Diplomarbeit

Life Cycle Assessment in plasma-derived pharmaceutical production with multi-process and multi-product system

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Wien, am 05.09.2023

Anna Pasztor

Preamble

I would like to thank all the people who supported me in the completion of this diploma thesis.

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Abstract

Reducing greenhouse emissions on a global scale is essential and urgent. Up until now, the focus was concentrated on the industrial sectors in reference to emissions reduction, and the pharmaceutical sector has received little attention.

With the 2030 Climate Target Plan, the European Commission proposes to raise the EU's ambition on reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030. The first step to the reduction is quantifying the emissions. Quantifying and comparing the environmental impacts of goods and services requires tools and methods.

The aim of this work is to develop a method that makes environmental impacts seeable and detectable during plasma-derived pharmaceutical production processes. The aim is to identify hotspots through one product and to create a monitoring which can be a foundation for analysing other products henceforward. The developed method should have the ability to provide information about Scope 1, 2 and 3 emissions and other environmental impacts of the processes.

To reach these goals, a cradle-to-gate life cycle assessment (LCA) is carried out according to the DIN EN ISO 14040 and 14044 standards. Data from industrial production are collected (refers to one year) and displayed in an MS Excel model, then a life cycle assessment is performed using the software Sima Pro. The used database is Ecoinvent.

In this work four items are compared with different amount of action unit and volume: 500 IU/10 ml, 500 IU/ 20 ml, 1000 IU/20 ml, and 2500 IU/50 ml. The examined impact categories are the following: global warming potential, freshwater eutrophication, freshwater ecotoxicity, and water consumption.

After carrying out the life cycle assessment, some conclusion can be summarized. Water is in the largest amount used material in comparison to chemicals and other materials because of the used amount of solutions for washing, elution and cleaning. The most emission usually come from the downstream processes because the transportation occurs by airplane. The greenhouse gas emissions are divided in three scopes, transport and materials have the largest effect on the environment. The main greenhouse gas sources are the steps sterile filling, freeze drying and ultra/diafiltration in the production. Among the four items, 2500 IU/50 ml contributes the most and 500 IU/10 ml the less to the emissions.

The LCA is completed with a sensitivity analysis. Some scenarios are presented relating to transportation, steam production, and polymer recycling.

Essential question is the allocation because it is necessary after more products are produced from the same plasma collection.

Kurzzusammenfassung

Die Verringerung der Treibhausgasemissionen im globalen Maßstab ist von entscheidender Bedeutung und dringend erforderlich. Bisher konzentrierte man sich bei der Emissionsreduzierung auf die Industriesektoren und schenkte dem pharmazeutischen Sektor wenig Aufmerksamkeit.

Mit dem Klimazielplan 2030 schlägt die Europäische Kommission vor, das Ziel der EU, die Treibhausgasemissionen bis 2030 auf mindestens 55 % unter das Niveau von 1990 zu senken, zu erhöhen. Der erste Schritt zur Reduzierung ist die Quantifizierung der Emissionen. Um die Umweltauswirkungen von Waren und Dienstleistungen zu quantifizieren und zu vergleichen, sind Tools und Methoden erforderlich.

Ziel dieser Arbeit ist es, eine Methode zu entwickeln, die die Umweltauswirkungen bei der Produktion von Arzneimitteln aus Plasma sichtbar und nachweisbar macht. Dabei sollen Hotspots durch ein Produkt identifiziert und ein Monitoring erstellt werden, das als Grundlage für die Analyse anderer Produkte dienen kann.

Die entwickelte Methode sollte in der Lage sein, Informationen über Scope 1, 2 und 3 Emissionen und andere Umweltauswirkungen der Prozesse zu liefern.

Um diese Ziele zu erreichen, wird eine cradle-to-grave Lebenszyklusanalyse (LCA) nach den Normen DIN EN ISO 14040 und 14044 durchgeführt. Daten aus der industriellen Produktion werden für ein Jahr erfasst und in einem MS-Excel-Modell dargestellt. Anschließend erfolgt die Lebenszyklusanalyse mithilfe der LCA-Software Sima Pro. Die verwendete Datenbank ist Ecoinvent.

In dieser Arbeit werden vier Produkte mit unterschiedlichen Mengeneinheiten und Volumen verglichen: 500 IU/10 ml, 500 IU/ 20 ml, 1000 IU/20 ml und 2500 IU/50 ml. Die untersuchten Wirkungskategorien sind: Treibhauspotenzial, Süßwasser-Eutrophierung, Süßwasser-Ökotoxizität und Wasserverbrauch.

Nach Durchführung der Ökobilanz lassen sich einige Schlussfolgerungen zusammenfassen. Im Vergleich zu Chemikalien und anderen Materialien wird am meisten Wasser verbraucht, da eine große Menge an Lösungen zum Waschen, Eluieren und Reinigen benötigt wird. Die meisten Emissionen stammen in der Regel aus den nachgelagerten Prozessen, da der Transport per Flugzeug erfolgt. Die Treibhausgasemissionen werden in drei Bereiche unterteilt, wobei Transport und Materialien die größten Auswirkungen auf die Umwelt haben. Die wichtigsten Treibhausgasquellen sind die Schritte Sterilverfüllung, Gefriertrocknung und Ultra-/Diafiltration in der Produktion. Von den vier Produkten tragen 2500 IE/50 ml am meisten und 500 IE/10 ml am wenigsten zu den Emissionen bei.

Die Ökobilanz wird durch eine Sensitivitätsanalyse ergänzt. Es werden einige Szenarien für den Transport, die Dampferzeugung und das Polymerrecycling vorgestellt.

Eine wesentliche Frage ist die Allokation, da diese notwendig ist, wenn mehrere Produkte aus derselben Plasmasammlung hergestellt werden.

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ABBREVIATIONS AND SYMBOLS

ACS-GCI	American Chemical Society Green Chemistry Institute
ADP	Abiotic Depletion Potential
AP	Acidification Potential
API	Active Pharmaceutical Ingredient
CFm	Midpoint Characterization Factor
EMS	Environmental Management System
EOFP	Photochemical Oxidant Formation Potential: Ecosystems
EP	Eutrophication Potential
EPD	Environmental Product Declarations
FEP	Freshwater Eutrophication Potential
FETP	Freshwater Ecotoxicity Potential
FFP	Fossil Fuel Potential
GHG	Greenhouse Gas
GWP	Global Warming Potential
HOFP	Photochemical Oxidant Formation Potential: Humans
HTPc	Human Toxicity Potential (carcinogen)
HTPnc	Human Toxicity Potential (non-carcinogen)
IO LCI	Input Output LCI
IRP	Ionising Radiation Potential
IU	Action Unit
KIA	Key Issue Analysis
LCA	Life Cycle Analysis/ Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LOP	Agricultural Land Occupation Potential
MEE	Method of Elementary Effect
METP	Marine Ecotoxicity Potential
MP	Matrix Perturbation
OAT	One-at-a-Time Approaches
ODP	Ozone Depletion Potential
PCR	Product Category Rules
PE	Polyethylene
PMFP	Particulate Matter Formation Potential
POCP	Photochemical Ozone Creation Potential

RBD	Random Balance Design
SME	Sobol' Main Effects
SOP	Surplus Ore Potential
SRC	Standardized Regression Coefficients
STE	Sobol' Total Effects
TAP	Terrestrial Acidification Potential
TETP	Terrestrial Ecotoxicity Potential
UNFCCC	United Nations Framework Convention on Climate Change
WCP	Water Consumption Potential
WDP	Water Deprivation Potential

1 INTRODUCTION

1.1 Research problem

Reducing greenhouse emissions on a global scale is essential and urgent. In Paris Agreement within the United Nations Framework Convention on Climate Change (UNFCCC) aggressive greenhouse gases emission mitigation targets were set (Belkhir, 2019). The Paris Agreement predicates that the global warming must be kept under 1,5 °C, the emissions need to be reduced by 45 % by 2030 and reach net zero by 2050. Net zero means cutting greenhouse gas emissions to as close to zero as possible (United Nations, 2022).

The European Union supported the idea and composed an action plan for reaching the targets. The European Commission adopted a series of EU climate legislation that setting out how to achieve climate neutrality by 2050. It includes an intermediate target by 2030: at least 55 % net reduction in greenhouse gas emissions (European Commission, 2022).

Up until now, the focus was concentrated on the industrial sectors such as mining, energy and automotive industries in reference to emissions reduction, and the carbon footprint of the healthcare industry, especially the pharmaceutical sector has received little or no attention (Belkhir, 2019).

The reason can be the complexity of the production in pharmaceutical industry. To measure the real energy and mass flow in the pharmaceutical production numerous measuring instruments are needed. Because of the difficulty of division among different products, the main task firstly is to understand the mass flow and then to assign the emissions.

Our society's aim is to develop sustainability and reduce human activities for the provision of products. Quantifying and comparing the environmental impacts of goods and services requires tools and methods. Every product has a life cycle, and every life stage (including design of product, resource extraction, production and manufacturing, consumption, and waste management) result in environmental impacts (Rebitzer, 2004).

Environmental impacts can be categorized after contribution field such as climate change, smog creation, ozone depletion, eutrophication, acidification, the depletion of resources, water use, land use, toxicology on human health, noise, etc. (Rebitzer, 2004).

Life cycle analysis (LCA) is a steady-state, quantitative, global/regional analysis of environmental and social impacts of a product through entire life cycle. The effects on human health, resources and ecology are measured. (Farjana, 2021).

According to the European Environment Agency (2022), a „life-cycle assessment (LCA) is a process of evaluating the effects that a product has on the environment over the entire period of its life, and the use of results of the LCA can lead to increasing resource-use efficiency and decreasing liabilities. It can be used to study the environmental impact of either a product or the function the product is designed to perform. LCA is commonly referred to as a "cradle-to-grave" analysis. LCA's key elements are: (1) identify and quantify the environmental loads involved; e.g. the energy and raw materials consumed, the emissions and wastes generated; (2) evaluate the potential environmental impacts of these loads; and (3) assess the options available for reducing these environmental impacts" (European Environment Agency, 2022).

With the aim of achieving the goals in emission reduction, companies recognised the importance of including environmental factors in production. In the past improvements were carried out in the research & development stage but controlling the present production is non-negligible (Rebitzer, 2004).

1.2 Purpose of the thesis/ Scientific question

The aim of this work is to develop a method that makes environmental impacts seeable and detectable during plasma-derived pharmaceutical production processes. The aim is to identify hotspots through one product and to create a monitoring which can analyse other products henceforward. The developed method should have the ability to provide information about greenhouse gas (Scope 1, 2 and 3) emissions and other environmental impacts of the processes.

Scope 1 emissions evolve directly from company production facilities. In contrast Scope 2 & 3 emissions are indirect, Scope 2 comes from purchased energies and Scope 3 includes all emissions from purchased materials and services and on the other hand, from processing, use, and waste treatment of sold products (Kircher, 2021).

To reach these goals, a life cycle assessment (LCA) is carried out completed with a sensitivity analysis. Essential question is the allocation because it is necessary after more products are produced from the same plasma collection, and system expansion as recommended by the ISO 14040 is not possible.

The observed topics are summarized in the following research questions:

- How should the method for quantifying the environmental impacts of pharmaceutical products from a manufacturing perspective look?
- How can an allocation be executed in a pharmaceutical production in multi-process and multi-product systems?
- Which emissions are relevant during the production of the examined product and where are the relevant information sources?

- How can a tool be improved for quantifying the environmental impact to determine CO_2-emissions of all the production processes?
- Can the method estimate the environmental effects after modification of process steps?

The research takes place in the production (foreground system), not in R&D section. The supply chain before and after the production, and the end-of-life state (background system) are also examined but not as in details as the production part.

1.3 Methods & Materials

To achieve the research objectives and to answer the research question, a cradle-to-grave LCA was carried out according to the DIN EN ISO 14040 and 14044 standards. In the process, data from industrial production were collected and displayed in an MS Excel model, then a life cycle assessment was performed using the LCA software Sima Pro (Version 9303). Sima Pro helps companies and organizations assess the environmental impact of products and services over their entire lifecycle, from raw material extraction to end-of-life disposal. The software allows users to perform comprehensive LCAs by inputting data on product inputs and outputs, energy and resource use, emissions, and other environmental impacts. Sima Pro can provide as results from a life cycle assessment environmental impact, carbon footprint, energy use, water use, land use, waste generation and life cycle costs (PRé Consultants, 2016a). The results of the LCA can then be used to make informed decisions about product design and production processes, as well as to communicate environmental performance to stakeholders. Sima Pro is widely used in a variety of industries, including consumer goods, electronics, construction, and agriculture (PRé Consultants, 2016b).

Because of the complexity of the production and the special processes, a sensitivity analysis is attached. The used database is Ecoinvent 3.7.1. The system model allocation cut-off by classification was used because it was important to know how the waste treatment contributes to the production and wastes in this system model are the producer's responsibility. The principle of this system, that the primary production of materials is allocated to the primary user. Recyclable materials therefore are burden-free.

Some processes are not found among the unit processes of the database, here the input and output materials and energy were estimated based on literature or industrial measurements. The data collection refers to one year.

There is a workstream with different specific subject experts to identify and cluster necessary information from all manufacturing areas. The approach is to identify all relevant process steps from a mass flow perspective and combine it with relevant environmental impacts.

This work is not a simulation, the data are collected and examined, but the data show an actual status not scenarios for the future. Water and material consumption, energy demand and waste treatment were collected for the analysis, and in the end of the work a few scenarios were proposed for the highest impacts.

1.4 Thesis structure

This work is divided into four main sections and their subchapters. After the introduction of the research focus (state of the field, research object including the problem and the aim), chapter 2 deals with the theoretical background by describing the general principles of the LCA and its use in pharmaceutical industry. In this context, the definition, classification, and use of LCA are addressed, and the concept of pharmaceutical life cycle assessment is explained in more details. In addition, it presented a comparison, how other companies and research groups did the allocation in pharmaceutical industry, especially in case of multi-process and multi-product systems. The literature was chosen after the similar type of life cycle assessment and similar product system. All the articles are from the pharmaceutical industry. The first one represents a medicament from a catalytic synthesis, the second one is an enzyme-produced drug, and the third one is a plasma-derived drug, such as the purpose of this analysis. The functional unit, reference flow, source of data, sensitivity analysis and chosen impact categories of the three companies are compared in a table.

The third part summarizes the cradle-to-gate LCA of the research object, the process of data collection, the calculation of the environmental impacts and the evaluation in the sensitivity analysis are systematically described. It covers the data resulting from the LCA. This section also points out the allocation and its complexity, and the data collection and evaluation are also shown in detail. The master thesis is concluded with the findings from the study and the outlook on possible next steps and on future changes in pharmaceutical industry.

2 THEORETICAL BACKGROUND

2.1 Environmental sustainability

"Environmental sustainability is the ability to maintain the qualities that are valued in the physical environment." Values such as human life, the quality of life and the beauty of environment, the functioning of society, renewable resources, clean water and air, a suitable climate, and the capability of the nature to maintain those living conditions for people and other species are wanted for maintenance by most people (Sutton, 2004).

The United Nations (2022) defined environmental sustainability as „meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them, and more specifically, as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity" (United Nations, 2022).

Confirming sustainability concepts and solving environmental problems are often discussed as urgent needs, but to take action is usually harder. For an efficient action there are several requirements that must be fulfilled: available technological solutions; a list of prioritized and best practices accounting for efficiency, cost, and resulting economic constraints; and optimized action for further reduction of impacts. LCA is a decision-making tool, that fulfils those needs by selecting and optimizing available technological solutions (Jolliet, Soucy, Shaked, Saade-Sbeih, & Crettaz, 2015).

2.2 Life cycle assessment

2.2.1 Definition of LCA

LCA is a methodological framework, can be used for estimating and assessing the environmental impacts of a product. It is a young method and a consequence of the energy requirements in the 1960s and pollution prevention in the 1970s (Rebitzer, 2004).

LCA is called ecobalance in some languages (German: Ökobilanz) where the quantified balance and inventory of polluting emissions and resource extractions are highlighted (Jolliet, Soucy, Shaked, Saade-Sbeih, & Crettaz, 2015).

LCA of pharmaceutical production evaluates the environmental impact of a product throughout its entire life cycle. The main stages of a pharmaceutical LCA include:

1. Raw material acquisition
2. Manufacturing and formulation
3. Packaging

4. Distribution and transportation
5. Use and disposal

The main environmental impacts associated with pharmaceutical production include energy consumption, greenhouse gas emissions, water usage, and waste generation. The LCA helps identify areas for improvement and ways to reduce the environmental impact of the production process (Jolliet, Soucy, Shaked, Saade-Sbeih, & Crettaz, 2015).

2.2.2 ISO and other standards

The International Organization for Standardization formulated a systemized framework related to LCA in period 1997-2000, resulting in the standards ISO 14040, 14041, 14042 and 14043. In 2006, those standards were completed and accreted into ISO 14040 and 14044 (Pryshlakivsky & Searcy, 2013).

The standards were inspired by the Code of Practice (developed by Society of Environmental Toxicology and Chemistry). ISO 14040 series is a supplementary tool of an overall Environmental Management System (EMS).

ISO 14000 standard series provided a framework for LCA (Rebitzer, 2004):

- International Standard ISO 14040 (1997) on principles and framework.
- International Standard ISO 14041 (1998) on goal and scope definition and inventory analysis.
- International Standard ISO 14042 (2000) on life cycle impact assessment.
- International Standard ISO 14043 (2000) on life cycle interpretation.

In 2006, in the document a little technical content was changed but that have meant significant improvements in clarity and language. Some definitions were redefined, some part removed and some explanations, new sections were added. The change resulted an amalgamation of the standards:

1. ISO 14040:2006: This standard provides the general principles and framework for conducting an LCA.
2. ISO 14044:2006: This standard provides specific requirements and guidelines for conducting an LCA, including goal and scope definition, inventory analysis, impact assessment, and interpretation of results.

Since 2006 there are a few minor improvements, but the overall content will not change in the future, more likely (Pryshlakivsky & Searcy, 2013).

ISO 14040/44 is the basis for many other standards such as ISO 14025, which introduces two concepts: Product Category Rules (PCR) and Environmental Product Declarations (EPD) (PRé Consultants, 2016b).

PCRs are guidelines that provide specific instructions for calculating the environmental impact of products within a particular product category. These guidelines are stricter and leave less room for interpretation than a general LCA. A product category consists of a group of products that share similar characteristics. The PCR may specify various requirements, such as the functional unit to be used, the databases to be used, or the impact categories to be included in the study. Program Operators are required for PCRs, and they can be a group of companies, an industrial sector, trade organization, or a public authority. Examples of Program Operators include Environdec (Sweden), PlasticsEurope (the Association of plastics manufacturers in Europe), Institut Bauen und Umwelt (Germany), EPD-norge (Norway), and JEMAI (Japan) (Siegert, Finkbeiner, Emara, & Lehmann, 2019).

EPDs are now widely used in many countries and sectors as a way to communicate a product's environmental impact. There are three types of environmental communication available, Type III is the EPD. However, to create an EPD, guidelines provided by ISO standard 14025 are not specific enough. Instead, a procedure to make product category rules is described. Once a PCR is established, the LCA can be performed according to the specification in the EPD. These rules are usually straightforward and allow for simple procedures. Also, the impact assessment method is relatively simple. In general, the impact categories are limited to:

- Global warming potential (GWP)
- Acidification potential (AP)
- Eutrophication potential (EP)
- Photochemical ozone creation potential (POCP)
- Ozone depletion potential (ODP)
- Abiotic depletion potential (ADP) for minerals and metals (non-fossil resources)
- Abiotic depletion potential (ADP) for fossil resources
- Water deprivation potential (WDP) (EPD Portal, 2023).

2.2.3 Parts of LCA

An LCA study consists of four main phases:

Step 1: Defining the goal and scope of the study.

Step 2: Making a model of the product life cycle with all the environmental inputs and outputs. This data collection effort is usually referred to as life cycle inventory (LCI).

Step 3: Understanding the environmental relevance of all the inputs and outputs. This part is called life cycle impact assessment (LCIA).

Step 4: The interpretation of the study. (PRé Consultants, 2016b)

Figure 1 shows the relationship between the phases.

The completed life cycle with material and energy flows is called product system (Rebitzer, 2004). ISO standards define a product system as a „collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product" (ISO, 2006b).

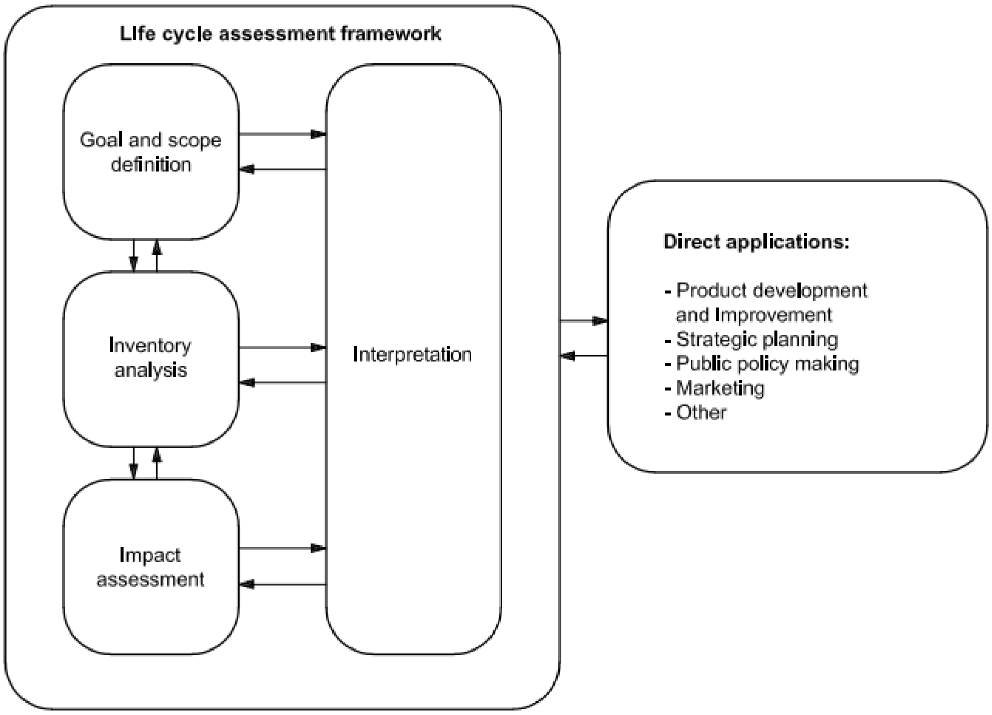


Figure 1: Stages of a Life Cycle Assessment
(ISO, 2006a)

2.2.4 Goal and scope

A Life Cycle Assessment is a representation of the life cycle of a product, service, or system. It is essential to recognize that a model is a simplified version of a complex reality, and therefore, it may not reflect the entire reality accurately. As a result, LCA practitioners face the challenge of creating a model that minimizes the impact of simplifications and distortions on the results. To address this issue, it is crucial to precisely define the goal and scope of the LCA study (PRé Consultants, 2016b).

The most important (often subjective) choices are described such as:

- The reason for executing the LCA (the questions which need to be answered).
- A precise definition of the product, its life cycle, and the function it fulfils.

- A definition of the functional unit (especially when products are to be compared).
- A description of the system boundaries and the way co-production will be dealt with.
- Data and data quality requirements, assumptions, and limitations.
- The requirements regarding the LCIA procedure, and the subsequent interpretation to be used.
- The intended audiences and the way the results will be communicated.
- If applicable, the way a peer review will be made.
- The type and format of the report required for the study.

In the goal and scope part of an LCA the system boundaries and a functional unit are defined.

ISO standards formulate the system boundary as a term that „determines which unit processes shall be included within the LCA. The selection of the system boundary shall be consistent with the goal of the study. The criteria used in establishing the system boundary shall be identified and explained" (ISO, 2006b).

Consequently, boundaries around the system are important to define, because not all inputs and outputs can be the part of the product system. Some of them cannot be traced and should be excluded, which means, the result may be affected. Drawing a diagram about the system helps to identify the boundaries. Figure 2 shows an example for a product system.

