Table 83: Descriptor list for Life cycle stages

CODE	NAME	NACE CODES
SU1	Agriculture, forestry, fishery	A
SU2a	Mining, (without offshore industries)	B
SU2b	Offshore industries	B 6
SU4	Manufacture of food products	C 10,11
SU5	Manufacture of textiles, leather, fur	C 13-15
SU6a	Manufacture of wood and wood products	C 16
SU6b	Manufacture of pulp, paper and paper products	C 17
SU7	Printing and reproduction of recorded media	C 18
SU8	Manufacture of bulk, large scale chemicals (including petroleum products)	C 19.2+20.1
SU9	Manufacture of fine chemicals	C 20.2 -20.6
SU11	Manufacture of rubber products	C 22.1
SU12	Manufacture of plastics products, including compounding and conversion	C 22.2
SU13	Manufacture of other non-metallic mineral products, e.g. plasters, cement	C 23
SU14	Manufacture of basic metals, including alloys	C 24
SU15	Manufacture of fabricated metal products, except machinery and equipment	C 25
SU16	Manufacture of computer, electronic and optical products, electrical equipment	C 26-27
SU17	General manufacturing, e.g. machinery, equipment, vehicles, other transport equipment	C 28-30,33
SU18	Manufacture of furniture	C 31
SU19	Building and construction work	F
SU20	Health services	Q 86
SU23	Electricity, steam, gas water supply and sewage treatment	D 35, D 36-37
SU24	Scientific research and development	M 72
SU0	Other	

Table 84: List for Chemical Products Category

CODE	NAME	Explanation and examples
PC1	Adhesives, sealants	
PC2	Adsorbents	
PC3	Air care products	
PC4	Anti-Freeze and de-icing products	
PC7	Base metals and alloys	
PC8	Biocidal products	Includes e.g. disinfectant products, pest control products.Note that the category refers to types of products, not to the technical function of the substance. PC 35 should be assigned to disinfectants being used as a component in a cleaning product.
PC9a	Coatings and paints, thinners, paint removers	
PC9b	Fillers, putties, plasters, modelling clay	
PC9c	Finger paints	
PC11	Explosives	
PC12	Fertilizers	
PC13	Fuels	
PC14	Metal surface treatment products	This covers substances permanently binding with the metal surface. It includes e.g. galvanic and electroplating products.
PC15	Non-metal-surface treatment products	It includes e.g. example treatment of walls before painting.
PC16	Heat transfer fluids	
PC17	Hydraulic fluids	
PC18	Ink and toners	
PC19	Removed from PC list and relocated in the technical function list (Table R.12- 15)[24].	
PC20	Processing aids such as pH-regulators, flocculants, precipitants, neutralization agents	This category covers processing aids used in the chemical industry.
PC21	Laboratory chemicals	
PC23	Leather treatment products	This category includes dyes, finishing, impregnation and care products.
PC24	Lubricants, greases, release products	
PC25	Metal working fluids	
PC26	Paper and board treatment products	This category includes e.g. bleaches, dye, finishing, impregnation products and other processing aids.
PC27	Plant protection products	
PC28	Perfumes, fragrances	
PC29	Pharmaceuticals	

PC30	Photo-chemicals	
PC31	Polishes and wax blends	
PC32	Polymer preparations and compounds	
PC33	Semiconductors	
PC34	Textile dyes, and impregnating products	This category includes e.g. bleaches and other processing aids.
PC35	Washing and cleaning products	This category includes water and solvent based products.
PC36	Water softeners	
PC37	Water treatment chemicals	
PC38	Welding and soldering products, flux products	
PC39	Cosmetics, personal care products	This category includes products covered by the Cosmetics Regulation (EU Regulation 1223/2009) and other personal care products. It includes products such as toothpaste, deodorants, etc.
PC40	Extraction agents	
PC41	Oil and gas exploration or production products	
PC42	Electrolytes for batteries	Mixtures (liquids or pastes) designed to serve as electrolytes in batteries.
PC0	Other	

List for Chemical Products Category 1

Table 85: Descriptor list for Articles Categories

CODE	NAME	EXPLANATION & EXAMPLES
Categories of complex articles		
AC1	Vehicles	
AC1a	Vehicles covered by End of Life Vehicles (ELV) directive	e.g. personal vehicles, delivery vans
AC1b	Other vehicles	e.g. boat, train, metro, planes
AC2	Machinery, mechanical appliances, electrical/electronic articles	
AC2a	Machinery, mechanical appliances, electrical/electronic articles covered by the Waste Electrical and Electronic Equipment (WEEE) directive	e.g. refrigerators, washing machines, vacuum cleaners, computers, telephones, drills, saws, smoke detectors, thermostats, radiators
AC2b	Other machinery, mechanical appliances, electrical/electronic articles	e.g. large-scale stationary industrial tools
AC3	Electrical batteries and accumulators	

Material-based categories of articles		
AC4	Stone, plaster, cement, glass and ceramic articles	
AC4a	Stone, plaster, cement, glass and ceramic articles: Large surface area articles	Construction and building materials e.g. floor coverings, isolation articles
AC4b	Stone, plaster, cement, glass and ceramic articles: Toys intended for children's use (and child dedicated articles)	
AC4c	Stone, plaster, cement, glass and ceramic articles: Packaging (excluding food packaging)	
AC4d	Stone, plaster, cement, glass and ceramic articles: Articles intended for food contact	e.g. dinner ware, drinking glasses, pots, pans, food storage containers
AC4e	Stone, plaster, cement, glass and ceramic articles: Furniture & furnishings	
AC4f	Stone, plaster, cement, glass and ceramic articles: Articles with intense direct dermal contact during normal use	e.g. jewellery
AC4g	Other articles made of stone, plaster, cement, glass or ceramic	
AC5	Fabrics, textiles and apparel	
AC5a	Fabrics, textiles and apparel: Large surface area articles	Construction and building materials e.g. floor or wall materials: carpets, rugs, tapestries
AC5b	Fabrics, textiles and apparel: Toys intended for children's use (and child dedicated articles)	e.g. stuffed toys, blankets, comfort objects
AC5c	Fabrics, textiles and apparel: Packaging (excluding food packaging)	
AC5d	Fabrics, textiles and apparel: Articles intended for food contact	
AC5e	Fabrics, textiles and apparel: Furniture & furnishings, including furniture coverings	e.g. sofa cover, car seat cover, fabric chair, hammock
AC5f	Fabrics, textiles and apparel: Articles with intense direct dermal contact during normal use	e.g. clothing, shirts, pants, shorts

AC5g	Fabrics, textiles and apparel: Articles with intense direct dermal contact during normal use: bedding and mattresses	e.g. blankets, sheets
AC5h	Other articles made of fabrics, textiles and apparel	
AC6	Leather articles	
AC6a	Leather articles: Large surface area articles	Construction and building materials
AC6b	Leather articles: Toys intended for children's use (and child dedicated articles)	
AC6c	Leather articles: Packaging (excluding food packaging)	
AC6d	Leather articles: Articles intended for food contact	
AC6e	Leather articles: Furniture & furnishings, including furniture coverings	e.g. sofa, car seat, chair
AC6f	Leather articles: Articles with intense direct dermal contact during normal use	e.g. clothing such as jackets, shoes, or gloves
AC6g	Other leather articles	e.g. domestic articles such as decoration articles, leather boxes
AC7	Metal articles	
AC7a	Metal articles: Large surface area articles	Construction and building materials e.g. roof sheets, pipes,
AC7b	Metal articles: Toys intended for children's use (and child dedicated articles)	
AC7c	Metal articles: Packaging (excluding food packaging)	
AC7d	Metal articles: Articles intended for food contact	e.g. packaging containers, metal tins, knifes, cooking pots
AC7e	Metal articles: Furniture & furnishings	e.g. outdoor furniture, benches, tables
AC7f	Metal articles: Articles with intense direct dermal contact during normal use	e.g. handles, jewellery
AC7g	Other metal articles	
AC8a	Paper articles: Large surface area articles	Construction and building materials e.g. insulation panels, wall papers
AC8b	Paper articles: Toys intended for children's use (and child dedicated articles)	

AC8c	Paper articles: Packaging (excluding food packaging)	
AC8d	Paper articles: Articles intended for food contact	
AC8e	Paper articles: Furniture & furnishings	
AC8f1	Paper articles: Articles with intense direct dermal contact during normal use: personal hygiene articles	e.g. nappies, feminine hygiene products, adult incontinence products, tissues, towels, toilet paper
AC8f2	Paper articles: Articles with intense direct dermal contact during normal use: printed articles with dermal contact in normal conditions of use	e.g. newspapers, books, magazines, printed photographs
AC8g	Other paper articles	e.g. lampshades, paper lanterns
AC10	Rubber articles	Includes foam materials
AC10a	Rubber articles: Large surface area articles	Construction and building materials e.g. flooring
AC10b	Rubber articles: Toys intended for children's use (and child dedicated articles)	e.g. baby bottle nipples, soothers
AC10c	Rubber articles: Packaging (excluding food packaging)	
AC10d	Rubber articles: Articles intended for food contact	
AC10e	Rubber articles: Furniture & furnishings, including furniture coverings	
AC10f	Rubber articles: Articles with intense direct dermal contact during normal use	e.g. gloves, boots, clothing, rubber handles, gear lever, steering wheels
AC10g	Other rubber articles	
AC11	Wood articles	
AC11a	Wood articles: Large surface area articles	Construction and building materials e.g. floor, claddings
AC11b	Wood articles: Toys intended for children's use (and child dedicated articles)	
AC11c	Wood articles: Packaging (excluding food packaging)	
AC11d	Wood articles: Articles intended for food contact	
AC11e	Wood articles: Furniture & furnishings	