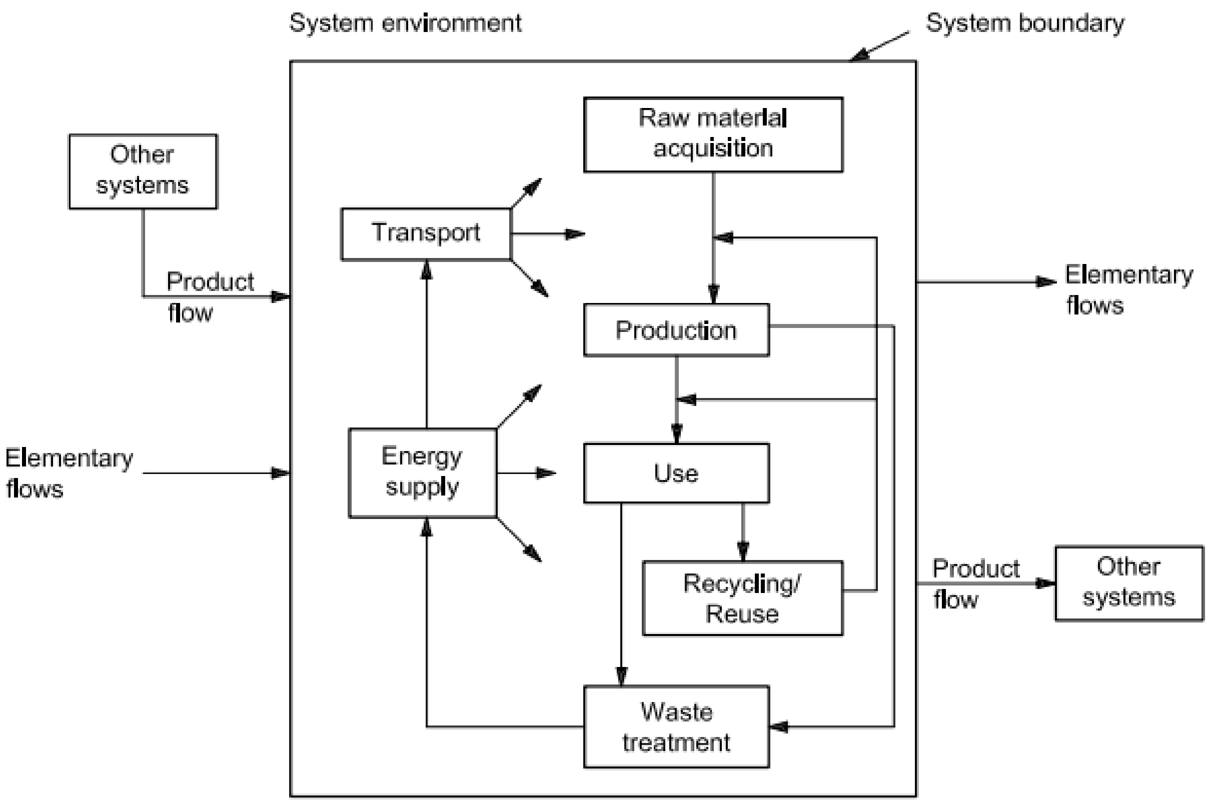


Figure 2: Example of a product system for Life Cycle Assessment
(ISO, 2006a)

When determining the boundaries, it is important to consider whether the production and disposal of capital goods should be included, and if so, to what extent. There are three orders to distinguish:

1. First order: Only the production of materials and transport are included (this is rarely used in LCA).

2. Second order: All processes during the life cycle are included but the capital goods are left out.

3. Third order: All processes including capital goods are included. Usually, the capital goods are only modelled in a first order mode. So, only the production of the materials needed to produce the capital goods are included (Rebitzer, 2004).

It is also important to determine the boundary with nature. In agricultural systems, it is necessary to decide whether agricultural areas are considered part of nature or a production system (technosphere). As example in an LCA on paper, the first task to decide if the growing of a tree is also included. If it is, one can include the CO_2 uptake and the land use effect. If this is seen as nature, all pesticides that are applied are to be seen as an emission. If agricultural areas are seen as an economic system, one can exclude the pesticides.

The functional unit is the basis that can provide a quantifying of input and output materials and a comparation of products or services. (Rebitzer, 2004). In the ISO standards it is defined as the following: “The functional unit shall be consistent with the goal and scope of the study. One of the primary purposes of a functional unit is to provide a reference to which the input and output data are normalized (in a mathematical sense). Therefore, the functional unit shall be clearly defined and measurable” (ISO, 2006b). Defining a functional unit can be quite difficult since it is not always obvious what function a product fulfils (PRé Consultants, 2016b).

A unit process represents one or more activities, such as production processes, transport, retail (Rebitzer, 2004). According to ISO standards a “unit process is the smallest element considered in the life cycle inventory analysis for which input and output data are quantified” (ISO, 2006a).

The goal and scope definition helps to ensure that LCA was performed consistently. The goal and scope can be adjusted at any time during the steps of the LCA, if the initial choices reveal themselves not to be optimal or practical. Any adjustments to the goal and scope should be described (PRé Consultants, 2016b).

Two categories of LCA goals exist: attributional LCA and consequential LCA. The attributional LCA describes a product system and its environmental exchanges. The second one describes how the environmental exchanges change after taking actions in the system.

ISO 14044 suggests setting a threshold for data collection on inputs or outputs in addition to system boundary criteria. One or more of the following criteria can be used:

1. If the inflow mass is below a certain percentage, but this approach only applies to materials and not transport distances or energy, and low mass flows may still have significant environmental impacts.

2. If the economic value of the inflow is below a certain percentage of the total value of the product system, but low-value flows may still have significant environmental impacts.

3. If the contribution of the inflow to the environmental load is below a certain percentage, but this approach has limitations as we cannot determine the environmental contribution until the flow is investigated.

Moreover, the term "the environmental load" is undefined, and using single environmental impact score results may not be allowed. Input-output data can be used to estimate the environmental load per unit of cost, which allows for estimating the environmental load of associated flows if the cost is known. This is an alternative to option 3's complex process of determining the contribution of a flow against all relevant data and impact categories.

The effect of using cut-off criteria can be analysed in the process tree or network window in SimaPro. In many LCAs, process trees become large. LCAs with over 2000 processes are quite common. These process trees contain many processes that have negligible contribution. This can be illustrated by setting the cut-off threshold for displaying processes in the process tree at 0.1 % of the environmental load (for a single score or an impact category). In most cases, only 10 to 30 processes turn out to have a contribution that is above this threshold.

Generally, two different types of data are required for developing an LCA study:

1. Data related to the impact assessment (e.g., characterization factors).
2. Inventory data (e.g., in- and outputs crossing the system boundaries).

The data quality requirements are mainly determined by the temporal and geographic validity as well as the description of the product system and shall be applied for primary and secondary data (Siegert, Finkbeiner, Emara, & Lehmann, 2019).

2.2.5 Life cycle inventory

Life Cycle Inventory is a crucial phase of LCA that deals with the quantification of inputs and outputs data of a system. It estimates the quantities of emissions, waste flows and consumption of resources. This part is found being the mostly cost- and time-consuming and complicated of the four steps of an LCA (Islam, Ponnambalam, & Lam, 2016).

There are 3 methods currently for an LCI:

1. Process based modelling
2. Input output (IO) LCI
3. Hybrid method

The methods are distinguished after factors like aims, scope and resources. Different studies adopt different methods and different methods provide different environmental impact results for the same product. Proper comparison between models can be made after accuracy and boundary completeness. Before choosing a method, it is highly recommended to know their methodology complexity, strengths, weaknesses, data and time requirements.

For pharmaceutical products usually the process-based modelling is the appropriate. It offers greater accuracy but lacks system boundary completeness. This method is performed via process flow diagram, or sometimes via matrix. Due to intensive data collection requirement, it is a time- and cost-consuming method what for rapid aims not suitable. However, ignoring some data can cause significant error. The process flow diagram shows the connection of processes in the system, and with plain algebra the amount of commodities for fulfilling a certain functional unit can be calculated. Multiplying it by the amount of environmental interventions during the production gives the result for an LCI.

The following conditions need to meet if the chosen method is process based LCI:

- each production process produces only one material or energy
- each waste treatment process receives only one type of waste

- the product system under study delivers inputs to, or receives outputs from another product system
- material or energy flows between processes do not have loop(s) (Suh & Huppes, 2003).

Therefore, it works well for simple product but in the reality under industrial circumstances processes have multiple input stream or generate multiple output streams, so allocation problem comes into consideration (Islam, Ponnambalam, & Lam, 2016).

As a solution for the complexity of the industrial production with more streams, the matrix method was introduced. Matrix method expresses the whole product system with vast range of linear equations and solves them simultaneously. The commodity flows for processes are arranged in a coefficient matrix (A) and the environmental flows in an environmental load matrix (B). In the A matrix inputs are expressed by negative coefficients and the outputs by positive ones. The boundary condition for the commodity flow is expressed by the vector α. The process vector (p) is derived from the equation:

$$A \cdot p = \alpha$$

which can be converted in

$$p = A^{-1} \cdot \alpha$$

where A^{-1} is the inverse matrix of A.

Each item in the vector p is the scaling factor corresponding to one unit process.

Respectively, the final environmental load vector (β) can also be obtained with the help of those equations in matrix B.

$$B \cdot p = \beta$$

$$\beta = B \cdot A^{-1} \cdot \alpha$$

A and B are called technology matrix and intervention matrix, and α, p, β are final demand vector, scaling vector and inventory vector respectively. The solution of the matrices gives the value of the LCI.

Nevertheless, whatever the allocation method followed, process-oriented modelling needs a lot of primary and axillary process data, which makes this method complicated.

2.2.6 Life cycle impact assessment

Life cycle impact assessment provides additional information to assess life cycle inventory results and helps to understand the environmental significance of natural resource use and environmental releases (Margni & Curran, 2012).

Because of the large quantity of data in the life cycle inventory about inputs and outputs, it is difficult to interpret, to decide what the environmental impacts of a system are by considering only the mass that is extracted or released. An amount of a pollutant has different effects under different circumstances.

LCIA is the phase of evaluation of potential human health and environmental impacts of resources and releases, collected in inventory. The aim is to determine the relative importance of each elementary flow. The absolute values of LCIA indicators do not predict absolute or precise environmental impacts because of the following reasons:

- The expression of potential environmental impacts to a reference unit is relative
- The integration of environmental data is over space and time
- In modelling environmental impacts there is an inherent uncertainty
- Some possible environmental impacts may occur in the future

The LCIA consists of several elements: classification, characterization, normalization, grouping, weighting, and Data Quality Analysis. The first two elements are mandatory (Lee & Inaba, 2004).

The first step is to select the impact categories in connection with the defined goal and scope of the study. These categories are linked to the potential impacts and effects to entities what are aimed to protect (Margni & Curran, 2012).

After classification a characterization takes place, which is the quantification of impact elements by each inventory parameter on the impact category. The result is expressed in an impact score within the impact category called characterization factor. For instance, greenhouse gases contribute the impact category Global warming, and the given quantity is kg of CO_2-equivalents. In this case, the characterization factor of CO_2 is 1 since the characterization factor for methane is more than 20. It means namely a higher contribution (European Commission , 2010).

Optional elements are normalization, grouping, weighting and Data Quality Analysis (Margni & Curran, 2012).

Normalization means a calculation of the magnitude of category indicator results relative to reference information.

Grouping is a sorting with the aim to reduce the number of impact categories. It ranks them in order of importance.

Weighting is converting and aggregating indicator results across the impact categories. Numerical factors are used that based on value-choices.

Data Quality Analysis develops a better understanding of the reliability of the indicator results.

2.2.7 Life cycle interpretation

The final phase of an LCA is the interpretation where the results of the other phases are considered and analysed. The first step is identification of potentially significant issues in the previous stages, and this significance is checked after completeness, sensitivity, and consistency for each of identified issues (Hauschild, Bonou, & Olsen, 2018).

The outcome of this phase is recommendations and conclusions concerning goal and scope definitions, the functional unit and system boundaries. The interpretation helps the users to understand the LCA, its robustness and potential weaknesses.

The three steps of interpretation process are:

1. Identification of the significant issues.
2. Evaluation of these issues. Firstly, evaluation of their influence on overall results, and also evaluation of completeness and consistency with which they were handled during the study.
3. Use of the results of evaluation in the formulation of conclusions and recommendations.

The evaluation part involves completeness check, sensitivity analysis in combination with uncertainty analysis and consistency check.

Completeness checks are performed to determine:

- the completeness of LCI unit process coverage and system modelling,
- completeness of intermediate and elementary flow coverage,
- approaches to identify and deal with missing or incomplete information and data,
- completeness check requirements for comparative assertions (Laurent, et al., 2020).

Aim is to determine the degree to which the available data is complete for the processes. If relevant information is missing or incomplete for the key elementary flows or impact categories, it is necessary to investigate those data to fulfil goal and scope requirements. Also inventory and impact assessment phases must be sometimes revisited. If an important data deficiency cannot be rectified, the limitations of the study should be adjusted. If the missing data do not have a high importance, it should be also documented. An example for completeness check is showed in Figure 3 (Hauschild, Bonou, & Olsen, 2018).

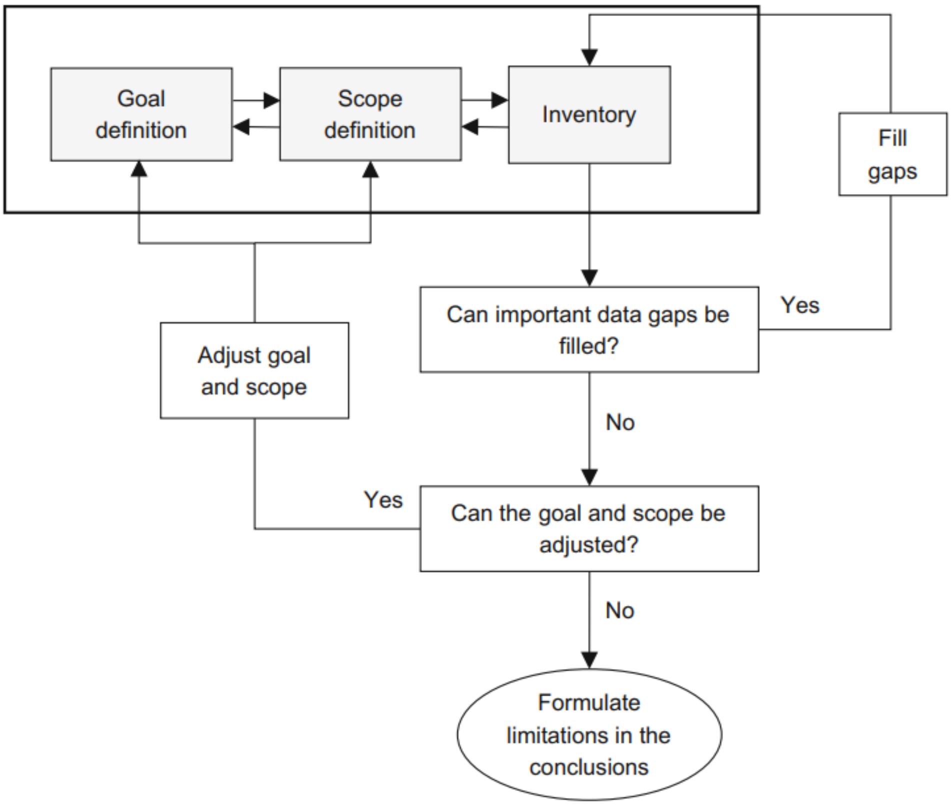


Figure 3: Iterative interaction between completeness check and the earlier phases of the LCA
(Hauschild, Bonou, & Olsen, 2018)

Sensitivity check is an identification of the key processes and most important elementary flows as those elements that contribute most to the overall impacts from the product system. It can be performed as a contribution analysis or a dominance analysis.

A contribution analysis shows which activities contribute to which environmental impact scores, by how much and through which elementary flows. Dominance analysis has the question which activities contribute most to which impacts or flows.

If the factor data uncertainty is checked for sensitivity, the tool is allowing the data to vary within the limits given by the uncertainty estimates while modelling the product system and checking the results. It is possible to calculate the uncertainty of the final results of inventory and environmental impacts. The method is usually Monte Carlo simulation.

When the factor is the methodological uncertainty, it is checked by analysing different possible choices. These can be handling of multifunctional processes (system expansion or allocation rules), cut-off criteria, boundary setting, system definition, judgement and assumptions concerning data in the inventory, for the impact assessment: selection of impact categories, assignment of classification, characterization, normalization, or weighting.

Combining the sensitivity analysis with uncertainty analysis, focus points can be identified for improved inventory or impact assessment data collection. That is represented in Figure 4.

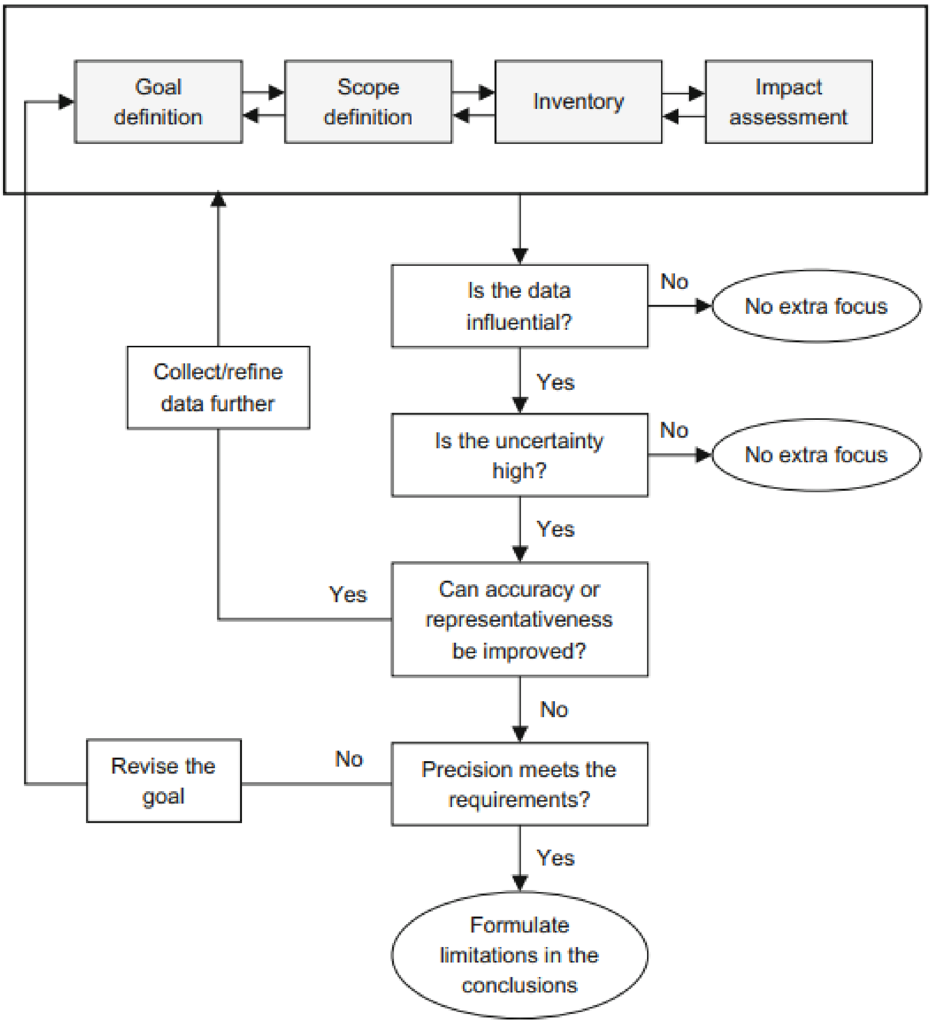


Figure 4: Focusing collection of improved data by combining sensitivity and uncertainty information
(Hauschild, Bonou, & Olsen, 2018)

The purpose of the consistency checks to see, whether the assumptions, methods, and data of the study are consistent with the goal and scope. The differences of the quality of inventory data during the product life cycle are examined. Inventory data quality concerns time-related, technological and geographical representativeness of the data, the appropriateness of the unit process, and the uncertainty of the data.

By inconsistencies their effects on the results are evaluated and are composed in the conclusions.

2.2.8 Sensitivity Analysis

As above mentioned, a sensitivity analysis is crucial to do in the most cases.

ISO defines sensitivity analyses as a „systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study" (ISO, 2006b).

There are various factors that can contribute to uncertainty in the results of a life cycle assessment study, including methodological choices, initial assumptions (such as allocation rules, system boundaries, and impact assessment methods), and the quality of the data used. In order to increase the accuracy and usefulness of the eco-profiles generated by the study, experts must assess the degree of uncertainty introduced by these factors. This evaluation is crucial for obtaining reliable, transparent, and representative LCA results, which can inform decision-makers when choosing between different product or process options (Cellura, Longo, & Mistretta, 2011).

The following types of uncertainty can be distinguished:

- Parameter uncertainty, due to imprecise, incomplete, outdated, or missing values of data needed in the inventory analysis or in the impact analysis.

- Models uncertainty, often due to the adoption of linear models to describe the relationships among environmental phenomena and of aggregate data regarding spatial and temporal features.

- Uncertainty due to unavoidable methodological choices in LCA, such as allocation methods, functional unit, system boundaries, cut-off rules, data collection methods.

- Spatial variability across location and temporal variability over a short and long-time scales in the Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) parameters.

- Variability between sources in LCI (e.g., variation in comparable technical processes) and between objects of the assessment in LCIA (e.g., human characteristics).

A parameter of which a change influences a result or contributes the variance of the output, is called a sensitive parameter. The sensitivity analysis helps to identify sensitive parameters (Groen, Heijungs, Bokkers, & de Boer, 2014).

Three types of sensitivity analyses can be distinguished: local sensitivity analysis, screening and variance-based sensitivity analysis or global sensitivity analysis. The input requirements and the type of output are different (Groen, Heijungs, Bokkers, & de Boer, 2014).

For local sensitivity analysis there are some methods like matrix perturbation (MP) or one-at-a-time approaches (OAT).

Matrix perturbation (MP) is a local sensitivity analysis method introduced in LCA by Heijungs and Suh in 2002. This approach estimates sensitivity using first-order partial derivatives, which are then transformed into relative multipliers. A higher multiplier indicates that a change in the input parameter will have a greater impact on the output. The method doesn't consider distribution functions or dispersion parameters, but instead focuses on how small perturbations in input parameters can affect the results. One limitation of the approach is that it only applies to small changes around the original parameter values and doesn't take into account the certainty of each input parameter's range.

The one-at-a-time (AOT) approach involve selecting a subset of input parameters and adjusting them individually, either within their predetermined ranges or by using arbitrary values, to gauge their impact on the output. Although this approach is simple to execute and comprehend, it can be a time-consuming process when dealing with complex systems. Additionally, this technique may not consistently consider all relevant parameters and could potentially overlook parameters that are sensitive and have a significant impact on the output.

The method of elementary effect (MEE) belongs to type of screening analysis.

It is a screening approach designed by Morris in 1991 and modified by Campolongo et al. in 2007. MEE considers the range of each input parameter and can be seen as an extension of the one-at-a-time approach. It involves evaluating various combinations of parameter values at predetermined proportional steps within their ranges and calculating the resulting difference from the original model, known as the elementary effect. The standard deviation of the elementary effect can be calculated to assess interaction and non-linear effects. MEE is a useful preliminary step for computationally intensive sampling methods like regression. However, it doesn't provide an accurate estimation of the actual variance decomposition and is thus one of its limitations.

Global sensitivity analyses are standardized regression coefficients (SRC), key issue analysis (KIA), random balance design (RBD), Sobol' indices (SME and STE).

Standardized regression coefficients (SRC) estimate the contribution of each input parameter to output variance through the slope of the least square line. To calculate SRC, pseudo-random samples are drawn from all input parameters, and the output is determined for each run. Next, the regression coefficient is calculated for each input parameter, and the coefficients are standardized based on their standard deviation. Although SRC is widely used both within and beyond LCA, a drawback of this method is the need for many runs to compute the variance decomposition.

Key issue analysis (KIA) was initially proposed as a method for determining variance contribution through a first-order Taylor expansion, but it has been since applied in LCA. This approach combines the steepness of a function with the individual parameter variances to calculate the variance decomposition up to first order. Since the covariance between input parameters is typically unknown, KIA only utilizes the variances of individual parameters. However, it has a drawback of not producing an output distribution function, which makes comparing multiple studies more challenging.

The concept of random balance designs (RBD) was initially developed by Cukier et al. (1978) and later adapted by Tarantola et al. (2006). Although a closely related method, Fourier amplitude sensitivity test, has been applied in LCA, RBD itself has not yet been used in LCA. RBD estimates the contribution to variance by employing Fourier transformations and periodic sampling. For each input parameter, the Fourier spectrum is computed, which serves as an estimate for the first order sensitivity index. However, a disadvantage of RBD is that it only allows for the calculation of main effects.