AC11f	Wood articles: Articles with intense direct dermal contact during normal use	e.g. handles, pencils
AC11g	Other wood articles	
AC13	Plastic articles	includes foam materials
AC13a	Plastic articles: Large surface area articles	Construction and building materials e.g. flooring, insulation
AC13b	Plastic articles: Toys intended for children's use (and child dedicated articles)	includes baby-bottles
AC13c	Plastic articles: Packaging (excluding food packaging)	
AC13d	Plastic articles: Articles intended for food contact	e.g. plastic dinner ware, food storage
AC13e	Plastic articles: Furniture & furnishings, including furniture coverings	
AC13f	Plastic articles: Articles with intense direct dermal contact during normal use	e.g. handles, ball pens
AC13g	Other plastic articles	
AC0	Other	

Descriptor list for Articles Categories 1

Table 86: Descriptor list for Technical functions

TECHNICAL FUNCTION	
NAME	EXPLANATION
Ablative	Substance that is applied to a substrate to protect it from heat by dissipating heat through the process of erosion, melting, or vaporization of the material.
Abrasive	An abrasive is a substance used to abrade, smooth, or polish an object. Abrasives are used to remove imperfections from a surface; used to smooth, scour, scrub, clean, wear down, or polish surfaces by rubbing against the surface; usually fine powders of hard substances. Examples include sandstones, pumice, quartz, silicates, aluminium oxides, and glass.
Absorbent	Chemical substance used to retain other substances by assimilation.
Adhesion promotor	Any substance, inorganic or organic, natural or synthetic, used to join opposite surfaces to each other, promote bonding between other substances, promote adhesion of surfaces, or fasten other materials together. They are generally applied from a solvent solution and allowed to dry on the two facing surfaces.
Adsorbent	Chemical substance used to retain other substances by accumulation on their surface; substance with a large surface area which can attract dissolved or finely dispersed substances from another medium.
Aerating and dearating agents	Substance that influences the amount of air or gases entrained in a material.

Antiadhesive	Substance that prevents or reduces the adhesion of a material to itself or to another material; prevents bonding between other substances by discouraging surface attachment; functions as the antitheses of adhesive.
Alloying element	Substances that are added to metals alloys like steel to modify its properties such as strength, hardness, or to facilitate its treatment.
Anticaking agent	Substance that prevents granular or particulate materials from sticking or caking during transfer, storage, or use.
Anticondensation agent	Substance or material that is used to avoid condensation on surfaces and in the atmosphere.
Antifreeze agent	A substance added to fluids, especially water, to reduce the freezing point of the mixture, or applied to surfaces to melt or prevent the build-up of ice. Examples of products include antifreeze liquids, windshield de-icers, aircraft de-icers, lock release agents, ice melting crystals, and rock salt.
Antioxidant	Substance that retards oxidation, rancidity, deterioration, and gum formation; used to maintain the quality, integrity, and safety of finished products by inhibiting the oxidative degradation of the ingredients in the formulation. Saturated polymers have greater oxidative stability and require relatively low concentrations of stabilizers.
Antiredeposition agent	Any substance that prevents dirt and grease from resettling on a cleaned surface or that helps keep soils from re-depositing onto clothing in the wash water after they have been removed. Antiredeposition agents are water-soluble and typically negatively charged.
Antiscaling agent	Substances added to products to prevent the build-up of inorganic oxide deposits. The formation of scale can be caused by the deposition of salts or minerals and may not necessarily lead to surface corrosion, therefore these chemicals are not corrosion inhibitors. Substances prevent the build-up or removes limescale and fouling. These substances are also called ‘Descalers’.
Antistain agent	Antistain agent is a substance that provides stain blocking and soil resistance to soft surface cleaners and protectors.
Antistatic agent	Any substance that prevents or reduces the tendency of a material to accumulate a static charge or alters the electrical properties of materials by reducing their tendency to acquire an electrical charge.
Antistreaking agent	A substance which serves to enhance evaporation or reduce film formation in order to prevent the formulation of streaks on a surface during cleaning.
Barrier (Sealant)	Material designed only to fill up a space, prevent seepage of moisture or air, passage of liquid or gas. The spaces can be joints, gaps or cavities that occur between two substrates.
Binder	Any cementitious material that is used to hold dry powders or aggregate together; added to compounded dry powder mixtures of solids to provide adhesive qualities during and after compression to make tablets or cakes; is soft at high temperatures and hard at room temperature.
Biocide	Substance intended for preventing, neutralizing, destroying, repelling, or mitigating the effects of any pest or microorganism; that inhibits the growth, reproduction, and activity of organisms, including fungal cells; decreases the number of fungi or pests present; deters microbial growth and degradation of other ingredients in the formulation.