The Sobol' method, introduced by Sobol' (2001), provides a sensitivity measure for each input parameter by determining the proportion of output variance that can be attributed to each input parameter. The approach involves decomposing a model into increasing order terms, where the first order terms are the Sobol' main effects (SME) that represent the contribution of each input parameter to the output variance. This method also allows the computation of interaction effects (variance caused by simultaneously varying two or more parameters) and the total effect index. The Sobol' total effect index (STE) indicates the variance resulting from the sum of the main and interaction effects of an input parameter. A drawback of the Sobol' method is that it is computationally expensive, as numerous runs are necessary to compute the indices.

2.2.9 Use of LCA

LCA is a sustainable decision support tool for product/process improvement of a company. The development can be on design, manufacturing, use phase, or end-of-life phase of a product (Farjana, 2021).

The two most important application of an LCA are to prioritize improvements on products and processes, and to compare products for internal use. The utilization of LCA method can help in looking for life cycles with minimal negative impact on the environment, in decision-making in relation to strategic planning, product design and process change, in choosing important indicators of environmental behaviour, and in marketing (Muralikrishna, 2017). Moreover, it can help to reduce the costs of production and to generate public policy thorough sustainable development goals.

The use of environmental information from LCA can assist in decision-making, it supports capital investment in green design and waste management, green procurement or operational management, financial management through cutting carbon taxes, cleaner technology development, ecolabelling for marketing-verified certification (Farjana, 2021).

2.3 LCA in pharmaceutical industry

2.3.1 Pharmaceutical process

Pharmaceutical processes usually consist of two main processing stages: primary and secondary. The first is the active pharmaceutical ingredient (API) production and the second is the final drug formulation (Mata, et al., 2012).

The primary process is divided in two steps: upstream processing, where the API is produced and downstream processing, where the API is separated and purified.

By the secondary process the following steps should be taken:

1. Addition of various excipients to stabilize the final product performance, vial filling and closing.
2. Freeze-drying of the product.
3. Final product manufacture and quality control.

The primary and secondary processing use a few operations as heat sterilization, water treatment and supply, residues collection and management, and energy and heat generation. These processes serve certain purposes. The water treatment has the goal to recycle the water used in manufacturing and to provide fresh water for the process. Heat and steam sterilization is responsible for processing the solid and liquid wastes to gain them back inert and biological contamination-free. Energy and heat generation as well as cooling are based on tri-generation process, the most complex auxiliary processes.

Many pharmaceutical compounds pass through the human or animal body, so they often land in the environment and can cause harmful effects. Also, the production of these compounds needs to be analysed from environmentally aspects. With the help of LCA not only the effect of the production but also of end-of-life or distribution parts can be seen and influenced with process-optimizing (Wernet, Conradt, Isenring, Jimenez-Gonzalez, & Hungerbühler, 2010).

2.3.2 LCA in multi-process and multi-product systems

When a specific process produces more than one product of commercial value, the waste treatment option, raw material requirements, energy consumption, and emissions need to be allocated (Jimenez-Gonzalez, 2022).

In a system with multiple products and processes, allocation in a Life Cycle Assessment can be a challenging task. The allocation process aims to divide the environmental impacts of the system between the co-products or subsystems.

There are two main types of modelling ways for dealing with this in LCA: consequential modelling and attributional modelling.

The type of modelling depends on the goal and scope of the project. Consequential modelling is applied when the aim is to investigate the consequences of a change compared to a baseline situation. Multifunctional processes can make consequential modelling complex and data demanding. Additionally, identifying which co-products and functions avoid certain products can be challenging.

Attributional modelling is effective in knowing the environmental impact of a product or a function and the hotspots in the life cycle or comparing the impacts of two products with the same functional unit. In the case of multifunctional processes, the environmental load of the inputs and outputs is divided among the co-products and functions. The options for doing this are the following:

1. Subdivide the multifunctional process: Subdividing a process involves identifying inputs and outputs per sub-process, but this can be data-intensive, and sometimes data is unavailable when inputs and outputs can't be measured separately. For instance, electricity and heat use may not be tracked for each production line in a factory. Similarly, when a raw material generates multiple co-products, subdivision isn't always feasible, and allocation becomes necessary.

2. Determine a physical causality for allocation: It shows how quantitative changes in a process's products or functions affect other inputs and outputs, such as mass, volume, energy, exergy, chemical composition, or proteins. However, if volume is the limiting factor, allocation based on volume may be more appropriate. In cases of combined heat and power, energy or exergy may be more suitable criteria for allocation.

3. Use the economic revenue as the key for allocation: Revenue is a common criterion for allocation when a physical relationship can't be established or when there is no common physical characteristic between co-products or functions. For instance, if one co-product is related to its energy content while another is related to its mass, revenue can be a suitable allocation criterion. Similarly, when co-products or functions aren't produced by alternative single-output processes, revenue can be used for allocation.

Although ISO mentions economic allocation as the last option, it is often used in practice. The strength of economic allocation is that economic value is a good way to distinguish waste from an output. Additionally, it expresses the relative importance of an output.

The ISO standards are defined in a rather vague language, which makes it difficult to assess whether an LCA has been made according to the standard. Unlike the 14000 standards, it is not possible to get an official accreditation stating that an LCA, LCA methodology, or LCA software has been made according to the ISO standard. Therefore, no software developer can claim that LCAs made with a certain software tool automatically conform to the ISO standards. It is true for allocation rules as well as system boundaries or weighting across impact categories. The user has the responsibility to use them properly according to ISO (PRé Consultants, 2016b).

2.3.3 Previous life cycle assessments in pharmaceutical industry

In this chapter three previous life cycle assessments are compared that were carried out in the pharmaceutical industry. This first medicament is a result of a catalytic synthesis, the second one is an enzyme-produced pharmaceutical product, and third one is a plasma-derived drug. Table 1 shows the summary of the three assessments.

Finding an article which is similar to this work was difficult, this study is not a typical LCA application, in the literature there was found only one another article (Kedrion) with this type of pharmaceutical product. The data collection from the company, the multi-purpose plant, the special product system makes it different from other works. Articles that analyse allocation is hardly detectable in the present literature, and these few are not about the pharmaceutical industry. That is why the following articles are not appropriate for comparing the results with the results of this work, but it gives some information about other LCAs in pharmaceutical industries.

The first one is a cradle-to-grave life cycle assessment of an ibuprofen analgesic from 2020. The authors proposed to identify environmental hotspots during the life cycle of the analgesic fiu® Extra. The production takes place as a multistep manufacturing process by BASF in the US, the API is transported to Germany, where the formulation and packaging is performed. In the distribution part the product is shipped in German pharmacies and the patients use it as self-treatment at home. Transportation and disposal of unsold pharmaceuticals are also included, but storage during the distribution and use stage are excluded (Siegert, et al., 2020).

Primary data was available for the API production, the formulation, and the packaging. Not available data were obtained from patents and other sources and upscaled to an industrial scale.

As a result, production and distribution stages have the highest effect on environment. The use and end-of-life stages do not contribute to the overall results. The hotspots depend on the impact category. Sensitivity analysis was calculated for the production of catalyst (impact category: abiotic depletion (elements) and the production of leaflet (impact category: ecotoxicity).

The second life cycle assessment is a summary of three studied enzymes to determine the suitability for pharmaceutical production. Since it is a cradle-to-gate analysis, the production and purification of the enzymes, energy generation, raw material production, and transportation of the raw materials were included. Enzyme production information was obtained from internal process descriptions. LCI information was obtained from GlaxoSmithKline´s inhouse LCA database FLASC™, from LCA commercial databases and literature. Mass allocation was applied to multi-output processes in the upstream processes (Kim, Jiménez-González, & Dale, 2009).

The involved processes are the following: media preparation includes the upstream processes for substrate production (including transportation) and energy consumption in substrate mixing, fermentation includes energy consumption and heating, steam consumption in sanitization, separation includes water and energy consumption, cell disruption and immobilization includes energy consumption and chemicals, waste management includes a wastewater treatment facility.

The conclusions that from this life cycle assessment were obtained that the production of immobilized enzymes is energy-intensive, and immobilization and media preparation processes have the highest effect on the environment (acidification, eutrophication, and photochemical smog formation).

The third company is Kedrion in Italy and produce plasma-derived medicine for patients suffering from Hemophilia, Immunodeficiencies and other serious illnesses. A cradle-to-grave analysis involve processes from raw material production to waste treatment of the product. Some processes are not included such as the production of plasma from human blood in transfusions centres and its transport to reception centres, transport to the end user and the use of the product.

The result of the LCA is, that the energy use is the most relevant aspect in terms of environmental impact management. The production of waste and the use of chemical products determine also relevant effects.

Table 1: The summary of three life cycle assessments in the pharmaceutical industry

	Ibuprofen analgesic (Eudorlin® Extra)	**Enzymes (GSK)**	**Albumin (Kedrion)**
Type	Cradle-to-grave	Cradle-to-gate	Cradle-to-grave
Functional unit	The treatment of an adult in Germany with the purpose of pain relief for 4 days	1 kg of immobilized enzyme	A single dose kit of Albumin
Reference flow	One package Eudorlin® Extra (10 tablets with 400 mg ibuprofen per tablet)	-	-
Data	Primary data from the manufacturing company, as well as commercial databases and literature	Primary data from the manufacturing company, as well as commercial databases and literature	Primary data from the manufacturing company, secondary data from Ecoinvent database v.3.4
Product system	From resource extraction to the final disposal of the product	Immobilized enzyme production	Production and transport of raw materials to production and transport of materials for the final product packaging, distribution and end-of -life treatment
Sensitivity analysis	Yes	Monte Carlo simulation	-
Impact categories	• Abiotic depletion (ADP elements and fossil) • Global Warming (GWP) • Ecotoxicity • Human toxicity (cancer and non-cancer)	• Nonrenewable energy consumption • Global warming • Acidification • Eutrophication • Photochemical smog formation	• Global Warming Potential • Acidification potential • Eutrophication Potential • Photochemical Formation Oxidation Potential

2.4 Greenhouse gas emissions

Scope 1 emissions evolve directly from company production facilities. This includes emissions from fuel combustion in boilers, vehicles, and other equipment.

In contrast Scope 2 & 3 emissions are indirect, Scope 2 comes from purchased energies (electricity, steam, heat, or cooling) and Scope 3 includes all emissions from purchased materials and services and on the other hand, from processing, use, and waste treatment of sold products. Scope 2 is often the largest source of emissions for organizations that use a significant amount of energy from the grid. (Kircher, 2021). Figure 5 shows the connection between emissions and process parts.

When measuring and reporting on emissions, it is important to consider all three scopes in order to have a comprehensive understanding of an organization's carbon footprint. Additionally, some organizations may also consider other scopes, such as Scope 4, which includes emissions from the production of inputs used in the production of goods and services.

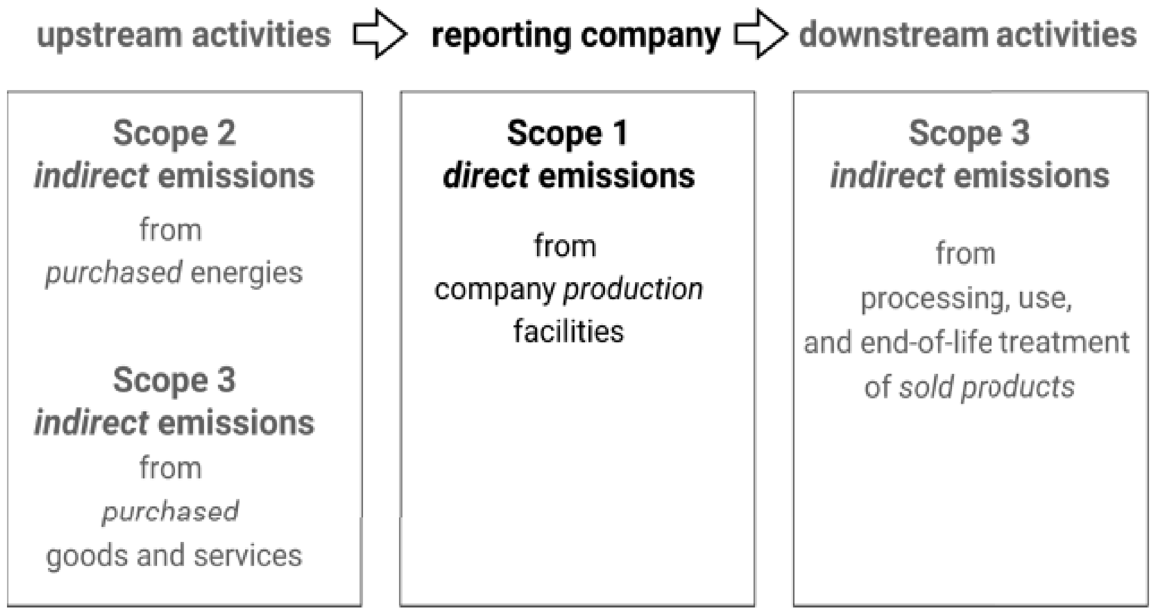


Figure 5: Scope 1, 2 & 3 emissions
(Kircher, 2021)

Direct emissions (through the combustion of fossil fuels) are those that occur at an establishment. Indirect emissions occur in the supply chain of the establishment in question, covering all steps in the production of the goods and services delivered to the establishment (Hertwich & Wood, 2018).

In national and international climate policy making, there is no consistent practice of taking scope 2 or 3 emissions into account, despite the appreciation of the importance of treating emissions embodied in trade.

In the accounting for carbon emissions, it is common to distinguish between production-based and consumption-based emissions inventories. Production-based inventories allocate emissions to the countries where the emissions occur or, in the case of emissions in international waters and airspace, to the country where the owner of the vessel resides. Consumption-based inventories allocate emissions occurring in the production of goods to the countries where the final consumer of the goods resides (Hertwich & Wood, 2018).

3 Results

In this chapter the goal & scope, life cycle inventory, life cycle impact assessment and sensitivity analysis are represented.

The goal & scope part contains the product description, describes the system boundaries, the examined data sources, explains the allocation process, and the chosen impact categories.

The inventory part describes the upstream, core and downstream processes with details, depicts the product systems, collects the inputs and outputs of a process step, and shows diagrams of mass balance.

In the impact assessment part, the results of the software Sima Pro for the chosen impact categories are collected and represented. Some consequences and explanation are mentioned under the tables and diagrams, the detailed discussion is to find in the next chapter.

A sensitivity analysis was carried out with a few scenarios for the highest greenhouse gas emission.

3.1 Goal & Scope

This thesis based on research by a biopharmaceutical company in Vienna that collects and fractionates blood plasma to produce and distribute plasma-derived therapies for use in treating patients suffering from serious and rare illnesses.

The aim was to carry out an attributional life cycle assessment of a specific product and to find the environmental hotspots, especially regarding to the greenhouse gas emissions. Hotspot means the highest environmental impact (regarding to in this work studied environmental impacts) on the process level.

The product is a concentrated solution containing the essential protein for blood coagulation. It is a human plasma-derived product for intravenous injection, lyophilized after viral inactivation. It is used in treatment of hemophilic patients with developed antibody against factor VIII (inhibitors), both in an on-demand as well as prophylactic treatment.

The product is provided in four types with different volumes and specific activity contents/units: 500 IU/10ml, 1000 IU/20ml, 2500 IU/50ml and 500 IU/20ml. For intravenous injection, this is combined with a bottle of solvent containing water for injection. (IU: international unit for activity.)

The functional unit is one vial of the product. For different volumes and activities there are four different results represented.

3.1.1 System boundaries

Production: The product is batch-wise produced in a multistep manufacturing process in Vienna. The formulation and packaging also take place there. In Vienna there are three factories where the production runs.

Distribution: The plasma comes from the plasma collection centres in USA. The distribution centre is in Kentucky. The blood plasma extraction is also included.

After manufacturing in Vienna, the product is shipped to hospitals in the USA. Transportation processes during the distribution phase (e.g., transport of the plasma from the USA to Vienna, transportations of the product from Vienna to the distribution centre in Kentucky, US) as well as the transportation of intermediates between the factories in Vienna are included in this scenario, whereas storage activities during the distribution and use stage are generally excluded.

Use: The product is applied intravenously, the packaging (primary and secondary) is disposed of as municipal waste. In the human body, the product undergoes different pharmacokinetic processes. This stage is excluded in this study.

End-of-Life: After the drug elimination process, the product and its metabolites enter the natural environment from the human body as elementary flows without any further technical treatment, also an excluded stage.

Details on the life cycle of the product are described in Chapter 3.3. The overall product system is illustrated in Figure 6. Here, material and energy that has not yet been transformed by human activities enter the product system (from ecosphere to technosphere) as elementary flows. Similarly, material and energy leave the product system as elementary flow without further treatment, e.g., emissions to air, water or soil.

The foreground system is the production, and the background are the upstream and downstream processes. The net production time for the foreground system is 15 days.

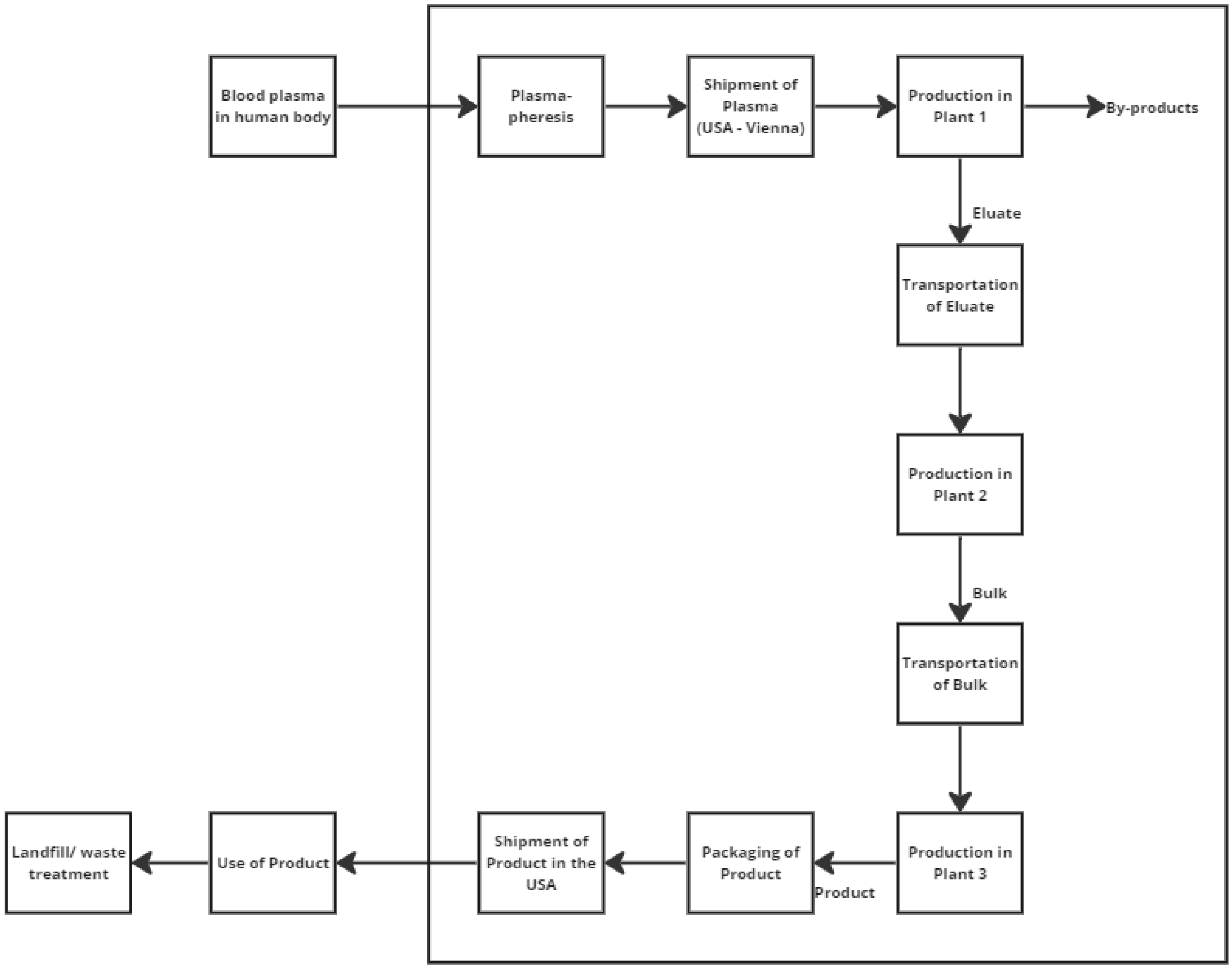


Figure 6: Flowchart of the production of a plasma-derived product from the plasmapheresis to waste treatment

3.1.2 Allocation

Because of the complexity of a multi-product and -process production, the decision-making for the type of allocation needed more time and discussion. Figure 7 shows a depiction about the allocation percentages in the different process steps.

The allocation was figured out on the first factory level. The starting material is the blood plasma, from that 7 different products are manufactured. After centrifugation both liquid and solid part are used for the next steps. The final intermediate in this plant for the studied product is the eluate, from that the product is finished in the next two factories. The processes of by-products weren't examined in this work.

The allocation was taken considering the protein amount of products. It is a physical allocation after mass, but the company divides profit after protein, that means, in this case the physical and economical allocations coincide.

If the allocation factor is product mass ratio, it means, if a given process produces 25 kg of product A and 75 kg of product B, then the emissions, raw materials, energy, etc., will be distributed in a proportion of 25% for product A and 75% for product B (Jimenez-Gonzalez, 2022).

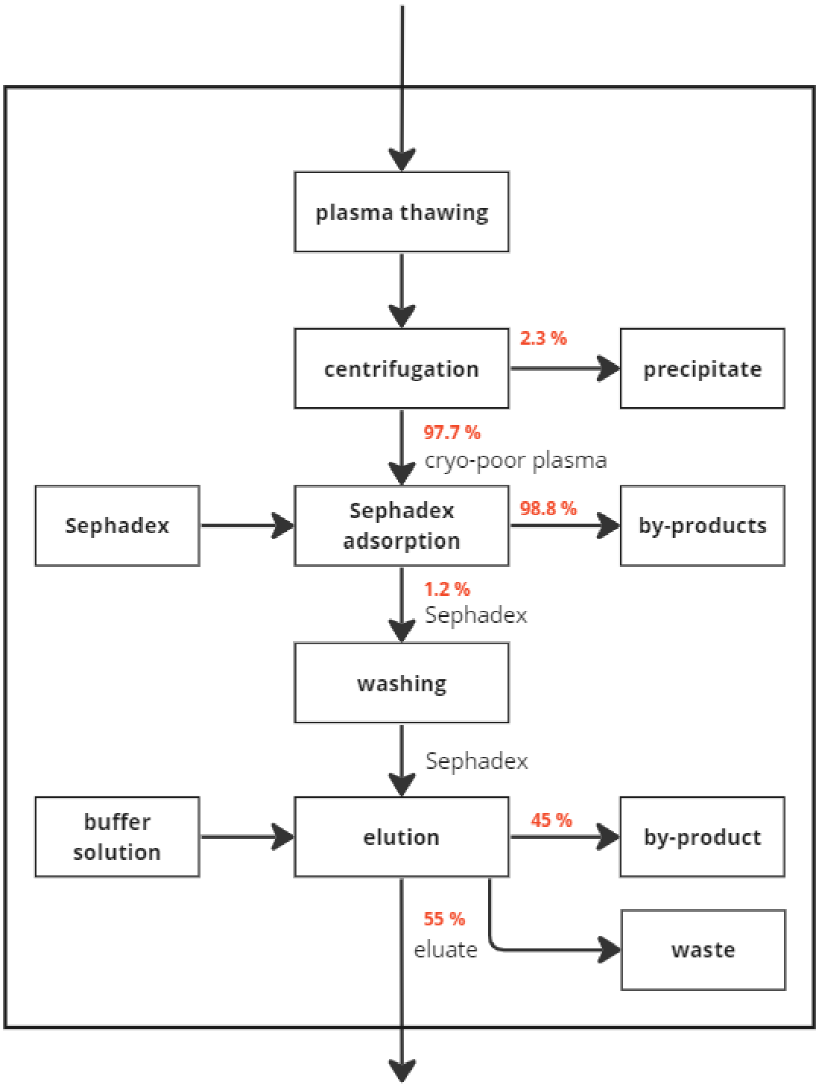


Figure 7: Allocation in the production after protein amount with percentages

3.1.3 Data sources

This work was installed on the level of Master Batch Records of the company.