Bleaching agent	A bleaching agent is a material that lightens or whitens a substrate through chemical reaction. The bleaching reactions usually involve oxidative or reductive processes that degrade colour systems. Bleaching and decolourization can occur by destroying one or more of the double bonds in the conjugated chain, by cleaving the conjugated chain, or by oxidation of one of the other moieties in the conjugated chain.
Brightener	Substance that is used to brighten, whiten, or enhance the appearance of colour of fabric and paper, usually by absorbing light in the ultraviolet and violet region (340-370 nm) of the electromagnetic spectrum, and re-emitting light in the blue region (420-470 nm). This causes a "whitening" effect by increasing the overall amount of blue light reflected. Optically colourless on the substrate and do not absorb in the visible part of the spectrum.
Catalyst	Substances that increase the efficiency of a chemical reaction e.g. reaction needs less energy. Catalysts take part in the reaction but are not consumed during the process.
Chain transfer agent	Substance that terminates the growth of a molecular chain and forms a new radical that can act as the initiator for a new chain.
Chelating agent	A substance that has the ability to complex with inactivate metallic ions; used to remove ions from solutions and soils by forming a type of coordination complex so that the ions usual precipitation reactions are prevented; material that cleans oxide films from metals by stabilizing metal ions through complexing heterocyclic rings around each ion. They contain two or more electron donor atoms that can form coordinate bonds to a single metal atom. After the first such coordinate bond, each successive donor atom that binds creates a ring containing the metal atom; this cyclic structure is called a chelation complex or chelate.
Cleaning agent	Substance or material used to remove dirt or impurities from surfaces; acts to loosen and remove dirt and grease from surfaces.
Cloud-point depressant	Substance that depresses the temperature at which solids begin to separate from a liquid, at a temperature lower than that normally allowed.
Coalescing agent	Ingredients that decrease the minimum film-forming temperature (MFT) and, upon evaporation, yield a hard film. In polishes, the most common coalescing agent is glycol ether however, pyrrolidines and benzoates are also used.
Compatibilizer	Enables a reaction between two or more dissimilar polymers, allowing them to become more intimately mixed than before.
Conductive agent	Material used to conduct electrical current.
Corrosion inhibitor	Chemical substance used to prevent or retard corrosion metallic materials. They are needed in many products packaged in metal containers (such as aerosol products) and also used in such products as lubricants and other metal treatment products to provide protection to the substrates or surfaces on which the lubricants are used.
Crystal growth modifiers (nucleating agents)	Substance used to reduce or increase crystal growth.
Deflocculant	Substance used to fluidize concentrated slurries to reduce their bulk viscosity or stickiness in processing or handling.

Defoamer	Chemical that is used to control foam; prevents foam from forming; breaks down any foam that does form; reduces foaming from proteins, gases, or nitrogenous materials. They reduce the tendency of finished products to generate foam on shaking or agitation. The ability of a material to act as an antifoam depends on its tendency to concentrate on the surface of existing or forming bubbles and to disrupt the continuous films of liquid surrounding them. As process aid, it improves filtration, dewatering, washing, and drainage of many types of suspensions, mixtures, and slurries.
Demulsifier	Substance used to destroy an emulsion or prevent its formation.
Density modifier	Substance that modifies the density of a material.
Deodorizer	Substance that reduces or eliminates unpleasant odour and protects against the formation of malodour on body surfaces. Counteraction, sometimes referred to as neutralization, occurs when two odorous substances are mixed in a given ratio and the resulting odour of the mixture is less intense than that of the separate components.
Diluent	Substance that serves primarily to reduce the concentration of the other ingredients in a formulation; volatile liquid that is added to modify the consistency or other properties. The term is most often used for liquid formulations, with the term filler used for solid or powder formulations.
Dispersing agent	Substance added to a suspending medium or suspension to improve the separation of particles; to ensure proper dispersion; to prevent settling or clumping; to encourage uniform and maximum separation of individual, extremely fine solid particles or liquid droplets, often of colloidal size. A typical use is dispersal of dyes to ensure uniform coloration.
Drier	These substances, which speed the drying of paint, ink, etc., are often organometallic compounds.
Durability agent	Durability agents are ingredients added to increase the durability and therefore the functional life of a material.
Dust suppressant	Substance used to control finely grained solid particles to reduce their discharge into the air.
Dusting agent	Substance that is dusted onto the surface of a material (e.g., rubber) to reduce surface tack.
Dye	Substance used to impart colour to other materials or mixtures; added to a material to add colour; soluble. Molecularly dispersed within a liquid, transferred to a material, and bound to that material through intermolecular forces. Typically an organic substance, although exceptions do exist. A dye requires some degree of solubility that allows it diffuse into the polymeric matrix of a textile fibre.
Elasticizer	Substance that increases the elasticity of a material.
Embalming agent	Substance used for the preservation of biological tissue.
Energy releasers (explosives, motive propellant)	Substance characterized by chemical stability, but may be induced to undergo rapid chemical change without an outside source of oxygen, rapidly producing a large quantity of energy and gas accompanied by a large increase in volume and an explosion, bursting, or expansion.

Etching agent	Etching Agent is a substance that removes unprotected areas of metal or glass surfaces. Etching agents are usually acids or bases.
Explosion inhibitor	Substance used to reduce the explosion potential of flammable materials.
Fertilizers (soil amendments)	Chemical substance used to increase the productivity and quality of farm crops, including plants, animals, and forestry; added to soil to supply chemical elements needed for plant nutrition.
Filler	Ingredient added to fill out a dry product formulation and to lower the concentration of other ingredients; used to provide bulk, increase strength, increase hardness, or improve resistance to impact; used to extend a material and to reduce its cost by minimizing the amount of more expensive substances used in the production of articles; used to fill cavities or tighten joints; relatively inert and normally non-fibrous, finely divided substance added usually to extend volume and sometimes to improve desired properties, such as whiteness, consistency, lubricity, density or tensile strength.
Film former	Any component of a material that aids the material in forming a thin continuous sheet on its substrate. This sheet will act as a barrier between the environment and its substrate. Silicone is a good film-former in furniture polishes because of its ease of application, soil removal, and depth of glossiness. Polymers are the most commonly used film formers.
Finishing agents	Chemical substances used to impart such functions as softening, staticproofing, wrinkle resistance, and water repellence. Substances may be applied to textiles, paper, and leather.
Fire extinguishing agent	Any agent incorporated or applied to slow down combustion once started; Removes heat faster than it is released; separates the fuel and oxidizing agent; dilutes the vapour phase concentration of the fuel and oxidizing agent below what is needed for combustion.
Fixing agent (mordant)	Substance used to interact with a dye on fibres to improve fastness.
Flame retardant	Flame retardation is a process by which the normal degradation or combustion processes of polymers have been altered by the addition of certain chemicals. They are substances used on the surface of or incorporated into combustible materials to reduce or eliminate their tendency to ignite when exposed to heat or a flame for a short period of time; used to raise its ignition point; used to slow down or prevent combustion.
Flocculating agent	A flocculating agent is a chemical or substance that facilitates flocculation of suspended solids in liquid. Flocculating agents are chemical additives, which, at relatively low levels compared to the weight of the solid phase, increase the degree of flocculation of a suspension. They act on a molecular level on the surfaces of the particles to reduce repulsive forces and increase attractive forces. The principal use of flocculating agents is to aid in making solid–liquid separations.
Flotation agent	Substance used to concentrate and obtain minerals from ores.
Flow promoter	Substance that reduces drag in fluids in motion and between a fluid and a conduit surface.
Flux agent	Substance used to promote the fusing of minerals or prevent oxide formation; for casting or joining materials.
Foamant	Any substance that promotes or enhances formation of a lather or foam (i.e., a dispersion of a gas in a liquid or solid); used to form physically, by expansion of compressed gases or vaporization of liquid, or chemically, by decomposition evolving a gas, a foam or cellular structure in a plastic or rubber material.