The analysis can be done more detailed, but the first aim was to give a clear and comprehensive view about the production and the life cycle of a product in a structured framework. The Master Batch Records show the right way of the production that must be kept in all circumstances. However, the most data come from the real production values, sometimes the only possibility was taking the prescribed instruction data due to the lack of measuring instrument or the complex data collection.

Secondary data were used from the Ecoinvent databases because materials and processes of the production of an auxiliary material (e.g., filter or hose) or other equipment are unknown, since they are purchased from other manufacturer.

The use of water, material and the energy-requirement, the quantity and quality of waste and waste treatment were collected and represented. The greenhouse gas emissions are arranged in Scope 1, 2 and 3 emissions. Figure 8 shows the source of data for the Scope 1, 2 and 3 emissions.

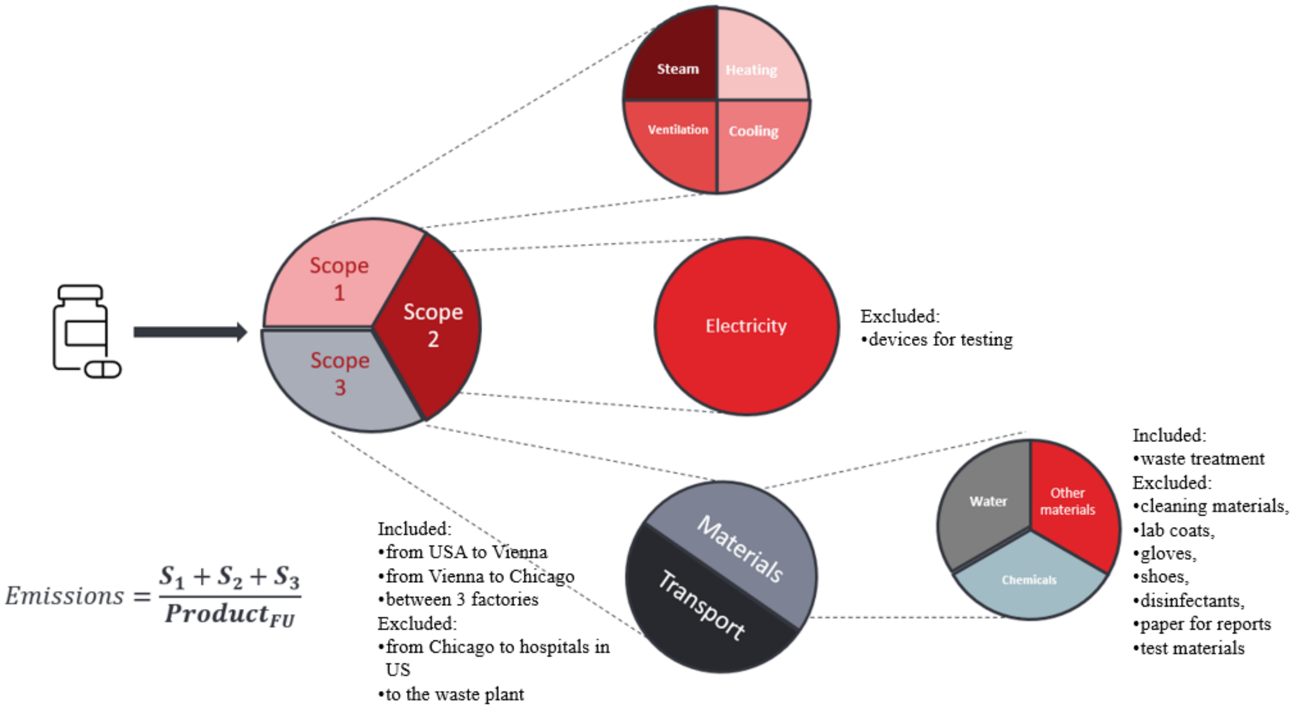


Figure 8: Scope 1, 2 and 3 emissions and their sources

To the Scope 1 belongs all energies used in company production facilities such as steam, heating, cooling, and air ventilation system. The transport of materials between the devices occurs with compressed air. Steam is used for cleaning of devices. In the clean rooms a proper ventilation with defined temperature is needed. Collected plasma is frozen and also some steps of production need cooling.

Electricity belongs to Scope 2 emissions since it is purchased from wind turbines abroad.

The scope 3 emissions come from all the used materials and transportation.

The materials are divided to 3 parts: chemicals, water and other materials. Chemicals get directly into the product. The term other materials mean filters and hoses and materials that are used by production stages but do not part directly the product. Cleaning materials, lab coats, gloves, shoes, disinfectants, or paper for reports are not included in this research.

The starting material comes from the USA, firstly the plasma was collected from the plasma centres by refrigerated truck and it was shipped over the sea by a ship, from Hamburg to Vienna then again by refrigerated truck. The use waste treatment of packaging materials is considered and in the upstream and downstream processes are in the calculation.

As a product it flew by airplane to Chicago. The last station of this research is Chicago where the distribution of product takes place. The way to the hospitals in America is not included, as well as the usage and the waste treatment. The plasmapheresis stage in the USA is included.

Waste from the production process that include contaminated materials (all the materials kept in touch with organic substances), were addressed to incineration. Non-contaminated paper and cardboard were considered 100% recycled. Plastic materials also include contamination from the product or semiproduct, therefore they were also incinerated.

Transport of waste to the waste plant was not considered because of time demand and complexity. Transport of other materials (e.g., empty vials for the product from other manufacturer to the plants) were also not considered. The study includes the transportation between the three factories. Transport of final products from points of distribution centre to the final user is not included.

Test materials and devices for intermediate and release testing are also out of scope.

3.1.4 Impact Categories

Two methods are available for deriving characterization factors: at the midpoint and endpoint level. Characterization factors at the midpoint level are located along the cause-impact pathway, usually at the point after, which the environmental mechanism is identical for each environmental flow. Characterization factor at endpoint level correspond to a damaging approach triggered by midpoint categories. The midpoint characterization has a stronger relation to the environmental flows and have lower parameter uncertainty, by the endpoint characterization is easier to interpret the relevance of environmental flows. Therefore, the two methods are complementary (Huijbregts, et al., 2017).

In this study the midpoint method ReCiPe 2016 Midpoint (H) V1.05 / World (2010) H was selected because it is the most up-to-date and comprehensive method to the author´s state of knowledge, and because of the above-mentioned advantages such as lower uncertainty and strong relation the the environmental flows. Table 2 shows the 18 ReCiPe impact categories and their mid-level indicators.

Table 2: Overview of the midpoint impact categories and related indicators (Huijbregts, et al., 2017)

Midpoint impact category	Indicator	CFm (midpoint characterization factor)	Unit
Climate change	Infrared radiative forcing increase	Global warming potential (GWP)	kg CO_2-eq. to air
Ozone depletion	Stratospheric ozone decrease	Ozone depletion potential (ODP)	kg CFC-11-eq. to air
Ionising radiation	Absorbed dose increase	Ionising radiation potential (IRP)	kBq Co-60-eq. to air
Fine particulate matter formation	PM2.5 population intake increase	Particulate matter formation potential (PMFP)	kg PM2.5-eq. to air
Photochemical oxidant formation: terrestrial ecosystems	Tropospheric ozone increase	Photochemical oxidant formation potential: ecosystems (EOFP)	kg NO_x-eq. to air
Photochemical oxidant formation: human health	Tropospheric ozone population intake increase	Photochemical oxidant formation potential: humans (HOFP)	kg NO_x-eq. to air
Terrestrial acidification	Proton increase in natural soils	Terrestrial acidification potential (TAP)	kg SO_2-eq. to air
Freshwater eutrophication	Phosphorus increase in freshwater	Freshwater eutrophication potential (FEP)	kg P-eq. to freshwater
Human toxicity: cancer	Risk increase of cancer disease incidence	Human toxicity potential (HTPc)	kg 1,4-DCB-eq. to urban air
Human toxicity: non-cancer	Risk increase of non-cancer disease incidence	Human toxicity potential (HTPnc)	kg 1,4-DCB-eq. to urban air
Terrestrial ecotoxicity	Hazard-weighted increase in natural soils	Terrestrial ecotoxicity potential (TETP)	kg 1,4-DCB-eq. to industrial soil
Freshwater ecotoxicity	Hazard-weighted increase in freshwaters	Freshwater ecotoxicity potential (FETP)	kg 1,4-DCB-eq. to freshwater

Marine ecotoxicity	Hazard-weighted increase in marine water	Marine ecotoxicity potential (METP)	kg 1,4-DCB-eq. to marine water
Land use	Occupation and time-integrated land transformation	Agricultural land occupation potential (LOP)	$m^2 \times$ yr annual cropland-eq.
Water use	Increase of water consumed	Water consumption potential (WCP)	m^3 water-eq. consumed
Mineral resource scarcity	Increase of ore extracted	Surplus ore potential (SOP)	kg Cu-eq.
Fossil resource scarcity	Upper heating value	Fossil fuel potential (FFP)	kg oil-eq.

The American Chemical Society Green Chemistry Institute (ACS-GCI) set forth nine impact categories that are the most relevant for a pharmaceutical product. Table 3 lists these categories. This list was determined in consultation with experts from academia, politics and the pharmaceutical industry, they chose eight categories, and the top five used impact categories for the most pharma-LCAs (Emara, Siegert, Lehmann, & Finkbeiner, 2018).

Table 3: Recommended impact categories for pharma-LCA (Emara, Siegert, Lehmann, & Finkbeiner, 2018)

ACS-GCI	Choice of experts	Top five in pharma-LCAs
Climate change	Climate change	Climate change
Acidification	Acidification	Human toxicity, cancer effects
Eutrophication	Eutrophication	Human toxicity, non-cancer effects
Net life cycle mass of materials used	Ozone depletion	Eutrophication, aquatic
Life cycle water usage, exclusive of process water	Cumulative energy demand	Ecotoxicity, freshwater
Cumulative energy demand	-	Ecotoxicity marine and terrestrial

Oil and natural gas depletion for materials manufacture	-	Resource depletion (fossil, mineral and renewables)
Photochemical ozone creation	-	Resource depletion, water
Total organic carbon load before waste treatment	-	-

For the company the most important categories are the climate change and water depletion, besides that freshwater eutrophication and freshwater ecotoxicity were selected. Because of the huge amount of water consumption eutrophication can also be important to see, and the protein waste can have effects on the ecotoxicity.

Because of the absence of any human material such as blood, plasma, or protein in the Ecoinvent databases, the blood plasma was as tap water selected.

By the water consumption category, it caused some understandability problems therefore the emissions of tap water were subtracted from the total environmental effects. Without this action the system acts like water would be produced during the production, and water consumption is a negative value.

3.2 Life cycle inventory

3.2.1 Upstream process

It consists of the processes from cradle to gate, these includes the plasmapheresis and the transport of plasma from the USA, the production of plasma in the human body is not included.

The data for plasmapheresis is from the USA. The used materials, energy and heat consumption, waste treatment data were collected per donation.

After collection of plasma in the centres, the transportation occurs by ship with refrigerated containers over the sea, and by refrigerated truck on the road. 1 kg plasma travel average 4480 km from the plasma centres to the collection centre and from the collection centre to the port further 980 km. The following 7660 km occur by ship and from the port to the first Viennese factory comes 915 km. For this step, secondary data were used since there is no information about the exact parameters of truck and ship, only about the shipped way length. Figure 9 shows the way of the plasma from the human body to the first factory in Vienna for production. The storage steps and thereby the cooling in the storage rooms in the USA and also in Vienna are out of scope.

The waste of the for plasmapheresis used materials are treated in the USA, the shipped packaging materials are disposed in Vienna. Hazardous waste is incinerated, there are some recycled materials such as corrugated bord box or paper, and the inert waste must be final disposed.

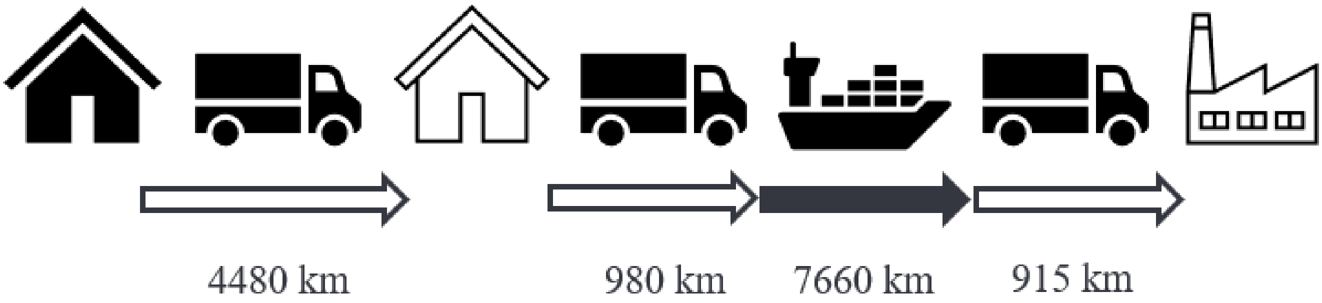


Figure 9: Transportation from plasma centres to Viennese factory

3.2.2 Core process

First factory

The product is manufactured in 3 factories in Vienna. In the first one the thawing, centrifugation, Sephadex adsorption, washing, and elution steps are taken. Figure 10 shows the life cycle of the product in the first factory with mass flow. In the Table 4 all used energies and materials are listed as input and waste or product as output. The net production time in this factory is 2 days.

The data collection in the production part was time-demanding because of the complexity of the production and the great number of coproducts. Some factors needed particular attention, such as:

- the duration of the life cycle assessment is 1 year, but the production is continuous, so it was difficult to distinguish the stages between years
- a proportion of intermediates is at a different site; it should be also distinguished
- the distribution of the product, because the plasma comes from the US but is sold also in other countries
- missing sensors to measure energies or material flows (e.g current)
- the proper allocation

The materials are booked in an internal system for each product separately. After defining the batches in the studied year, multiplying with the number of productions the amount of used materials is given.

The room conditions like heating, cooling, ventilation was taken in account as the company`s own energy aspect: the needed energy for ventilation is defined from the heating and cooling. The heating consists of steam generation and gas combustion, the cooling comes from cold water and cooling sole.

The electricity was measured during the project with datalogger, but some smaller devices with less consumption are neglected.

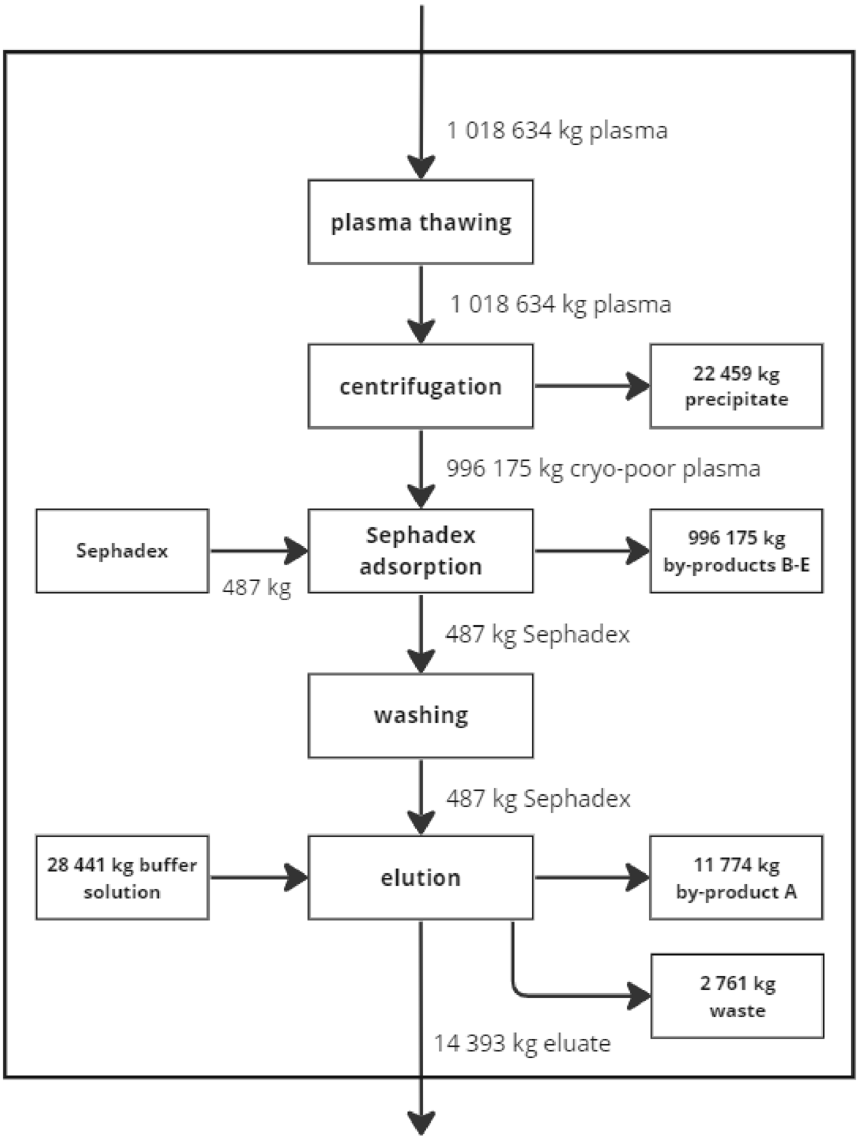


Figure 10: Flow chart of the production in the first factory with mass flow

After arriving of the plasma in a frozen state, the first step is the thawing. In the centrifugation step the solid and liquid part are separated, the solid part is called precipitate. Sephadex is a crossed-link dextran gel used for gel filtration. It helps to filter the proper protein. In the mass flow after adsorption the mass of dry Sephadex is added, because of the complexity of measuring this mass. In the reality this Sephadex gel contains the protein and some residue of cryo-poor plasma. By washing the impurities are removed and with the elution solution there is the first intermediate done. In the end the Sephadex and the surplus buffer solution go to waste.

Table 4: Inputs and outputs in the first factory

Process step	Input	Output
Thawing	Plasma	Packaging
	Ventilation	PE-bag
	Electricity	
	PE-bag	
Centrifugation	Foil	Foil
	Electricity	Precipitate
	Ventilation	
Sephadex Adsorption	Sephadex	Product B
	Electricity	Product C
	Ventilation	Product D
		Product E
Washing	Washing solution	Washing solution
	Filter	Filter
	Electricity	
	Ventilation	
Elution	Elution solution	Product A
	PE-bucket + cover	Sephadex
	Electricity	
	Ventilation	

Diagram 1 shows the weight of the used materials in the first factory applied to 1 l plasma. By step washing and elution the water is outstanding, because of the solution volumes. The washing solution is used to clean the product from other proteins. The solution for elution will build into the product.

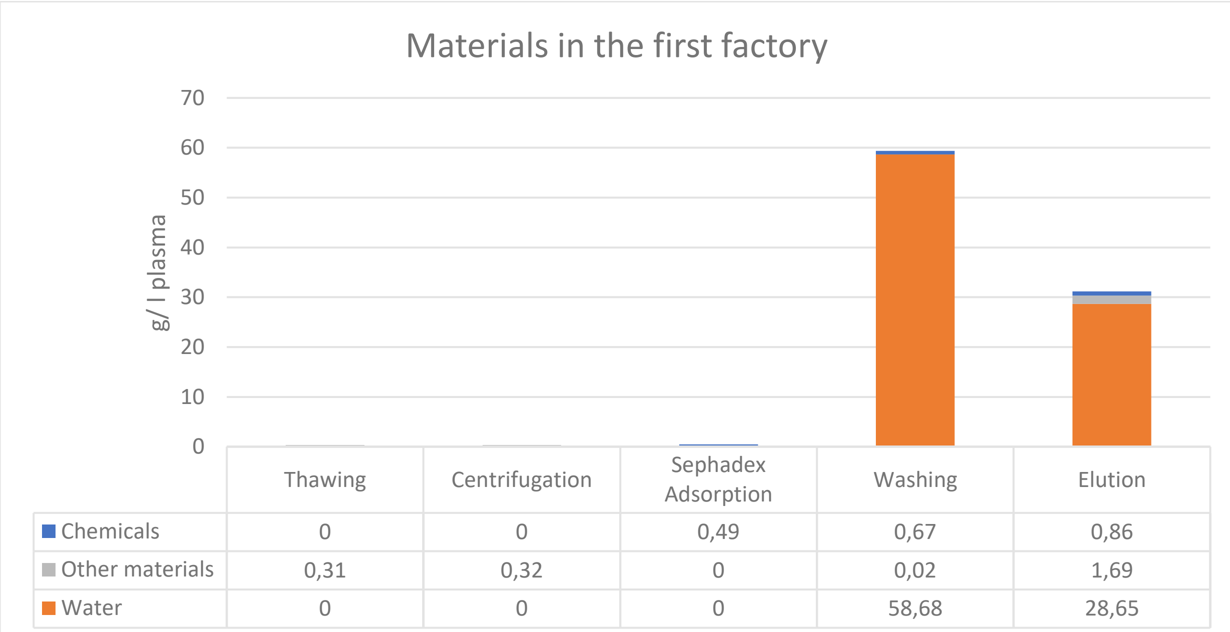


Diagram 1: Mass of used chemicals, other materials and water applied to 1 l plasma in the first factory

Second factory

The processes of the second factory are nanofiltration, ultra/diafiltration, freeze drying and heat treatment. In the step ultra/diafiltration beside the product waste water is formed, and in the step freeze drying waste vapour. The net production time is 9 days.

Figure 11 shows the steps in the second factory with mass flow.

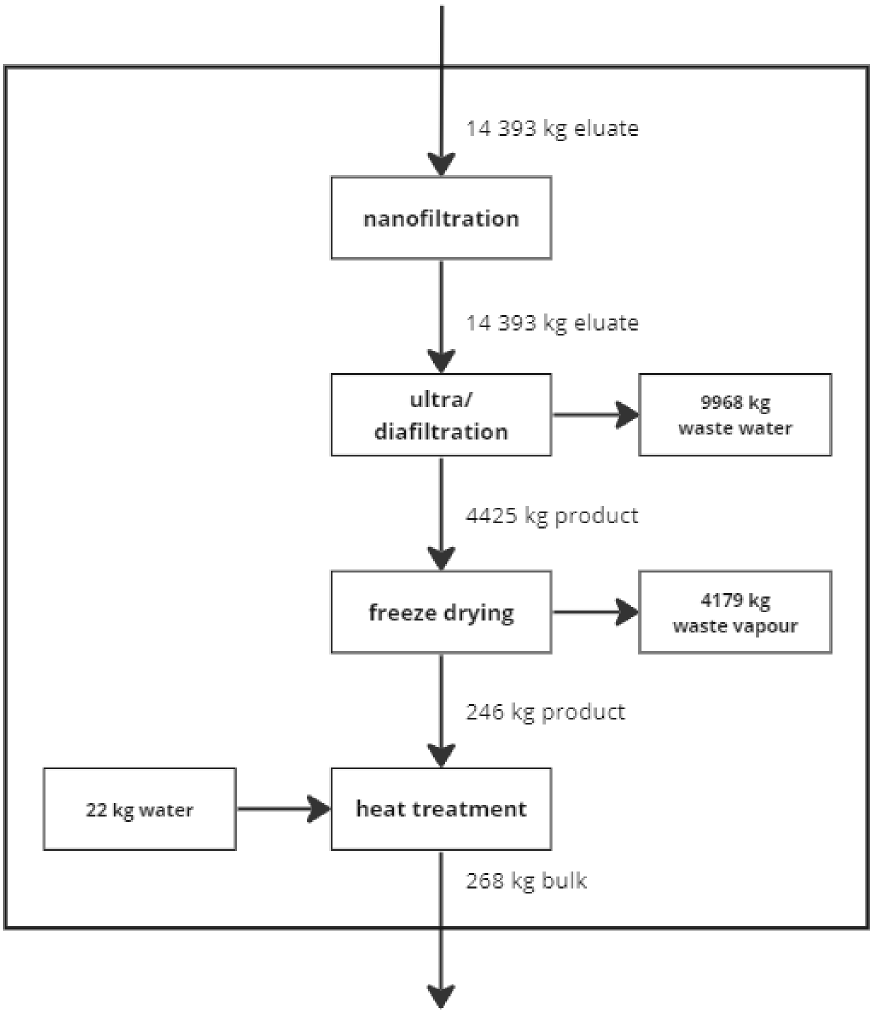
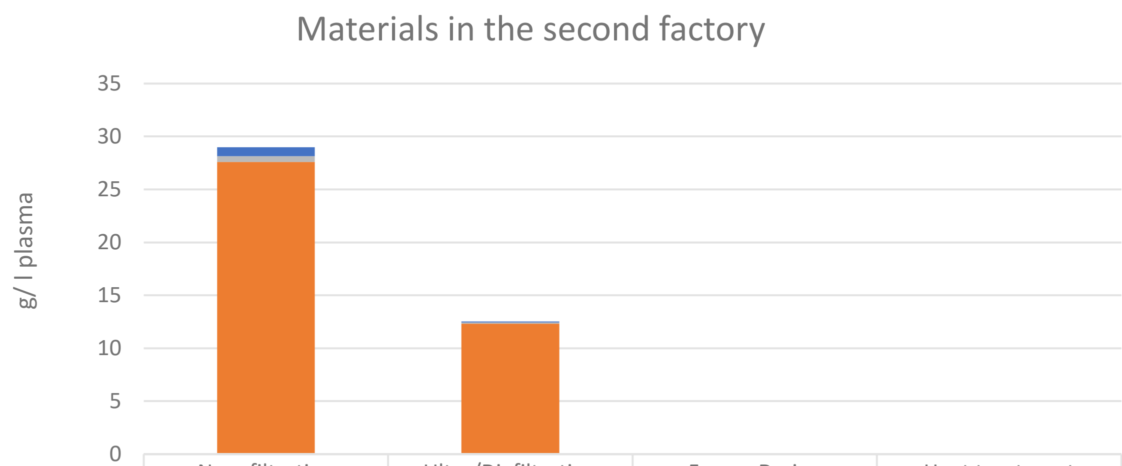


Figure 11: Flow chart of the production in the second factory with mass flow

Table 5 contains the inputs and outputs for the processes in the second factory. Diagram 2 shows the weight of used materials applied to 1 l plasma.

Table 5: Inputs and outputs in the second factory

Process step	Input	Output
Nanofiltration	Eluate	PE-bucket + cover
	Salts	
	Filter	Filter
	Silicone hose	Silicone hose
	Electricity	
	Ventilation	
Ultra/diafiltration	Filter	Filter
	Silicone hose	Silicone hose
	Electricity	Waste water
	Ventilation	
Freeze drying	Silicone hose	Silicone hose
	Electricity	
	Ventilation	
Heat treatment	WFI	Filter
	Filter	Silicone hose
	Silicone hose	
	PE-bag	
	Electricity	
	Ventilation	



	Nanofiltration	Ultra/Diafiltration	Freeze Drying	Heat treatment
Chemicals	0,83	0,09	0	0
Other materials	0,56	0,11	0,04	0,07
Water	27,60	12,32	0	0,02

Diagram 2: Mass of used chemicals, other materials and water applied to 1 l plasma in the second factory

Third factory

In the third factory the product bulk is formulated, sterile filtered, sterile filled and freeze dried. In the formulation step buffer solution is given to the dry plasma-derived material. By sterile filtration there is some product loss, but because of the neglectable amount it is not showed in the analysis. By sterile filling the product is filled into vials. There are four types of products, which means four different sizes of vial and different action units (IU). The type and mass of packaging materials are also distinguished by the four types. These steps in the software run parallel after the 4 items. The net production time is 4 days.

Figure 12 shows the process steps in the third factory during the production. Mass flow is also presented.

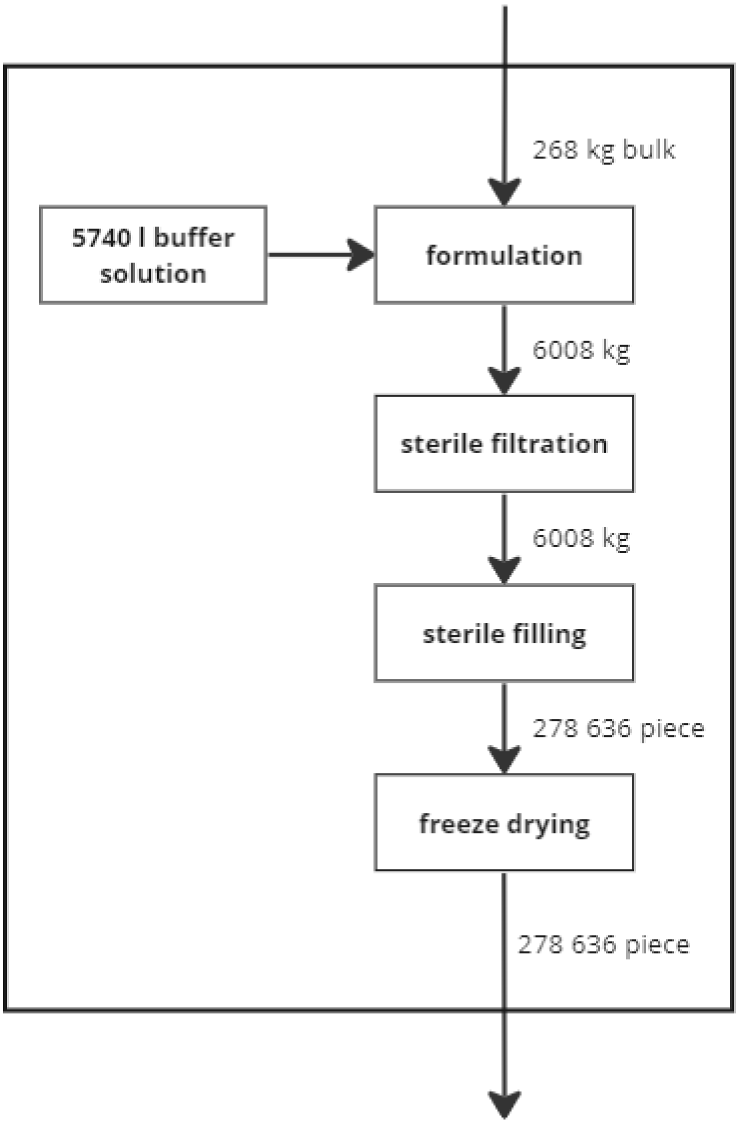


Figure 12: Flow chart of the production in the third factory with mass flow

The third factory also involves the packaging step, but in the software the packaging materials are calculated to the downstream process, and the energy use for the final packaging is neglected, since it is not significant data. This part of plant is not specifically dedicated to the production of the studied product, on the other hand, the final packaging is a semi-manual process.

Table 6 shows the four item with different action unit and volume.

Table 6: The volume and action unit of the four item

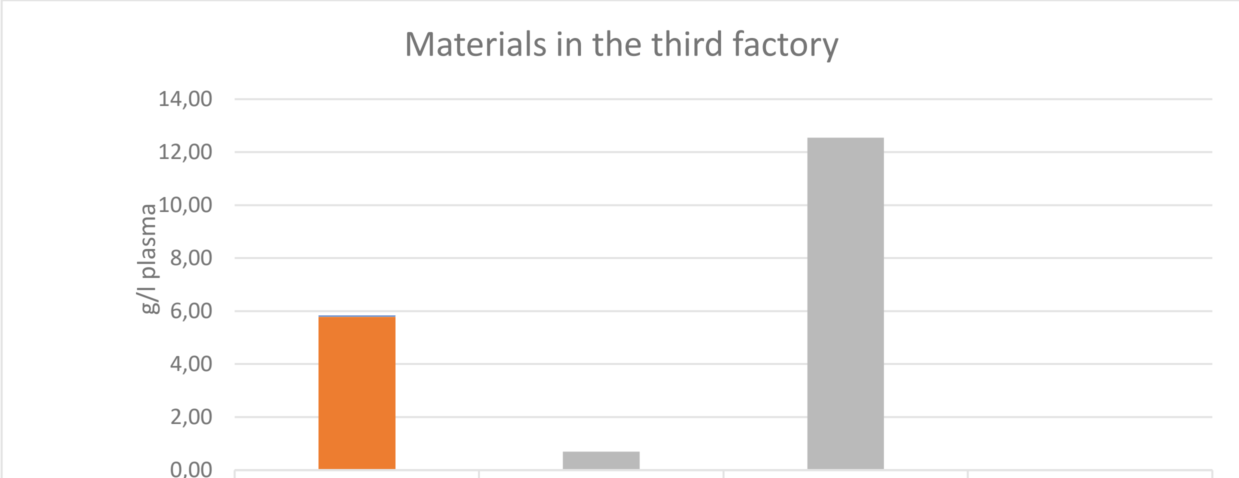
Volume (ml)	Action unit (IU)
10	500
20	1000
50	2500
20	500

Table 7 contains all the used and produced materials and energies in the third factory.

Table 7: Inputs and outputs in the third factory

Process step	Input	Output
Formulation	Bulk	PE-bag
	Salts	
	Acid	
	Electricity	
	Ventilation	
Sterile filtration	Filter	Filter
	Homogenization bag	Homogenization bag
	Electricity	
	Ventilation	
Sterile filling	Vials	Filter
	Stopper	
	Filter	
	Electricity	
	Ventilation	
Freeze drying	Crimp cap	
	Electricity	
	Ventilation	

Diagram 3 shows the weight of used materials applied to 1 l plasma. The step sterile filling has an outstanding material use because of the mass of glass vials.



	Formulation	Sterile filtration	Sterile filling	Freeze drying
Chemicals	0,04	0	0	0
Other materials	0,01	0,70	12,54	0,000026
Water	5,78	0	0	0

Diagram 3: Mass of used chemicals, other materials and water applied to 1 l plasma in the third factory

3.2.3 Downstream process

It consists of the from gate to grave processes that includes the distribution of the final product to the points of sale in this case the shipping of the product from Vienna to the distribution centre in Kentucky. The downstream process does not include the transport to the end user and the use of the product. The mode of transportation is airplane, the average distance is 7575 km.

3.2.4 Transportation between the factories in Vienna

The transportation of the intermediates between the Viennese factories occurs by truck.

In the first case the distance is 1,5 km. For the shipping a container is needed with refrigerator, that suits for temperature between 2-8 °C or under -20 °C. The weight of container 220 kg.

In the second case the distance is 1,1 km. The weight of carton box which is used for shipping in the truck is 1 kg.

3.3 LCIA

The results of Sima Pro software are in the appendix part where emissions of all impact categories are listed that the software with ReCiPe method calculates. In the appendix, Figure 22-32. also contain the mass flows referred to one year production, for 1 kg of product, and for the four different products. The mass flows divided after allocation of the software are represented in the same way. The calculated emissions after allocated mass flow are collected in tables as well.

The chosen impact categories are analysed in this part. The environmental impacts associated with the studied four items are presented in the following figures and the values are showed in the following tables. The company considers most important the environmental effects of the production, because the upstream and downstream processes are in the USA. Improvement of the production part can be taken in environmental aspects from their side, so this piece of work concentrates rather on the core processes.

Table 8, 9, 10 and 11 show the environmental impact according to upstream, core and downstream processes. The percentages are depicted in Figure 13, 14, 15 and 16. Core processes cover the production part in the three factories in Vienna.

By all impact categories downstream processes have the hugest effect on the environment, followed by the core processes and finally the upstream processes.

The impact category global warming potential shows the emitted kg of greenhouse gases, called CO_2 equivalent, which in this case between 2,6 and 5,2 kg per vial.

The 2500 IU/ 50 ml product has the highest emission, it can be explained by the hugest volume among the four items and the hugest amount of plasma-derived action unit. From the same reason has this item the highest percent value in core processes. The emission of core process is between 6 and 20 %.

Regarding to freshwater eutrophication, the emitted phosphate equivalent is $1{,}4 * 10^{-4}$ to $3{,}4 * 10^{-4}$ and the tendency is the same to the global warming potential. The core processes give the 16 to 43 % of all emissions.

Freshwater ecotoxicity is reported kg 1,4-dichlorobenzene-equivalent. The 2500 IU/ 50 ml has highest impact on the freshwater ecotoxicity with 0,009 kg 1,4-DCB, since 500 IU/20 ml the lowest with 0,0046 kg.

By water consumption the same can be observed, the values are between 0,024 and 0,05 m^3.

Table 8: Calculated environmental impacts with ReCiPe 2016 Midpoint (H) method for item 500 IU/ 20 ml, according to upstream, core and downstream processes

500 IU/ 20 ml					
Impact category	Unit	Upstream	Core	Downstream	Total
Global warming	kg CO_2 eq.	0,12	0,33	2,12	2,56
Freshwater eutrophication	kg P eq.	0,000005	0,00004	0,00009	0,00014
Freshwater ecotoxicity	kg 1,4-DCB	0,0001	0,0002	0,0043	0,0046
Water consumption	m^3	0,0001	0,003	0,02	0,024

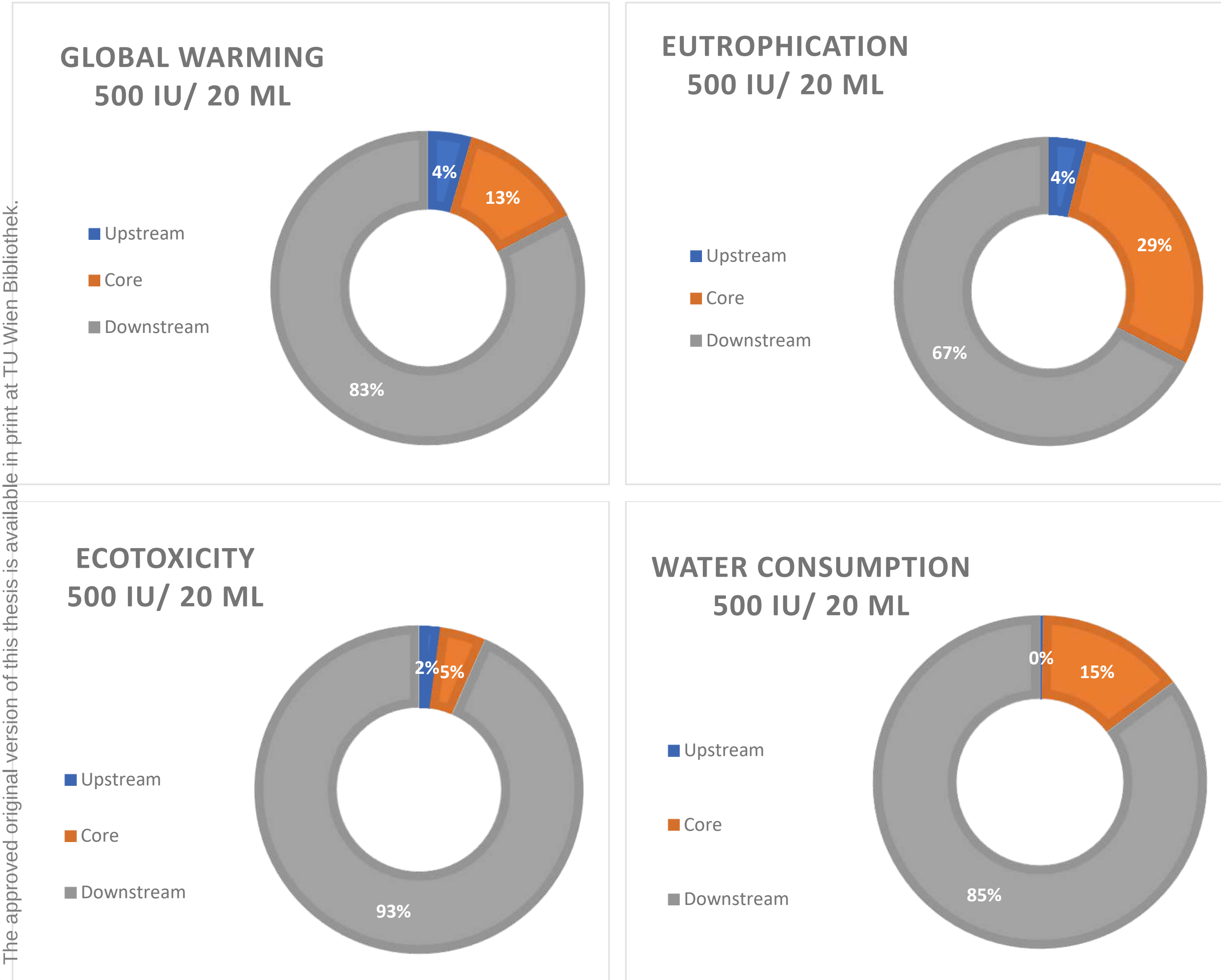


Figure 13: Environmental impacts for item 500 IU/ 20 ml, according to upstream, core and downstream processes, expressed in percentage

Table 9: Calculated environmental impacts with ReCiPe 2016 Midpoint (H) method for item 500 IU/ 10 ml, according to upstream, core and downstream processes

500 IU/ 10 ml					
Impact category	Unit	Upstream	Core	Downstream	Total
Global warming	kg CO_2 eq.	0,13	0,22	3,53	3,88
Freshwater eutrophication	kg P eq.	0,000006	0,00003	0,0002	0,000205
Freshwater ecotoxicity	kg 1,4-DCB	0,0001	0,0001	0,008	0,00785
Water consumption	m^3	0,00008	0,003	0,037	0,0399

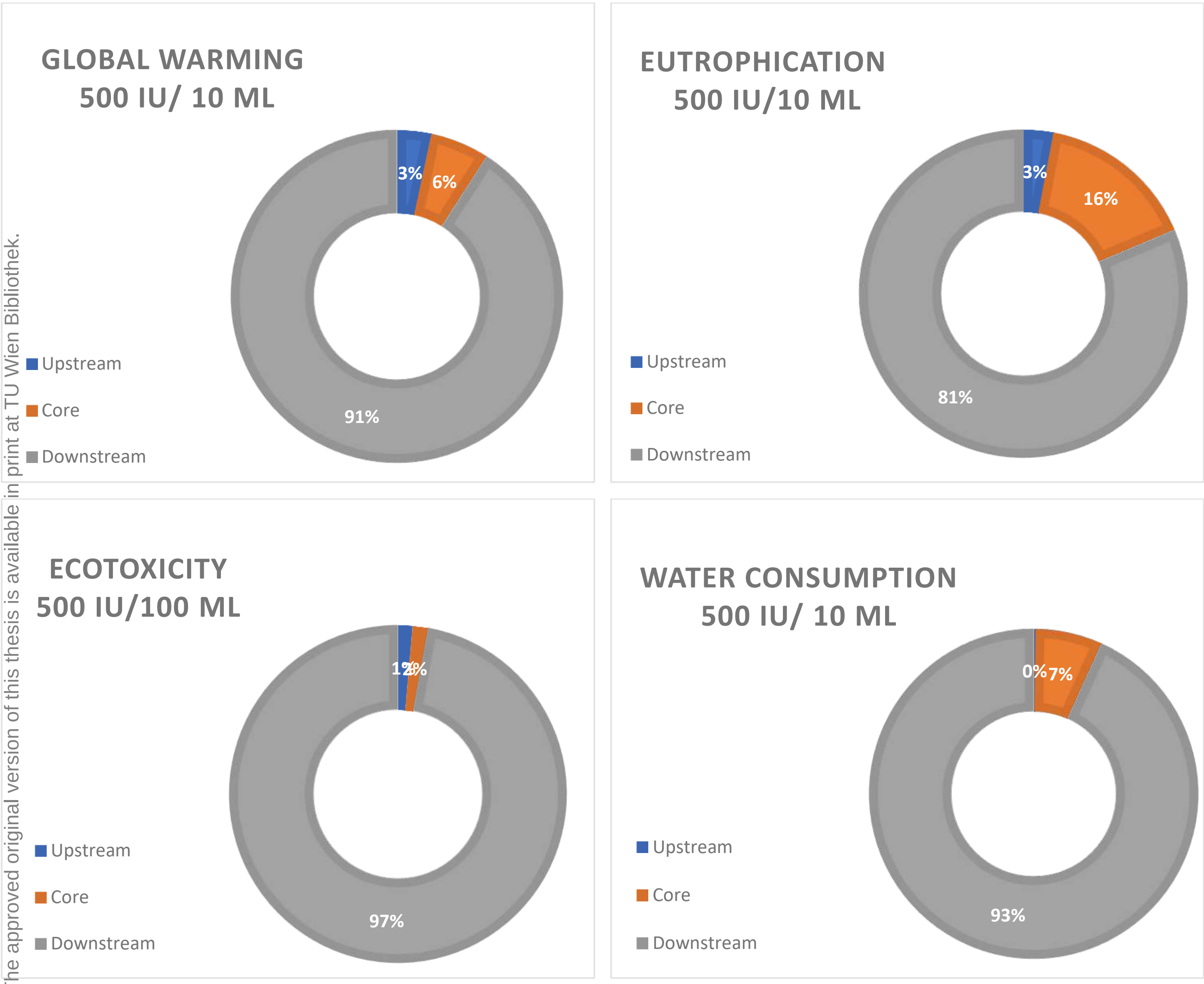


Figure 14: Environmental impacts for item 500 IU/ 10 ml, according to upstream, core and downstream processes, expressed in percentage

Table 10: Calculated environmental impacts with ReCiPe 2016 Midpoint (H) method for item 1000 IU/ 20 ml, according to upstream, core and downstream processes

1000 IU/ 20 ml					
Impact category	Unit	Upstream	Core	Downstream	Total
Global warming	kg CO_2 eq.	0,24	0,45	2,24	2,94
Freshwater eutrophication	kg P eq.	0,000011	0,000063	0,000092	0,000166
Freshwater ecotoxicity	kg 1,4-DCB	0,0002	0,0003	0,004	0,00474
Water consumption	m^3	0,0001	0,005	0,021	0,0258

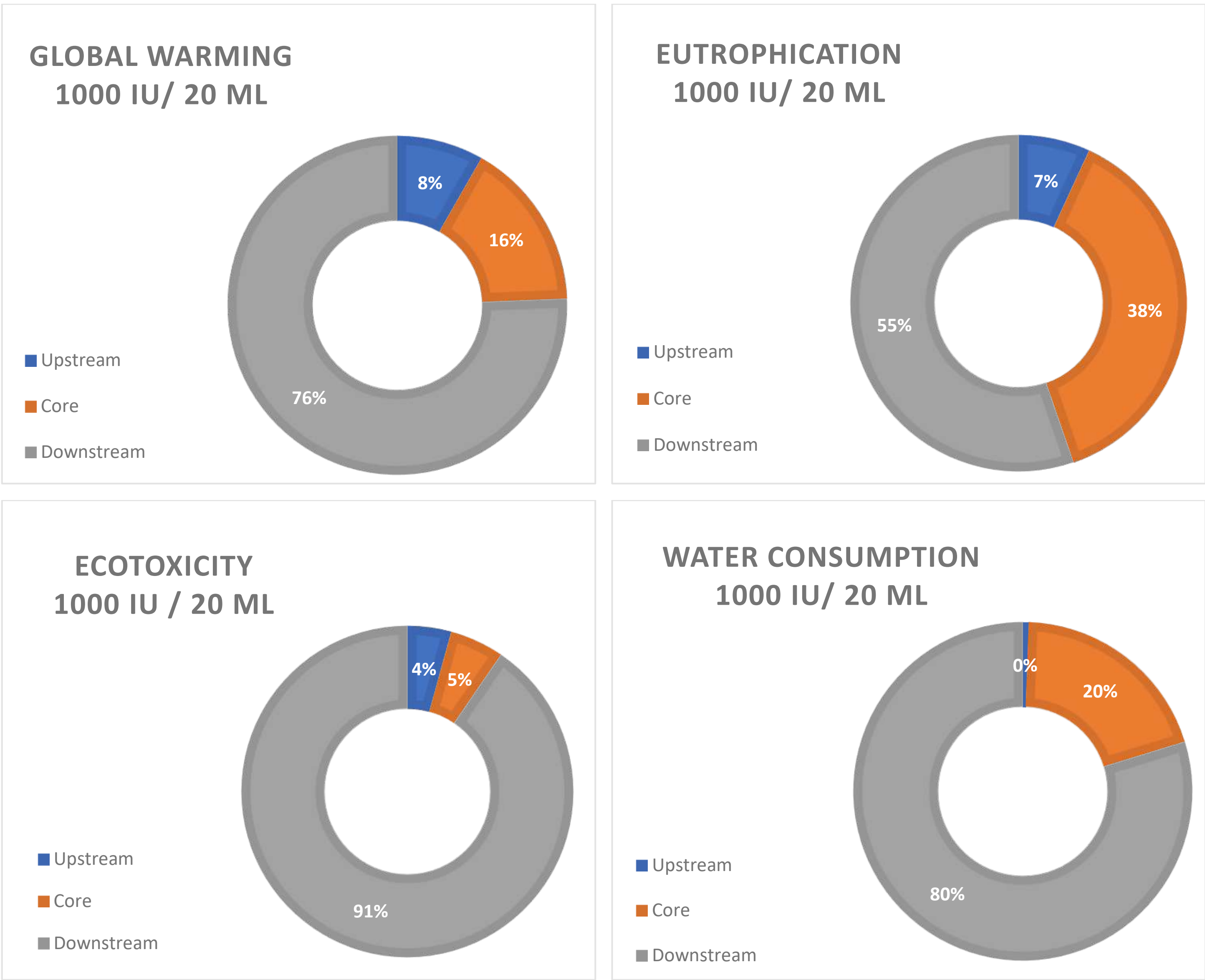


Figure 15: Environmental impacts for item 1000 IU/ 20 ml, according to upstream, core and downstream processes, expressed in percentage