Food flavouring and nutrient	Substance used in food or animal feedstuffs to produce or enhance taste or odour or nutritional value. Flavour compounds are molecules that stimulate the human taste chemical senses.
Fragrance	Chemical substances used to impart control odours or impart pleasing odours. Fragrance compounds are molecules that stimulate the human olfactory chemical senses.
Freeze-thaw additive	These synthetic resin emulsions or synthetic lattices enable paints, coatings, and other products to retain original consistency and to resist coagulation when exposed to freezing and thawing prior to application.
Friction agent	Materials used to enhance friction between two objects.
Fuel	Chemical substance used to create mechanical or thermal energy through chemical reactions; used to evolve energy in a controlled combustion reaction.
Fuel additive	Substances added to a fuel for the purpose of controlling the rate of reaction or limiting the production of undesirable combustion products; provide other benefits such as corrosion inhibition, lubrication, or detergency.
Gelling modifier	Substance that influences the formation or destruction of a gel.
Hardener	Increases the strength, hardness, and abrasion resistance of coatings, adhesives, sealants, elastomers, and other products
Heat stabilizer	Substance that protect polymers from the chemical degrading effects of heat or UV irradiation.
Heat transferring agent	Substance used to transmit or to remove heat from another material.
Humectant	Humectant is a substance that is used to retard moisture loss from the product during use. This function is generally performed by hygroscopic materials. The efficacy of humectants depends to a large extent on the ambient relative humidity.
Hydraulic (functional) fluids	Liquid or gaseous chemical substances used for transmitting pressure and EP-additives. Transfer power in hydraulic machinery.
Impregnation agent	Substance used to admix with solid materials, which retain their original form.
Incandescent agent	Substance that is used to emit electromagnetic radiation at high temperature.
Insulators	Substances used to prevent or inhibit the flow of heat, electrical current, light, and the transmission of sound between two media. (acoustic, electrical, and thermal insulators).
Intermediate (precursor)	Chemical substances consumed in a reaction in order to manufacture other chemical substances at an industrial processing facility.
Ion exchange agent	Chemical substances, usually in the form of a solid matrix, that are used to selectively remove targeted ions from a solution. In ion exchange, ions of a given charge (either cations or anions) in a solution are adsorbed on a solid material (the ion exchanger) and are replaced by equivalent quantities of other ions of the same charge released by the solid.

Leaching agent	Substance that, when added to a solvent, aids in the dissolution of a component of an insoluble solid mixture.
Lubricating agent	Substance introduced between two moving surfaces or adjacent solid surface to reduce the friction between them, improve efficiency, reduce wear, and reduce heat generation; enhance the lubricity of other substances. These lubricating films are designed to minimize contact between the rubbing surfaces and to shear easily so that the frictional force opposing the rubbing motion is low.
Luminescent agent	Substance that emits visible radiation upon absorption of energy in the form of photons, charged particles, or chemical change.
Magnetic element	Substance added into materials in order to make them magnetic.
Monomers	Substance usually containing carbon and of a low molecular weight and simple structure which is capable of conversion to polymers, synthetic resins, or elastomers by repetitive combination with itself or other similar molecules.
No technical function	To be used in the cases where the substance does not fulfil any particular technical function during the use described (e.g. case where a processing aid remains in the matrix of an article without fulfilling any technical function during service life)
Opacifier	Substance that renders solutions opaque; reduces transparency or the ability of light to pass through solution; added to finished products to reduce their clear or transparent appearance.
Oxidizing agent	Oxidizing agent is a substance that gains electrons during their reaction with a reducing agent. Oxidizing agents commonly contribute oxygen to other substances.
pH regulating agent	Maintains the desired pH range of a substance; used to alter, stabilize, or control the pH (hydrogen ion concentration). Substances used to alter or stabilize the hydrogen ion concentration (pH).
Photochemical	Chemical substance used for its ability to alter its physical or chemical structure through absorption of light, resulting in the emission of light, dissociation, discoloration, or other chemical reaction; used to create a permanent photographic image.
Pigment	Any substance, usually in the form of a dry powder, that imparts colour to another substance or mixture by attaching themselves to the surface of the substrate through binding or adhesion; may contribute towards opacity, durability, and corrosion resistance. Must have positive colorant value; larger than molecular particle size and held in place by corresponding low mobility; scatter and absorb light. Pigments differ from dyes in that they are insoluble in the vehicle and exist as dispersed compounds in paint rather than as a solute.
Plasticizer	An organic compound that softens synthetic polymers; added to a high polymer to facilitate processing and to increase flexibility, plasticity, fluidity and toughness of the final product by internal modification (solution) of the polymer molecule. Plasticizers may be added internally or externally. A rigid polymer can also be externally plasticized by addition of a plasticizer, which imparts the desired flexibility but is not chemically changed by reaction with the polymer.
Plating agent	Substances/materials used as a source for a layer of metal deposited on another surface, or that aid in such a deposition. These are used in processes such as electroplating, galvanization or coating.