Table 11: Calculated environmental impacts with ReCiPe 2016 Midpoint (H) method for item 2500 IU/ 50 ml, according to upstream, core and downstream processes

2500 IU/ 50 ml					
Impact category	Unit	Upstream	Core	Downstream	Total
Global warming	kg CO_2 eq.	0,54	0,97	3,66	5,17
Freshwater eutrophication	kg P eq.	0,00003	0,00014	0,00017	0,000338
Freshwater ecotoxicity	kg 1,4-DCB	0,00045	0,00050	0,00773	0,0087
Water consumption	m^3	0,0003	0,011	0,038	0,0491

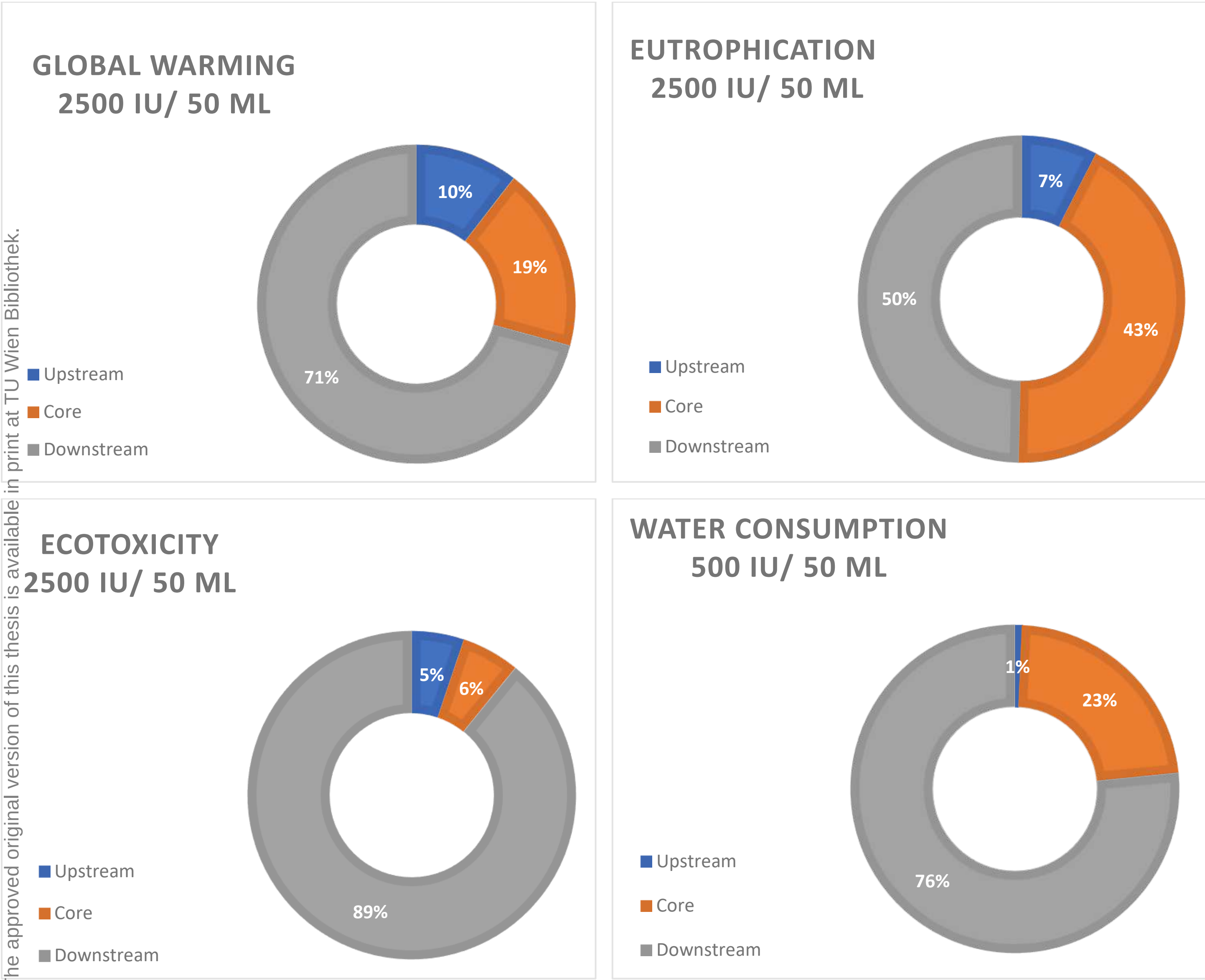


Figure 16: Environmental impacts for item 2500 IU/ 50 ml, according to upstream, core and downstream processes, expressed in percentage

The more action unit and more volume produce more environmental impacts, because of higher energy intensity, higher material need and higher mass. It is showed in the Diagram 4, 5, 6 and 7 for different impact categories.

The tendency is in all impact categories the same, the upstream processes have usually the lowest effect on the environment followed by the core and finally the downstream processes. In the upstream processes the same action unit in the first two items is observable, because the same amount of plasma is needed, therefore the amount of emissions is the same.

It is important to mention, that in the core processes the ranking is usually different. The item 500 IU/ 10 ml has the lowest effect in core processes because of the less amount of glass vials. However, in the downstream processes it has the second high values. The difference is because of the packaging material, for the two items with 20 ml there is needed smaller packaging carton and different kit items, that is why the downstream process of the 500 IU/10 ml item can show a higher impact in total. So, the two items with 20 ml volume and the two other items have approximately the same amount of emissions from the downstream processes.

So, although 3 products have the same ratio of 50 IU/ml, and only one has different ratio with 25 IU/ ml, the three products cannot be examined as the same because of the different type of packaging materials and kit tools. However, some trends are observable, that refer to the same ratio, e.g., in the core processes in Diagram 4, 5, 6, 7, or relating to hotspots during the production (Diagram 9, 10, and 11).

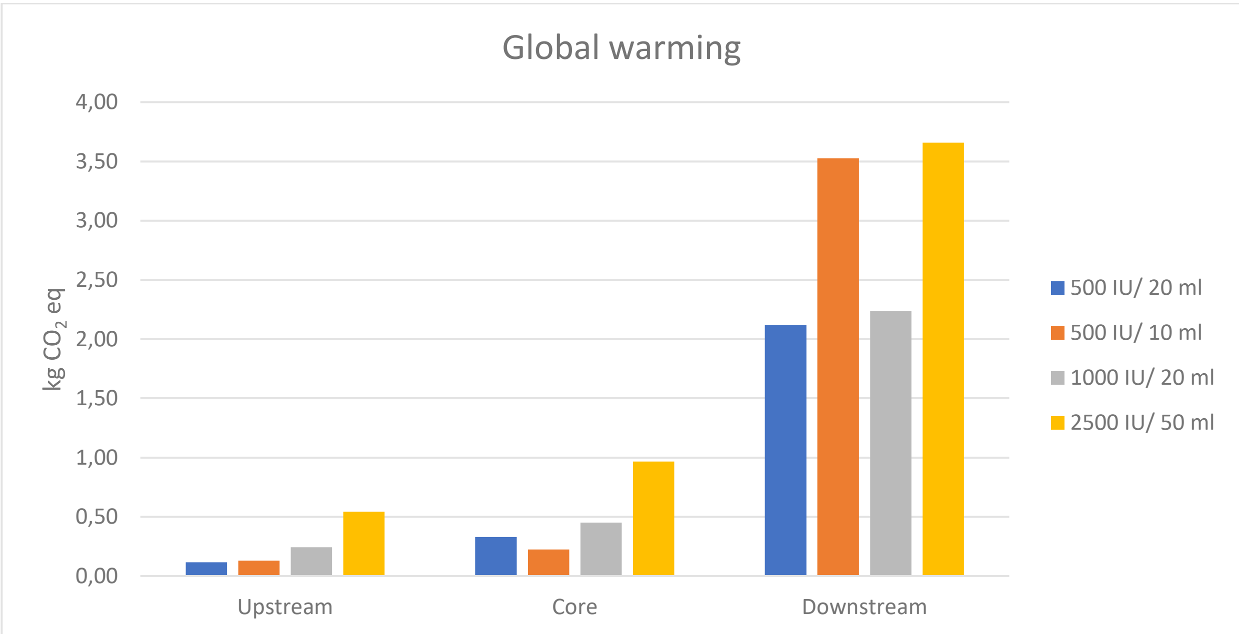


Diagram 4: Global warming potential for upstream, core and downstream processes by the four item

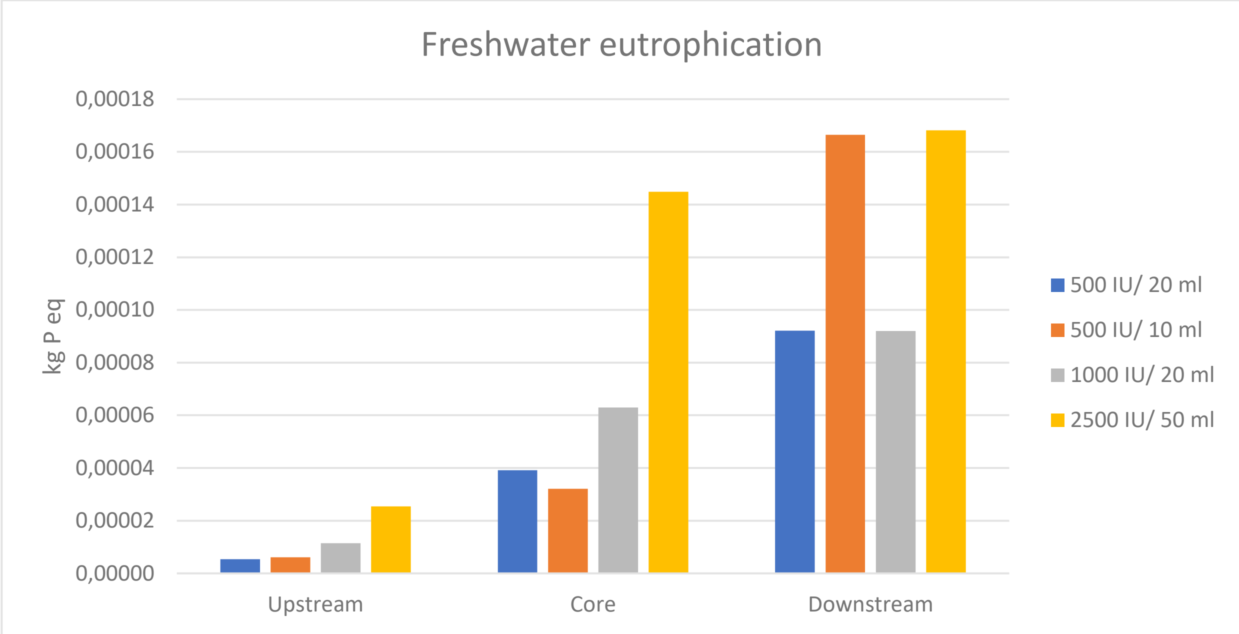


Diagram 5: Freshwater eutrophication for upstream, core and downstream processes by the four item

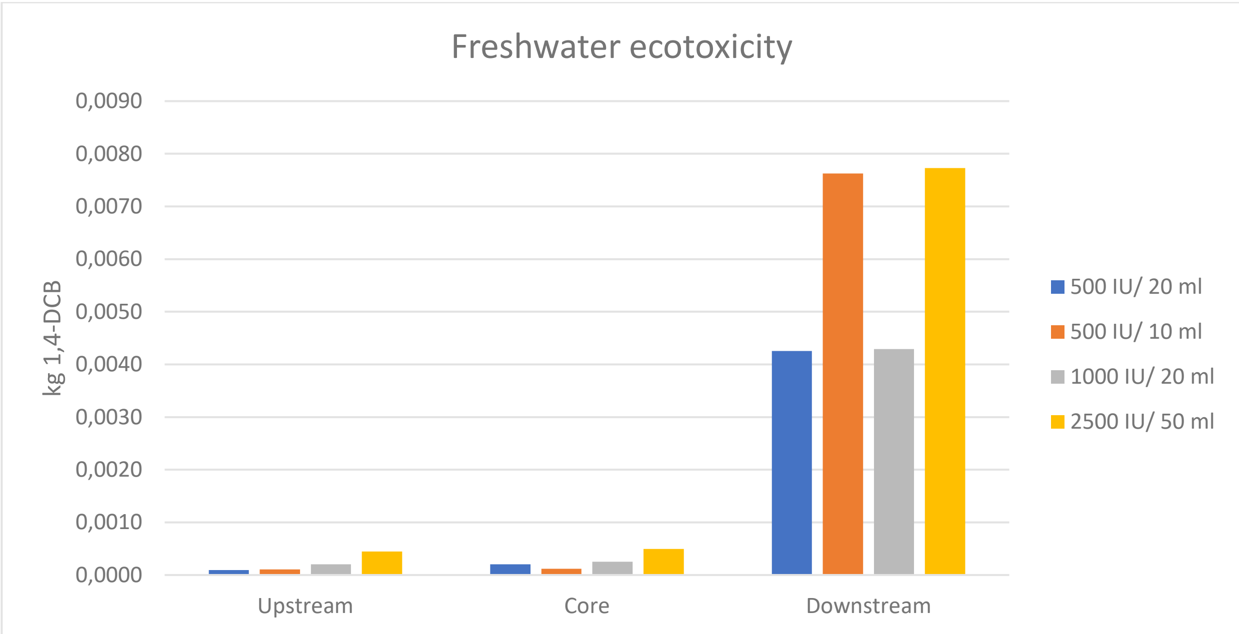


Diagram 6: Freshwater ecotoxicity for upstream, core and downstream processes by the four item

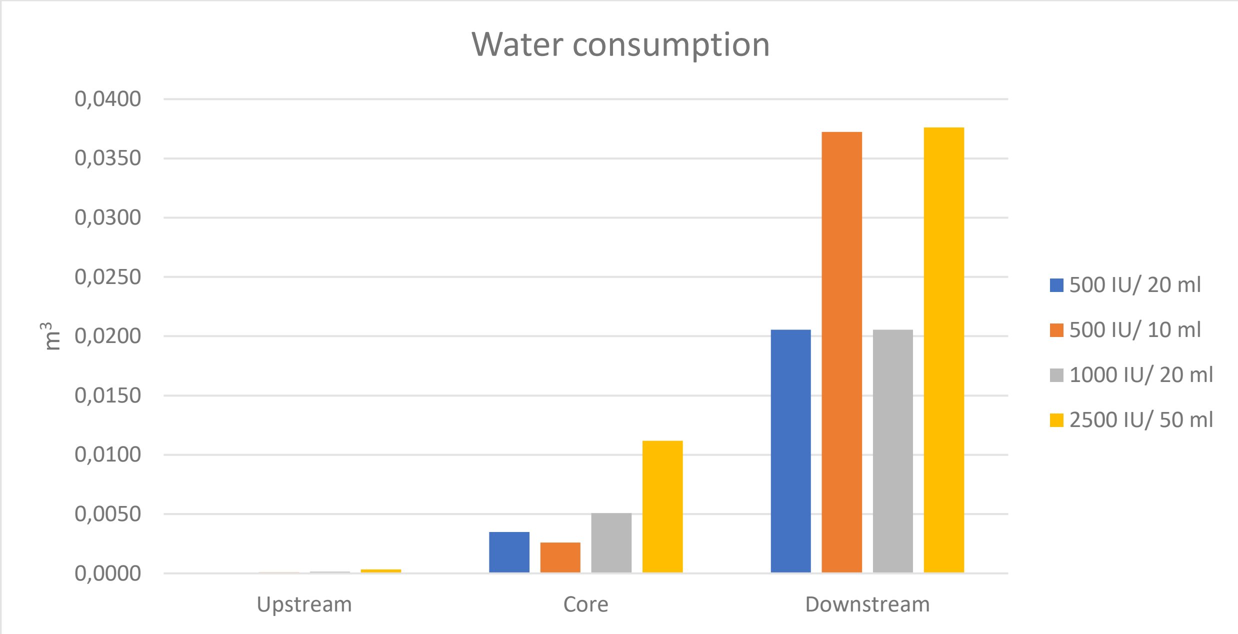


Diagram 7: Water consumption for upstream, core and downstream processes by the four item

The greenhouse gas emissions can be divided in the 3 Scopes. The most emissions come from the Scope 3 category, because of the transportation and the used materials. The Scope 3 emission values are between 87 and 96 % from all CO_2 emissions, since Scope 1 and Scope 2 are around only 2-7 %. Table 12 shows the three Scope and the total CO_2 eq. emission values of the four item, and Figure 17 presents the percentual division of the three scopes.

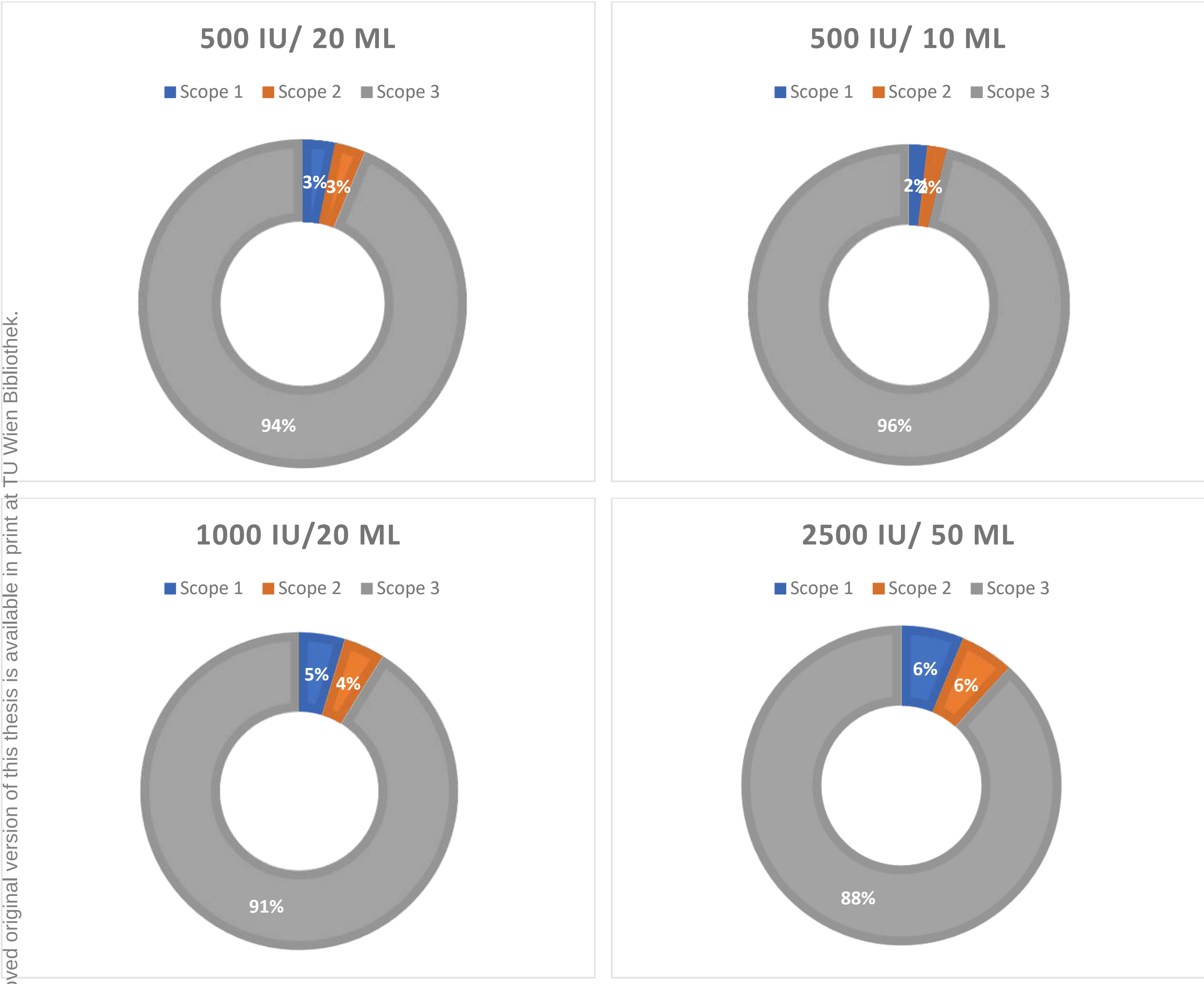


Figure 17: Scope 1, 2, 3 emissions for the four items expressed in percentage

Table 12: Scope 1, 2, 3 values and total CO_2 eq. emission values of the four items

Global Warming					
Impact category	Unit	Scope 1	Scope 2	Scope 3	Total
500 IU/ 20 ml	kg CO_2 eq.	0,08	0,08	2,40	2,56
500 IU/ 10 ml	kg CO_2 eq.	0,07	0,06	3,74	3,88
1000 IU/ 20 ml	kg CO_2 eq.	0,14	0,12	2,68	2,94
2500 IU/ 50 ml	kg CO_2 eq.	0,33	0,28	4,56	5,17

The following tables show the scope emissions per process steps to identify the hotspots where the highest impact on the environment can be observed. The values for item 500 IU/20 ml are listed in Table 13.

Table 13: CO_2 eq. emission of the steps from the upstream to downstream processes, according to Scope 1,2,3 definition for item 500 IU/20 ml

Steps	**Scope 3 (materials, transport)**	**Scope 1 (ventilation)**	**Scope 2 (electricity)**	**Total**
Plasmapheresis	0,083	-	-	0,08
Transport from USA	0,0322	-	-	0,03
Thawing	0,0000219	0,00107	0,00005	0,00114
Centrifugation	0,00003	0,0000015	0,00005	0,00008
Adsorption	0,000007	0	0,0000175	0,0000249
Washing	0,0012	0,0054	0,0001	0,0068
Elution	0,0131	0,0016	0,000143	0,0148
Transport between first and second plant	0,0000238	-	-	0,0000238
Nanofiltration	0,00494	0,00413	0,0006868	0,0097559
Ultra/diafiltration	0,00060	0,02238	0,0051672	0,0281428
Freeze drying	0,00041	0	0,0307422	0,0311572
Heat treatment	0,00066	0,01641	0,0022624	0,0193255
Transport between second and third plant	0,0000662	-	-	0,0000662
Formulation	0,00056	0,00015	0,00008	0,000783882
Sterile filtration	0,01580	0	0,00464	0,020436571
Sterile filling	0,1311	0,00134504	0,0046	0,1371
Freeze drying	0,0010	0,029576037	0,0290	0,0597
Packaging, transport	2,12	-	-	2,12
Summe	2,40	0,082	0,078	2,56

Diagram 8 represents the emitted greenhouse gases during the production in case of product 500 IU/ 20 ml. Scope 1, 2 and 3 are distinguished with different colours.

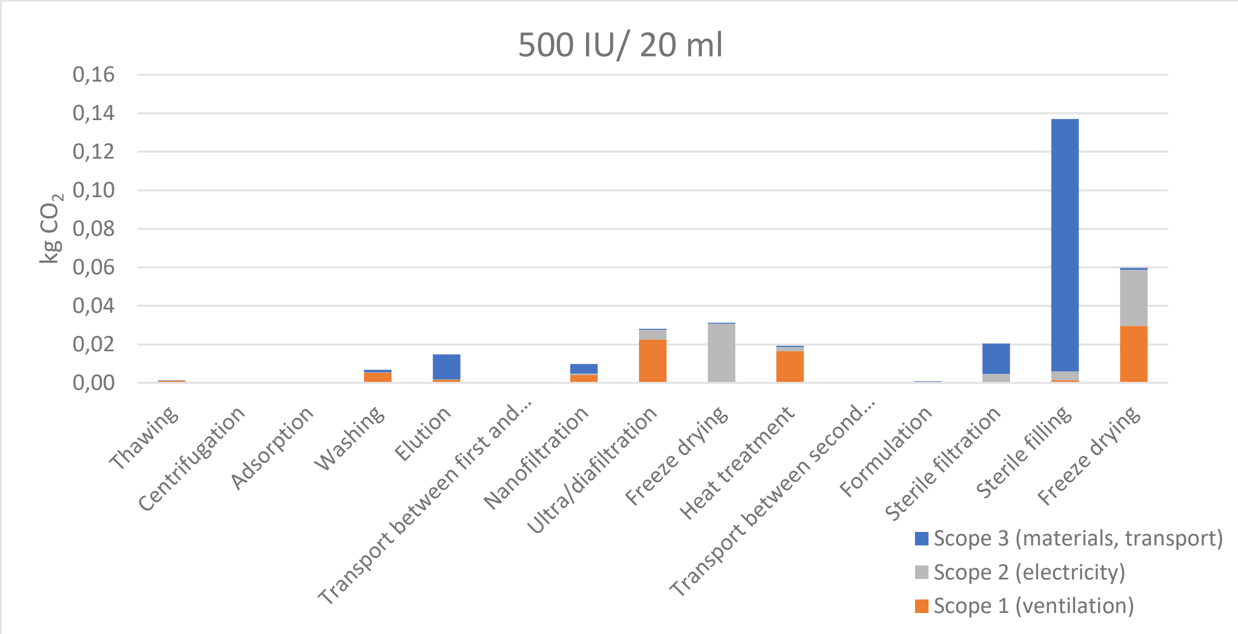


Diagram 8: Scope 1, 2 and 3 emissions for product 500 IU/ 20 ml in the core processes

As hotspot sterile filling can be highlighted followed by the two freeze drying steps and ultra/diafiltration. CO_2 released from step sterile filling is accounted for the mass of glass vials. Freeze drying has a high energy demand, and ultra/diafiltration has a high ventilation demand because of the long duration of this step.

Table 14 and Diagram 9 show these emissions for the item 500 IU/ 10 ml.

Table 14: CO_2 eq. emission of the steps from the upstream to downstream processes, according to Scope 1,2,3 definition for item 500 IU/10 ml

Steps	Scope 3 (materials, transport)	Scope 1 (ventilation)	Scope 2 (electricity)	Total
Plasmapheresis	0,09	-	-	0,09
Transport from USA	0,04	-	-	0,04
Thawing	0,000025	0,0012	0,0000524	0,001
Centrifugation	0,00003	0,0000017	0,0000564	0,000093
Adsorption	0,000007	0	0,0000175	0,000025
Washing	0,001	0,0054	0,0001418	0,007
Elution	0,014	0,0018	0,0001573	0,016
Transport between first and second plant	0,0000262	-	-	0,000026
Nanofiltration	0,0055	0,0046	0,00076	0,011
Ultra/diafiltration	0,00067	0,0252	0,0058	0,032
Freeze drying	0,00047	0	0,0348	0,035
Heat treatment	0,00066	0,0164	0,0023	0,019
Transport between second and third plant	0,0000662	-	-	0,000066
Formulation	0,0004	0,000077	0,00004	0,00049
Sterile filtration	0,0163	0	0,00237	0,019
Sterile filling	0,0482	0,00068892	0,00237	0,051
Freeze drying	0,0010	0,0151	0,01487	0,031
Packaging, transport	3,53	-	-	3,525
Summe	3,7436812	0,0703954	0,0637617	3,8778382

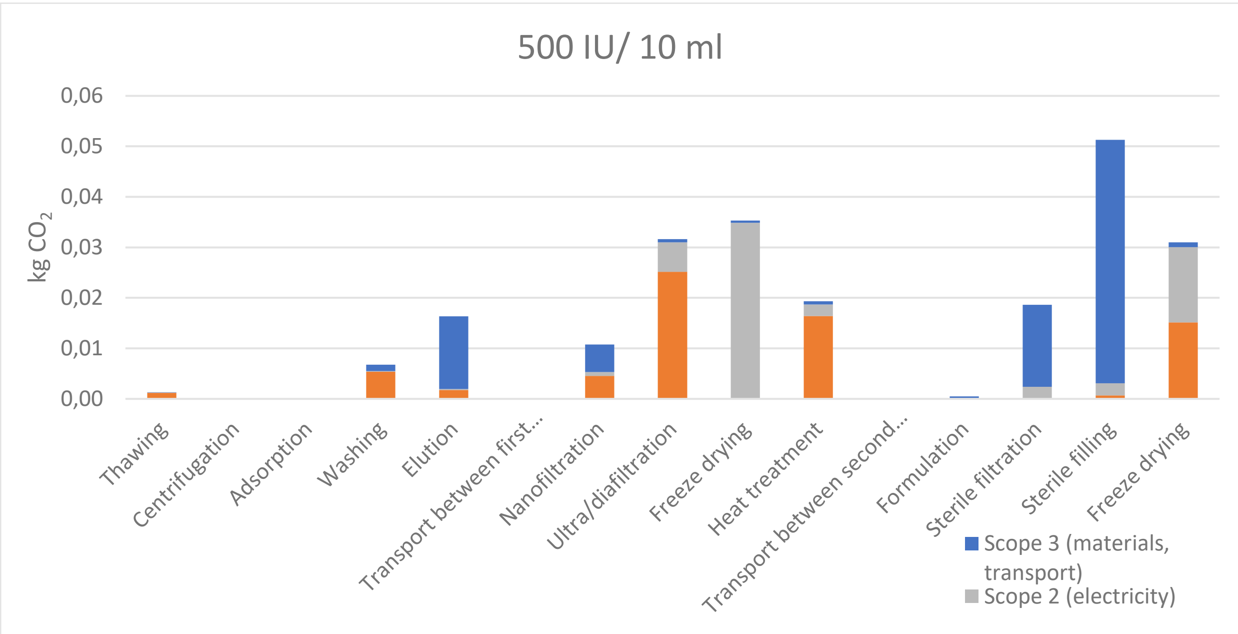


Diagram 9: Scope 1, 2 and 3 emissions for product 500 IU/ 10 ml in the core processes

In this case the hotspots are the same only the order changed. The released CO_2 from sterile filling is not as high as before. The reason is because the volume of this item is the half therefore the size and the mass of the vial also smaller. Also, the smaller freeze-drying emission in the last step can be interpreted with this explanation. The second and third source of GHG emissions is the freeze drying and the ultra/diafiltration in the second factory, conversely the first product.

By the product 1000 IU/20 ml the tendency is the same as observed before, because of the volume growth and the action unit growth the emission is two times higher, the hotspots are sterile filling, freeze drying in the second factory ultra/diafiltration and freeze drying in the third factory.

Table 15 and Diagram 10 represents product 1000 IU/20 ml.

Table 15: CO_2 eq. emission of the steps from the upstream to downstream processes, according to Scope 1,2,3 definition for item 1000 IU/20 ml

Steps	Scope 3 (materials, transport)	Scope 1 (ventilation)	Scope 2 (electricity)	Total
Plasmapheresis	0,18	-	-	0,18
Transport from USA	0,07	-	-	0,07
Thawing	0,000047	0,002274	0,000099	0,002419
Centrifugation	0,000065	0,000003	0,000107	0,000175
Adsorption	0,000015	0	0,000035	0,000050
Washing	0,002	0,011	0,0003	0,0135
Elution	0,027	0,003	0,00030	0,0310
Transport between first and second plant	0,0000497	-	-	0,0000497
Nanofiltration	0,0103	0,0086	0,0014	0,0204
Ultra/diafiltration	0,001272399	0,0476	0,0110	0,0598
Freeze drying	0,0009	0	0,0656	0,0665
Heat treatment	0,0013	0,0328	0,0045	0,0387
Transport between second and third plant	0,0001	-	-	0,0001
Formulation	0,0005	0,0002	0,0001	0,0007
Sterile filtration	0,0158	0	0	0,0205
Sterile filling	0,1307	0,0014	0,0047	0,1369
Freeze drying	0,0010	0,0303	0,0297	0,0611
Packaging, transport	2,24	-	-	2,24
Summe	2,67562141	0,13718109	0,12266856	2,93547106

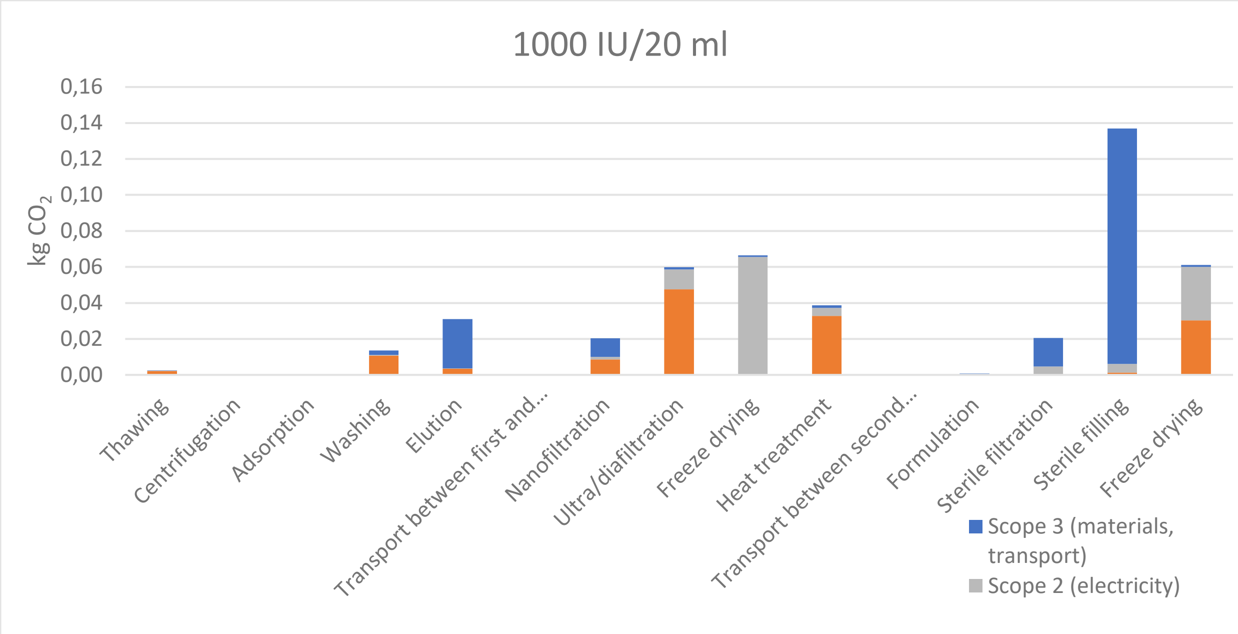


Diagram 10: Scope 1, 2 and 3 emissions for product 1000 IU/ 20 ml in the core processes

The last item is showed in Table 16 and Diagram 11. The hotspots, the tendency is unchanged, the values are five times higher than the 500 IU/10 ml item.

Table 16: CO_2 eq. emission of the steps from the upstream to downstream processes, according to Scope 1,2,3 definition for item 2500 IU/50 ml

Steps	Scope 3 (materials, transport)	Scope 1 (ventilation)	Scope 2 (electricity)	Total
Plasmapheresis	0,39	-	-	0,39
Transport from USA	0,15	-	-	0,15
Thawing	0,0001	0,0050	0,0002	0,0054
Centrifugation	0,0001	0,0000	0,0002	0,0004
Adsorption	0,00004	0	0,0001	0,0001
Washing	0,006	0,027	0,001	0,034
Elution	0,061	0,007	0,001	0,069
Transport between first and second plant	0,00011	-	-	0,00011
Nanofiltration	0,023	0,019	0,003	0,045
Ultra/diafiltration	0,003	0,106	0,025	0,134
Freeze drying	0,002	0	0,143	0,145
Heat treatment	0,003	0,082	0,011	0,097
Transport between second and third plant	0,00033	-	-	0,00033
Formulation	0,001	0,000	0,000	0,001
Sterile filtration	0,022	0	0,012	0,034
Sterile filling	0,235	0,0034	0,012	0,250
Freeze drying	0,003	0,076	0,074	0,153
Packaging, transport	3,66	-	-	3,66
Summe	4,5592586	0,3263251	0,2827195	5,1683032

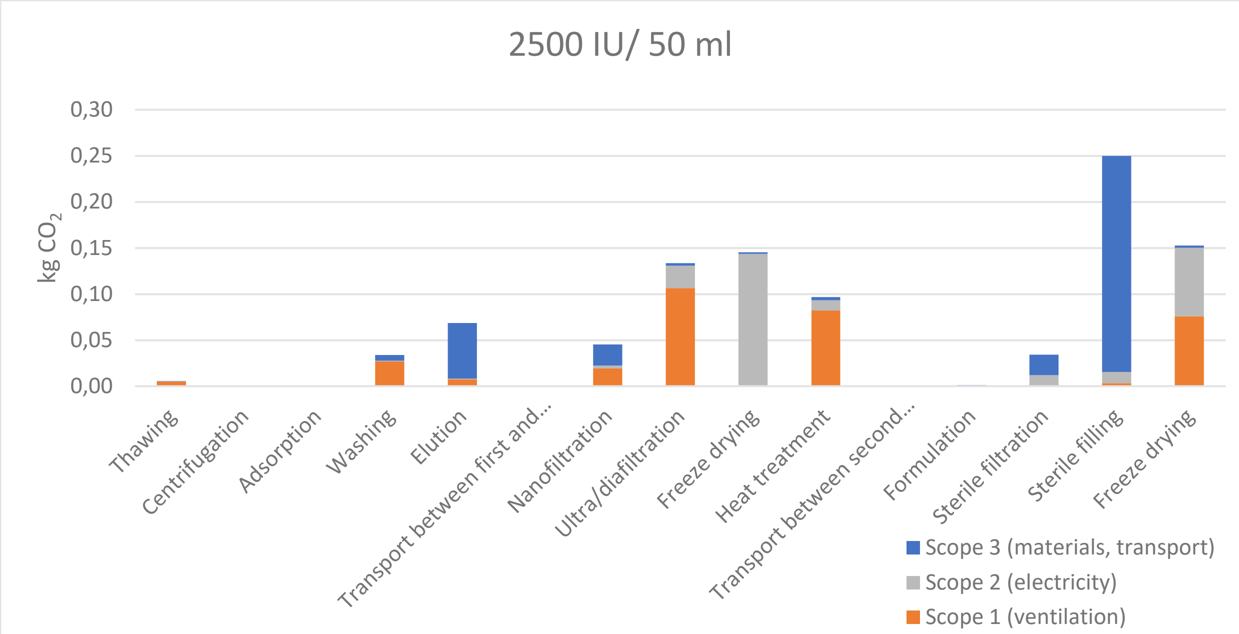


Diagram 11: Scope 1, 2 and 3 emissions for product 2500 IU/ 50 ml in the core processes

The CO_2 emissions of the three factories is compared in Figure 18 in percentages.

For the item 500 IU/20 ml the third plant is the primary greenhouse gas emission source for the production followed by the second plant. The third factory contributes 66 % of the overall global warming impacts, the second is 27 %. For the other three items both the third and second factory are around 45 %. The smallest emission value the first factory has with 14-22 % in all cases.

The difference between the percent values of the factories among the four items is caused by the mass of vial and the amount of used plasma for required action unit. Where the action unit is a greater number, the second factory has more effect on the environment, where the size of vial (volume) is greater, the third factory emits more greenhouse gases.

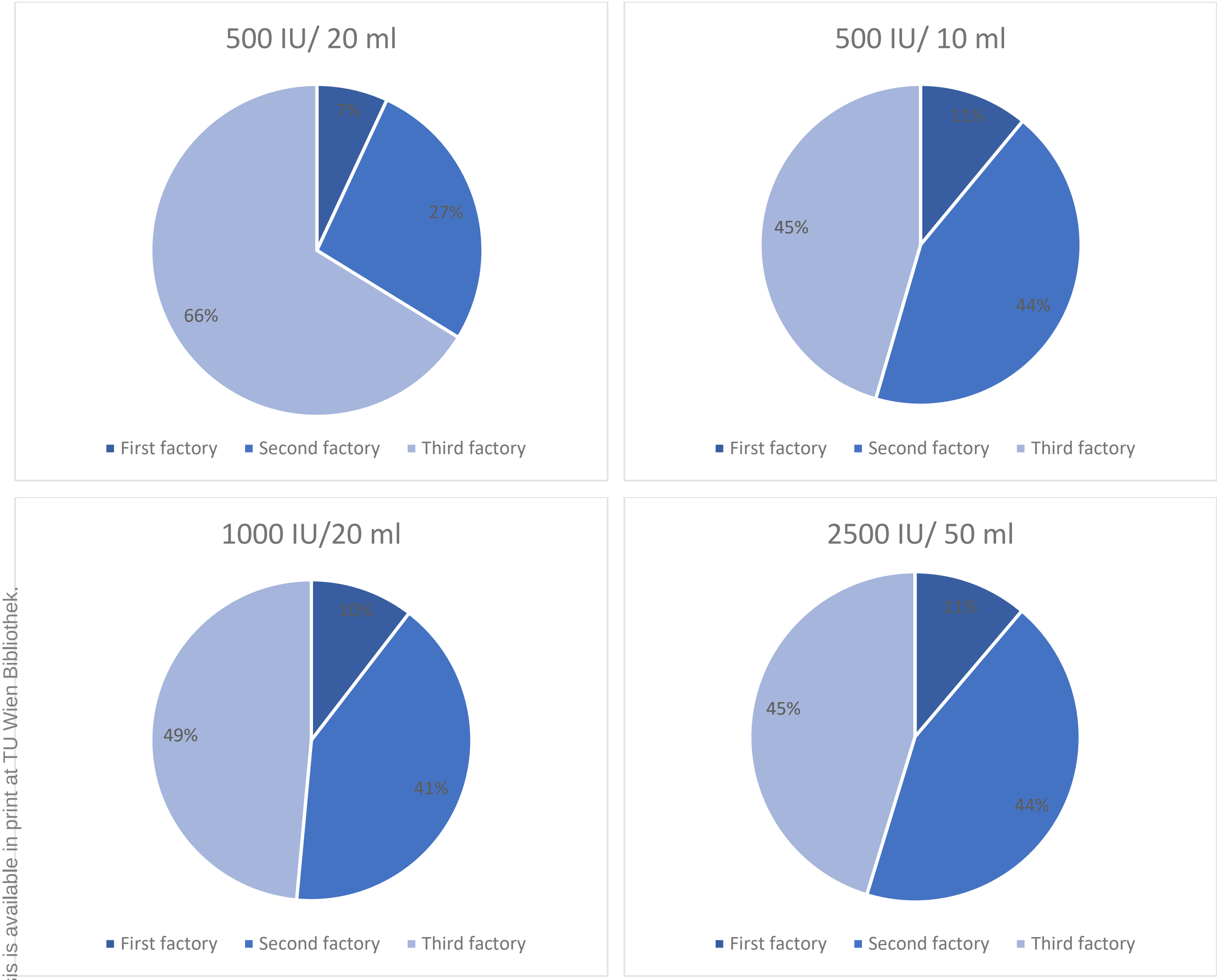


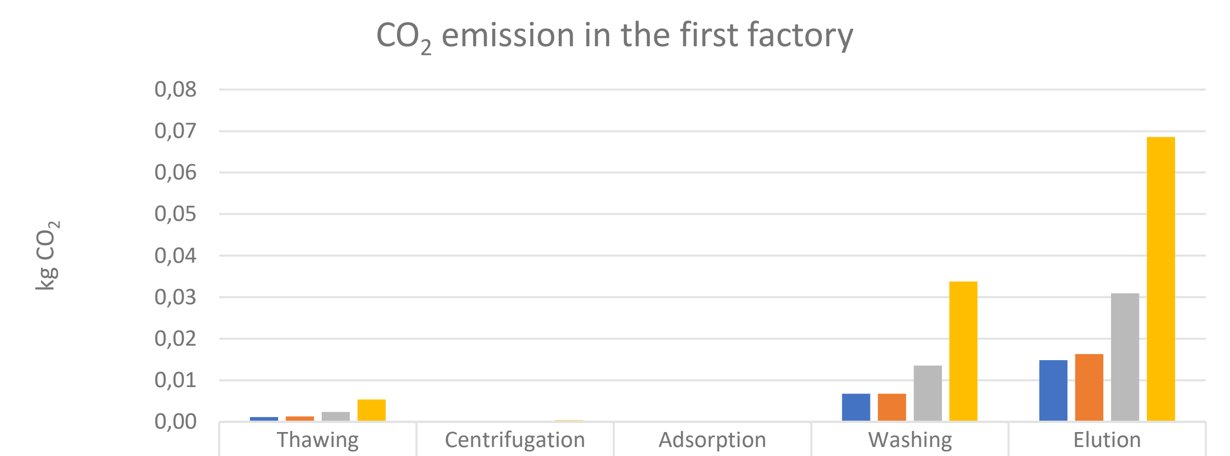
Figure 18: CO_2-emissions during the production divided in the three factory in percentages

The major greenhouse gas (GHG) source in the first factory is the step elution followed by washing. Centrifugation, adsorption have neglectable effect to compare with the two hotspots, and the emission of thawing is small as well.

In the second factory the major source is step ultra/diafiltration followed by freeze drying. Heat treatment can be identified as the third major source and finally the nanofiltration.

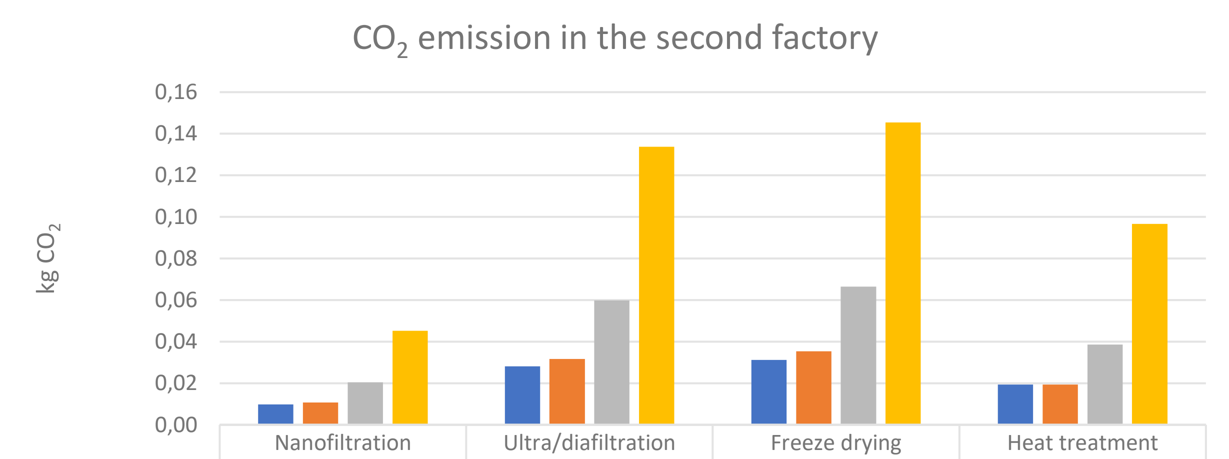
In the third factory the ranking is sterile filling, freeze drying, sterile filtration and the emission of formulation is unsignificant.

Diagrams 12, 13 and 14 represent the hotspots of the three factories.