Pressure transfer agent	Lubricating oil and grease additive that prevents metal to metal contact at high temperatures or under heavy loads where severe sliding conditions exist. Functions by reacting with the sliding metal surfaces to form oil-insoluble surface films.
Process regulator	Chemical substance used to change the rate of a chemical reaction, start or stop the reaction, or otherwise influence the course of the reaction. May be consumed or become part of the reaction product.
Processing aid	Chemical substances used to improve the processing characteristics or the operation of process equipment or to alter or buffer the pH of the substance or mixture, when added to a process or to a substance or mixture to be processed. Processing agents do not become a part of the reaction product and are not intended to affect the function of a substance or article created.
Propellants, non-motive (blowing agents)	Substance that is used for expelling products from pressurized containers (aerosol products); used to dissolve or suspend other substances and either to expel those substances from a container in the form of an aerosol or to impart a cellular structure to plastics, rubber, or thermo set resins; provides the force necessary to expel the contents of aerosol containers; liquefied or compressed gas within which substances are dissolved or suspended and expelled from a container upon discharge of the internal pressure through expansion of the gas. The formulated product in the pressurized container may be solution, emulsion, or suspension.
Reactive cleaning/removal agent	Substance that reacts with and removes surface contaminants and is generally consumed, e.g., oxides, sulfides.
Reducing agent	Substance that during reactions with oxidizing agents lose electrons; commonly contributes hydrogen to other substances; used to remove oxygen, hydrogenate or, in general, acts as electron donor in chemical reactions.
Refrigerants	Substances used within machines such as air conditioning units, refrigerators, and walk in freezers to cool indoor air and reduce temperatures.
Resins (prepolymers)	Usually high molecular weight polymers that lower viscosity. Thermoplastic resins soften when exposed to heat and return to original form at room temperature, and thermosetting resins solidify irreversibly when heated due to cross-linking.
Semiconductor and photovoltaic agent	Substance that has resistivity between that of insulators and metals; usually changeable by light, heat or electrical or magnetic field; generates electromotive force upon the incidence of radiant energy.
Sizing agent	Substance applied to substrates such as fabric, yarn, paper products, or plaster to increase abrasive resistance, stiffness, strength, smoothness, or reduce absorption.
Softener	Substance used for softening materials to improve feel, to facilitate finishing process, or to impart flexibility or workability; used in textile finishing to impart superior "hand" to the fabric and facilitate mechanical processing; has the capability of imparting softness and pliability to washable textile fabrics.
Solids separation (precipitating) agent	Chemical substances used to promote the separation of suspended solids from a liquid.
Solubility enhancer	A chemical additive that prevents chemicals or materials from separating or falling out of solution. Solubility enhancers are often used in concentrated formulations.

Solvent	Any substance that can dissolve another substance (solute) to form a uniformly dispersed mixture (solution) at the molecular or ionic size level; provides dissolving capability required for a stable formulation; dissolves certain components of the formulation to aid dispersion of components; aids oil cleansing power and controls film drying rate; allows the product to solubilize soils on surfaces and facilitate removal; used to dissolve, thin, dilute, and extract.
A substance that tends to keep a compound, solution, or mixture from changing its form or chemical nature; renders or maintains a solution, mixture, suspension, or state resistant to chemical change; used to prevent or slow down spontaneous changes in and ageing of materials.	A substance that tends to keep a compound, solution, or mixture from changing its form or chemical nature; renders or maintains a solution, mixture, suspension, or state resistant to chemical change; used to prevent or slow down spontaneous changes in and ageing of materials.
Surface modifier	Substance that may be added to other ingredients to adjust the optical properties associated with the surface of a material. These substances are designed to affect the luster, increase gloss, and alter the reflectance exhibited by a surface.
Surfactant	A surface active agent (surfactant) which, when added to water, causes it to penetrate more easily into, or to spread over the surface of another material by reducing the surface tension of the water (see detergent).
Swelling agent	Substance added to a material to cause that material to increase in volume and become softer.
Surface modifier	Substance that may be added to other ingredients to adjust the optical properties associated with the surface of a material. These substances are designed to affect the luster, increase gloss, and alter the reflectance exhibited by a surface.
Surfactant	A surface active agent (surfactant) which, when added to water, causes it to penetrate more easily into, or to spread over the surface of another material by reducing the surface tension of the water (see detergent).
Swelling agent	Substance added to a material to cause that material to increase in volume and become softer.
Tackifier	Provides stickiness
Tanning agent	Substance used for treating hides and skins.
Terminator/Blocker	Substance that reacts with the end of a growing polymer chain, stopping further polymerization (terminator) or a substance used to protect a reactive moiety on a precursor during organic synthesis of a product that is subsequently removed regenerating the reactive moiety (blocker).

Thickener/Thickening agentThickener/Thickening agent	Any of a variety of hydrophilic substances used to increase the viscosity of liquid mixtures and solutions and to aid in maintaining stability by their emulsifying properties. Four classifications are recognized: 1) Starches, gums, casein, gelatin and phycocolloids; 2) semisynthetic cellulose derivatives (e.g. carboxymethyl-cellulose); 3) polyvinyl alcohol and carboxy-vinylates (synthetic); and 4) bentonite, silicates, and colloidal silica.
Tracer	Substance that possesses a readily detectable radioactive/isotopic label or chemical moiety which is added to biological/environmental media or chemical reactions to elucidate the transformation/transportation processes that are occurring.
UV stabilizer	Substance that protects the product from chemical or physical deterioration induced by ultraviolet light; absorbs UV radiation, thereby protecting varnishes and pigments against UV degradation.
Vapour pressure modifiers	Substance added to a liquid to modify its vapour pressure (e.g., to reduce evaporation).
Vehicle (carrier)	The vehicle dissolves or disperses solid components of a substance, allowing even dispersion throughout application. The vehicle carries the other particles within a substance.
Viscosity modifier	Substance used to alter the viscosity of another substance; used to decrease or increase the viscosity of finished products; used to modify the flow characteristics of other substances, or mixtures, to which they are added; controls the deformation or flow ability of a wax product. Resins generally lower viscosity while thickeners (e.g., gums and hydroxyethyl cellulose) increase viscosity.
Waterproofing agent	A water repellent material functions by lowering the surface energy to protect surfaces against water by making water bead.
X-Ray Absorber	Substance use to block or attenuate X-rays.

Table 87: Water Use Category (WUC)

Irrigation Water
Process water
Product Water
Water for steam generation
Cooling Water
Utility Water
Wash Water

Table 88: Parameters to consider for salt reuse

Quantity	Purity
Moisture	pH
volatile matter	non volatile matter
organic matter	
NH_4^+	Sb (Antimony)

NO_3^-	Sb_2O_3
NO_2^-	Be (Beryllium)
NH_3	BeO
P	V (Vanadium)
PO_4^{3-} (phosphates)	VO
P_2O_5	V_2O_3
Cl^-	Ti (Titanium)
CO_3^{2-}	TiO_2
Fe	Ba (barium)
Fe_2O_3	BaO
Ca	SiO_2
CaO	Si (Silicon)
heavy metals	S (Sulphur)
Pb (Pb)	SO_4^{2-} (Sulphates)
As (Arsenic)	Sulphur compounds
Hg (Mercury)	S^{2-} (Sulphides)
Cd (cadmium)	Na^+ (Sodium)
Cr (Chromium)	Mg^{2+} (Magnesium)
Mn (Manganese)	MgO
MnO_2	K (Potassium)
Ni (Nickel)	K_2O
NiO	F (Fluoride)
Ni_2O_3	I (Iodine)
Cu	NaCl (sodium chloride)
CuO	Na_2SO_4 (sodium sulphate)
Cu_2O_3	Na_2CO_3 (sodium carbonate)
Al (Aluminium)	Na_2S (disodium sulphide)
Al_2O_3	K_2SO_4 (potassium sulphate)
Zn (Zinc)	CH_3COONa (sodium acetate)
ZnO	$NaNO_2$ (sodium nitrite)

Se (Sellenium)	H_2SO_4 (sulphuric acid)
SeO_2	$Na_2S_2O_5$ (sodium metabisulphite)
Br (Bromide)	SO_2 (sulphure dioxide)
Br_2O_3	$Na_2O_7S_2$ (disodium disulphate)
BrO_2	Na_2SO_3 (sodium sulphite)
Sr (Strontium)	$Na_2S_2O_3$ (sodium thiosulphate)
SrO	$MgCl_2$ (magnesium chloride)
Zr (Zirconium)	$CaSO_4$ (Calcium sulphate)
ZrO_2	$Ca(OH)_2$ (Calcium hydroxide)
Mo (Molybdenum)	$MgSO_4$ (Magnesium sulphate)
MoO_3	$CaCl_2$ (Calcium Chloride)
Sn (Tin)	KCl (Potassium Chloride)
SnO	$MgCO_3$ (Magnesium Carbonate)
SnO_2	