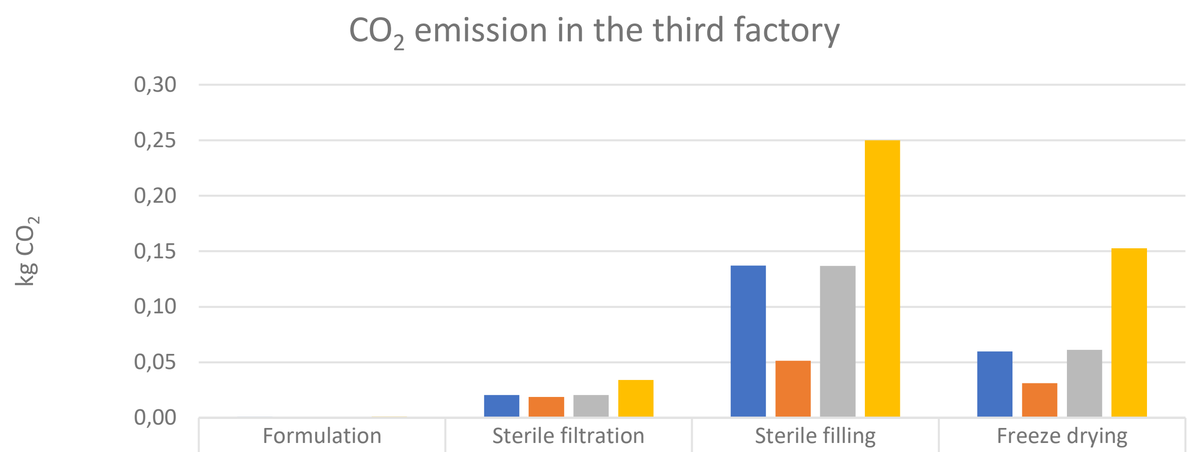
	Thawing	Centrifugation	Adsorption	Washing	Elution
500 IU/ 20 ml	1,14E-03	8,23E-05	2,49E-05	6,75E-03	1,48E-02
500 IU/ 10 ml	1,28E-03	9,25E-05	2,49E-05	6,75E-03	1,64E-02
1000 IU/20 ml	2,42E-03	1,75E-04	4,99E-05	1,35E-02	3,10E-02
2500 IU/ 50 ml	5,37E-03	3,88E-04	1,25E-04	3,38E-02	6,86E-02

Diagram 12: Hotspots (GWO) in the first factory



	Nanofiltration	Ultra/diafiltration	Freeze drying	Heat treatment
500 IU/ 20 ml	9,76E-03	2,81E-02	3,12E-02	1,93E-02
500 IU/ 10 ml	1,08E-02	3,17E-02	3,53E-02	1,93E-02
1000 IU/20 ml	2,04E-02	5,98E-02	6,65E-02	3,87E-02
2500 IU/ 50 ml	4,52E-02	1,34E-01	1,45E-01	9,66E-02

Diagram 13: Hotspots (GWP) in the second factory



	Formulation	Sterile filtration	Sterile filling	Freeze drying
500 IU/ 20 ml	7,84E-04	2,04E-02	1,37E-01	5,97E-02
500 IU/ 10 ml	4,90E-04	1,87E-02	5,13E-02	3,10E-02
1000 IU/20 ml	6,95E-04	2,05E-02	1,37E-01	6,11E-02
2500 IU/ 50 ml	1,16E-03	3,41E-02	2,50E-01	1,53E-01

Diagram 14: Hotspots (GWP) in the third factory

The other impact categories such as water consumption, freshwater eutrophication and freshwater ecotoxicity are summarized in Table 17. The example is the item 500 IU/20 ml. The effects on the environment of the different process steps are represented in Diagrams 15, 16 and 17.

Table 17: Water consumption, freshwater eutrophication and freshwater ecotoxicity during the production of one vial of item 500 IU/20 ml

Steps (500/20ml)	Water consumption (m^3)	Freshwater eutrophication (kg P eq.)	Freshwater ecotoxicity (kg 1,4-DCB)
Plasmapheresis	0,00E+00	4,99E-06	4,22E-05
Transport from USA	6,87E-05	4,00E-07	5,30E-05
Thawing	1,55E-05	1,71E-07	2,38E-07
Centrifugation	1,32E-06	6,95E-09	4,16E-08
Adsorption	5,41E-07	8,28E-07	4,58E-08
Washing	1,33E-04	3,63E-06	4,83E-06
Elution	1,42E-04	1,80E-06	1,31E-05
Transport between first and second plant	5,19E-08	2,52E-10	5,10E-08
Nanofiltration	9,11E-05	3,39E-06	6,34E-06
Ultra/diafiltration	2,41E-04	6,24E-06	4,95E-06
Freeze drying	6,59E-04	3,74E-06	1,00E-05
Heat treatment	1,46E-04	3,63E-06	2,43E-06
Transport between second and third plant	8,29E-07	4,20E-09	1,75E-07
Formulation	3,91E-05	9,60E-07	9,70E-07
Sterile filtration	2,37E-04	8,76E-07	1,14E-05
Sterile filling	1,02E-03	5,19E-06	1,38E-04
Freeze drying	7,69E-04	8,73E-06	1,21E-05
Packaging, transport	2,06E-02	9,21E-05	4,26E-03
Summa	**2,41E-02**	**1,37E-04**	**4,56E-03**

The tendency of water consumption is similar to greenhouse gas emission. The most water demanding step is sterile filling followed by the two freeze drying steps. From this aspect, by freeze drying the energy demand is responsible for the high values.

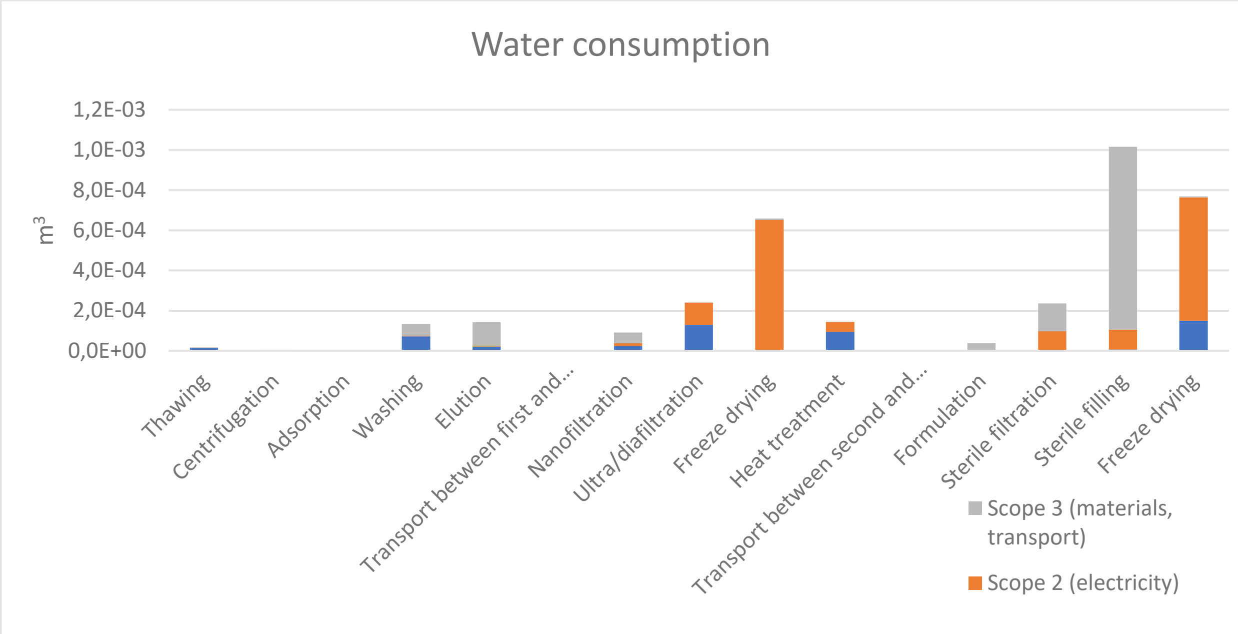


Diagram 15: Water consumption during the production of one vial of 500 IU/20 ml

Freshwater eutrophication comes from the increasing concentrations of plant nutrient, usually phosphate and nitrate, and this process leads to increasing biomass generation in water, to the growth of aquatic plants. During the production the freeze drying, ultra/diafiltration and sterile filling have the highest effect on eutrophication. Diagram 16 shows that by ultra/diafiltration and freeze drying steps the ventilation is the main source of emissions, and by sterile filling the materials, so more precisely from the glass vial production.

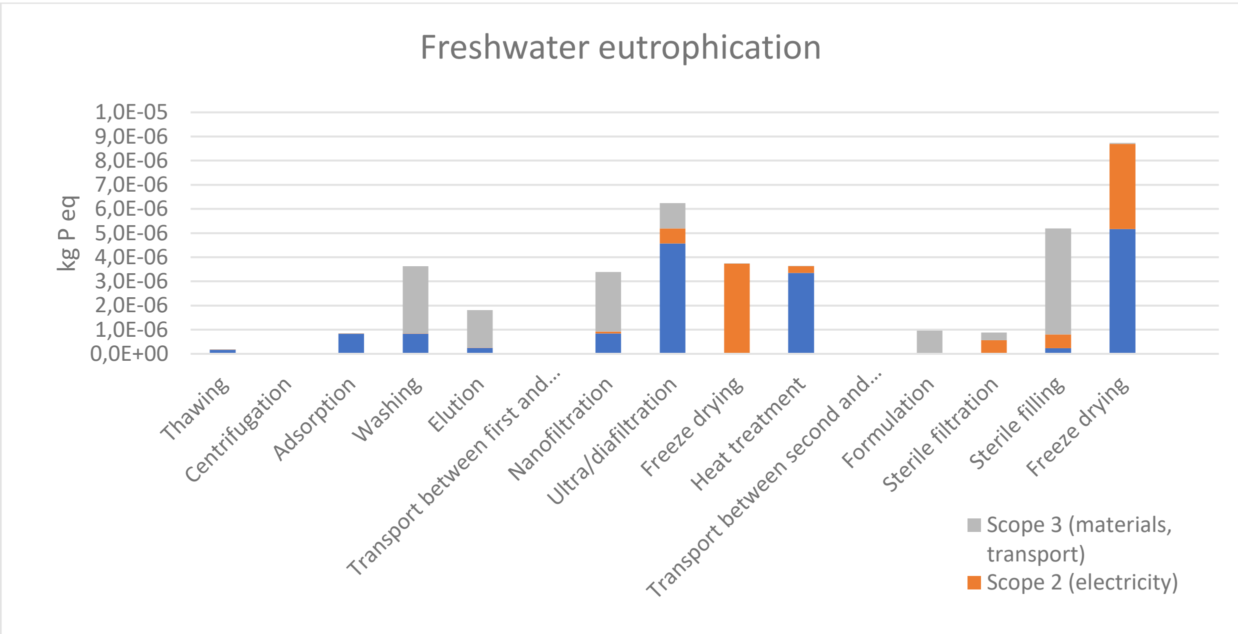


Diagram 16: Freshwater eutrophication during the production of one vial of 500 IU/20 ml

The freshwater ecotoxicity include every natural and synthetic pollutants may have the potential to cause toxic effects on aquatic ecosystems. During the production the sterile filling is outstanding in comparison to the other steps, which is caused by the glass vials. Usually by all steps the materials are the main sources for ecotoxicity emission.

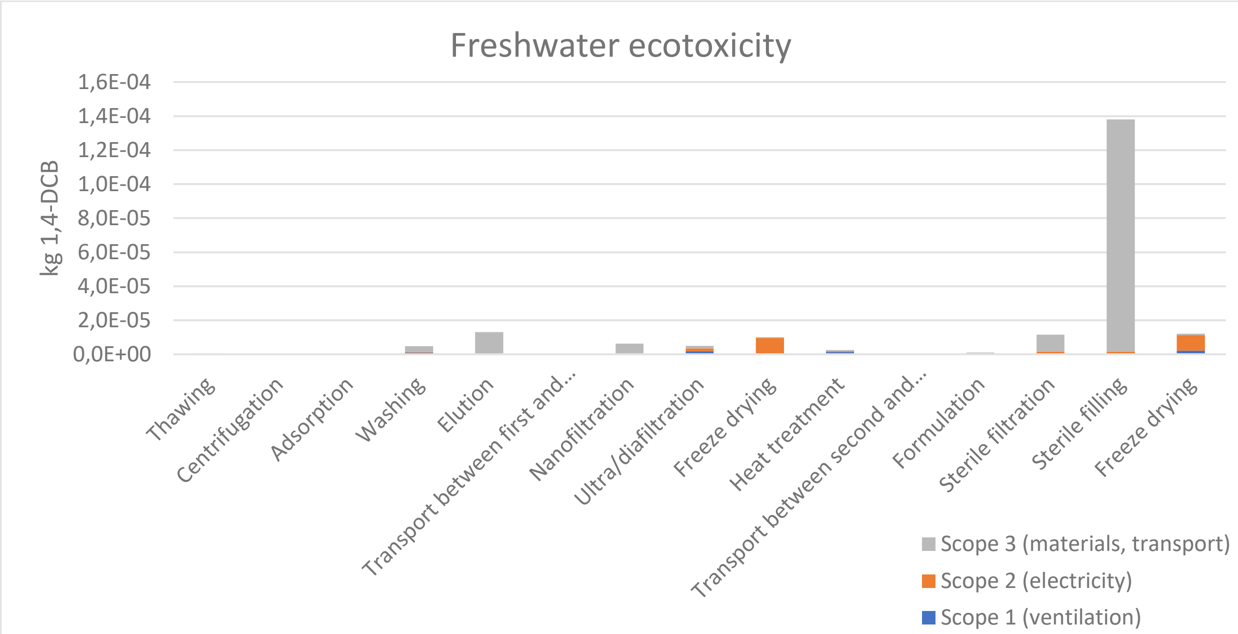


Diagram 17: Freshwater ecotoxicity during the production of one vial of 500 IU/20 ml

3.4 Fourth phase: Sensitivity-analysis

In order to examine how sensitive the results of the impact assessment react to changes in the various parameter; a sensitivity analysis is carried out.

The downstream process has the largest effect on the environment during the life cycle of the product. The reason is the high CO_2-emission of the airplane and the long distance between the place of production and the place of use. In this part two different scenarios are calculated: one for this distance but with a different mean of transport and the other one for a shorter distance but with airplane. The analysis is carried out for item 500 IU/20 ml because it has a higher impact proportionately to the other items as well as a higher mass for the transportation.

The first scenario (Scenario1) is consequently from Europa to the USA but by ship with refrigeration system. The first 1000 km is taken by a truck, then 7500 km by ship, and again 1000 km by a truck, similar to the upstream processes.

The second scenario (Scenario 2) is 1000 km by airplane, because this product is sold in Europa too, e.g., France or the Netherlands.

The comparison among the scenarios is showed in Table 18 and Figure 19.

Table 18: Base scenario and two different scenarios for transportation

Impact category	Unit	Base scenario	Scenario 1	Scenario 2
Global warming	kg CO_2 eq.	2,119	0,766	0,697
Freshwater eutrophication	kg P eq.	0,0000921	0,0000919	0,0000899
Freshwater ecotoxicity	kg 1,4-DCB	0,00426	0,00433	0,00375
Water consumption	m^3	0,0206	0,0204	0,0200

In the values of global warming potential, the difference between the three scenario is not neglectable. The value of Scenario 1 is one third of the value of the base scenario is the CO_2-emission. It means, approximately 1,5 kg greenhouse gas emission could be saved if the final transportation is changed for ship.

In the Scenario 2 it can be determined that the CO_2-emission is not proportional to the distance, the reason is the materials have also some CO_2-emissions, which are the same independently from the mean of transport or the distance.

The category freshwater eutrophication does not show a huge difference between the P eq. emissions, but both scenarios have smaller effect.

Conversely, the ecotoxicity in freshwater increases using ship and truck for the downstream process.

The water consumption has also the same tendency as by global warming potential and freshwater eutrophication.

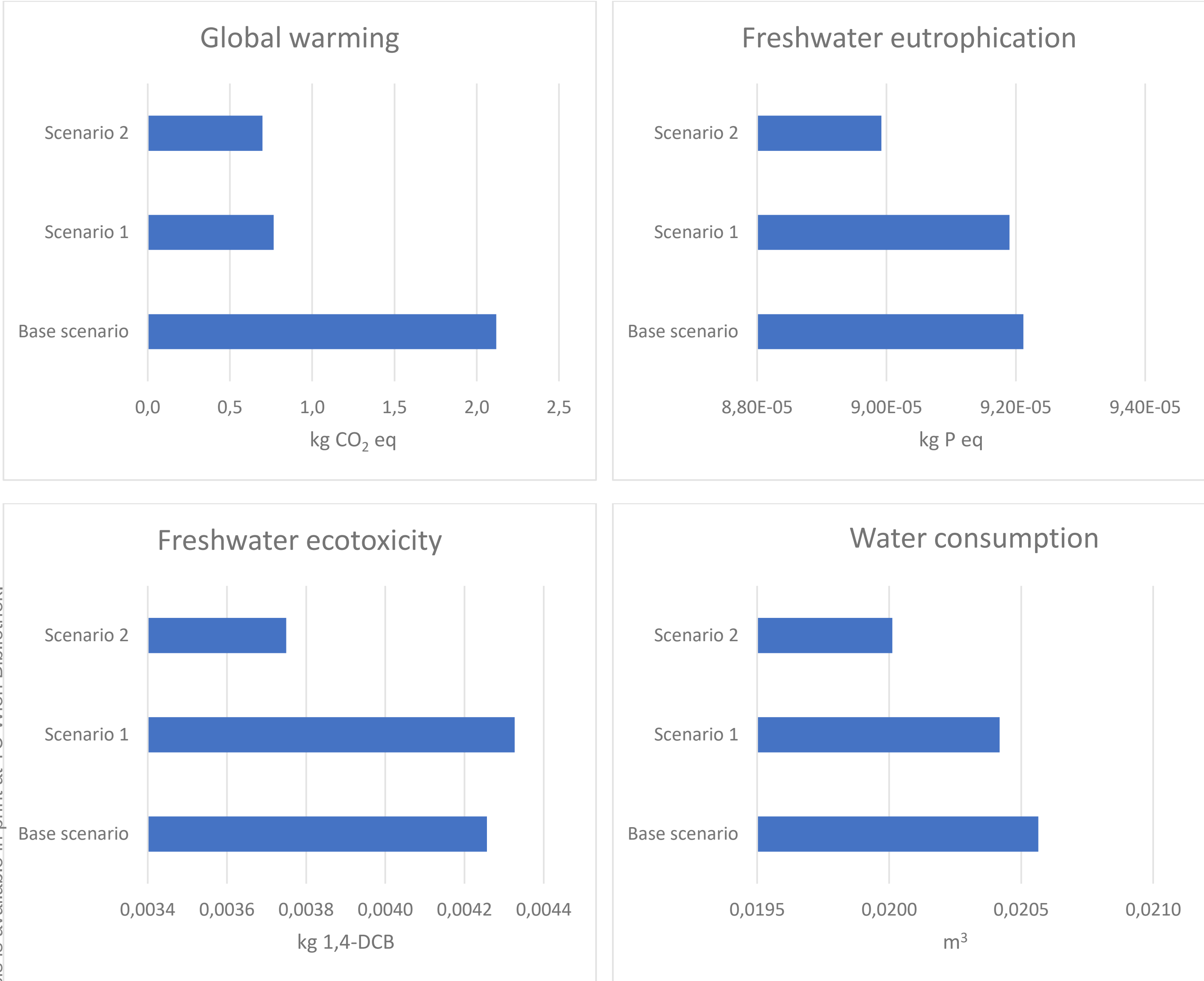


Figure 19: Sensitivity analysis for downstream processes according to the four studied environmental impact for item 500 IU/20 ml

Another hotspot was during the production the ventilation of the longer steps such as ultra/diafiltration or freeze drying in the third factory.

In the company the ventilation consists of steam production, gas, and electricity. For the steam production the company has a special proportion from heat and water (Base Scenario). In the sensitivity analysis instead of a steam production from the two ingredients a general steam production was taken for the chemical industry (Scenario 1).

Two processes are examined with this type of ventilation, the ultra/diafiltration step in the second plant, and the freeze drying step in the third plant. Table 19 and 20, and Figure 20 show the Base Scenario and the Scenario 1 by the two processes. The example is item 500 IU/20 ml.

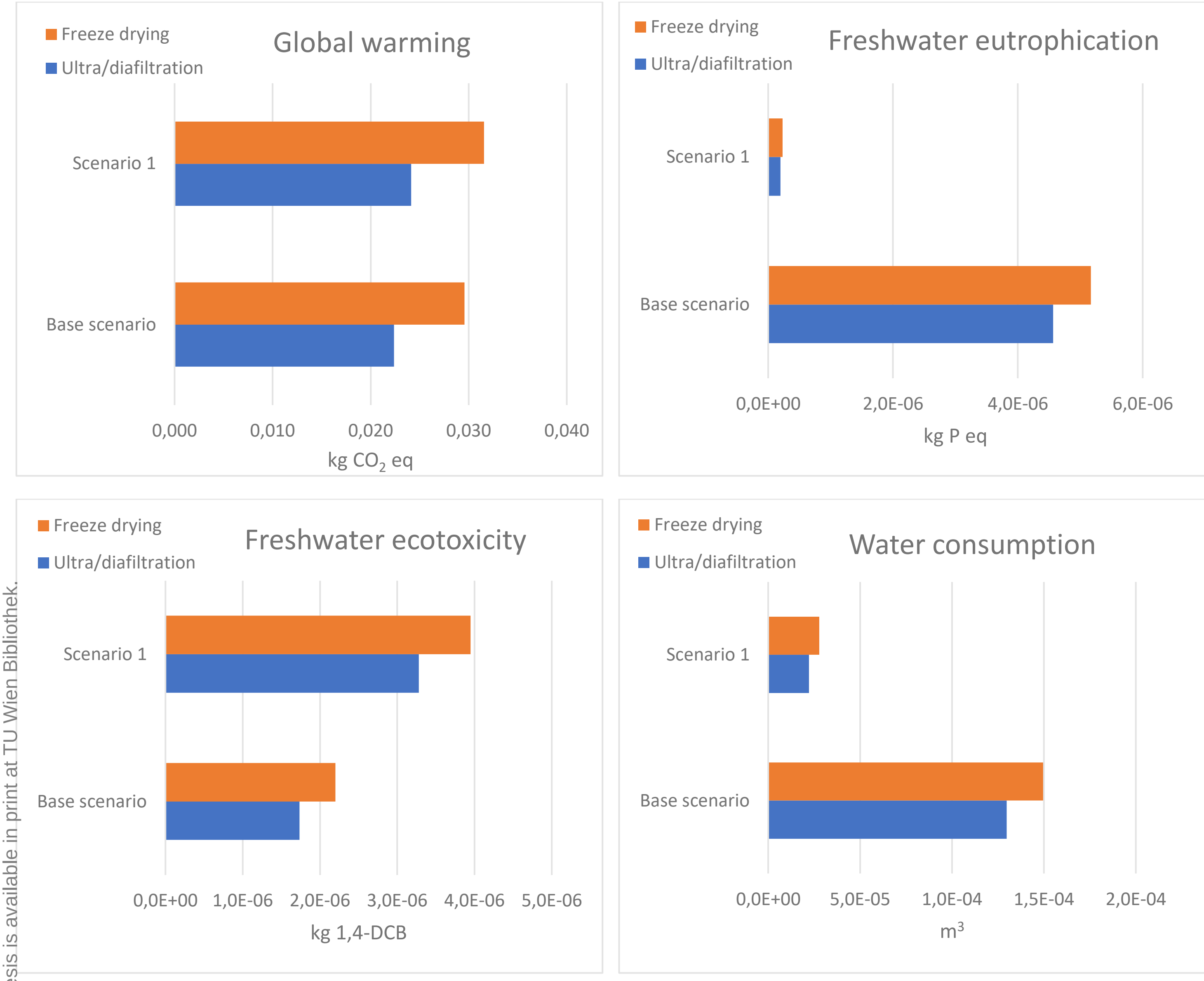


Figure 20: Sensitivity analysis for ventilation in two steps during the production according to the four studied environmental impact for item 500 IU/20 ml

Certainly, the tables show the same proportion between the Base Scenario and Scenario 1. The Scenario 1 shows a higher greenhouse gas emission and freshwater ecotoxicity, but the water consumption and the eutrophication are reduced in this case.

Table 19: Base scenario and one more scenario for the ventilation in step ultra/diafiltration in case of item 500 IU/20 ml

Impact category	Unit	Base scenario	Scenario 1
Global warming	kg CO_2 eq.	0,022	0,024
Freshwater eutrophication	kg P eq.	4,6E-06	2,0E-07
Freshwater ecotoxicity	kg 1,4-DCB	1,7E-06	3,3E-06
Water consumption	m^3	1,3E-04	2,2E-05

Table 20: Base scenario and one more scenario for the ventilation in step freeze drying in case of item 500 IU/20 ml

Impact category	Unit	Base scenario	Scenario 1
Global warming	kg CO_2 eq.	0,030	0,032
Freshwater eutrophication	kg P eq.	5,2E-06	2,3E-07
Freshwater ecotoxicity	kg 1,4-DCB	2,2E-06	3,9E-06
Water consumption	m^3	1,5E-04	2,8E-05

The major emission from materials comes from the polymers. For instance, in step elution there is used buckets from polyethylene for storage the eluate. The bucket is in contact with the product therefore it must be incinerated (base scenario). Scenario 1 show the values for the studied impact categories if the PE-buckets are recycled and not incinerated. However, it should be remembered, that for the recycling some washing steps are required, which also has environmental effect. Figure 21 and Table 21 depict the difference between the effect of the change in waste management.

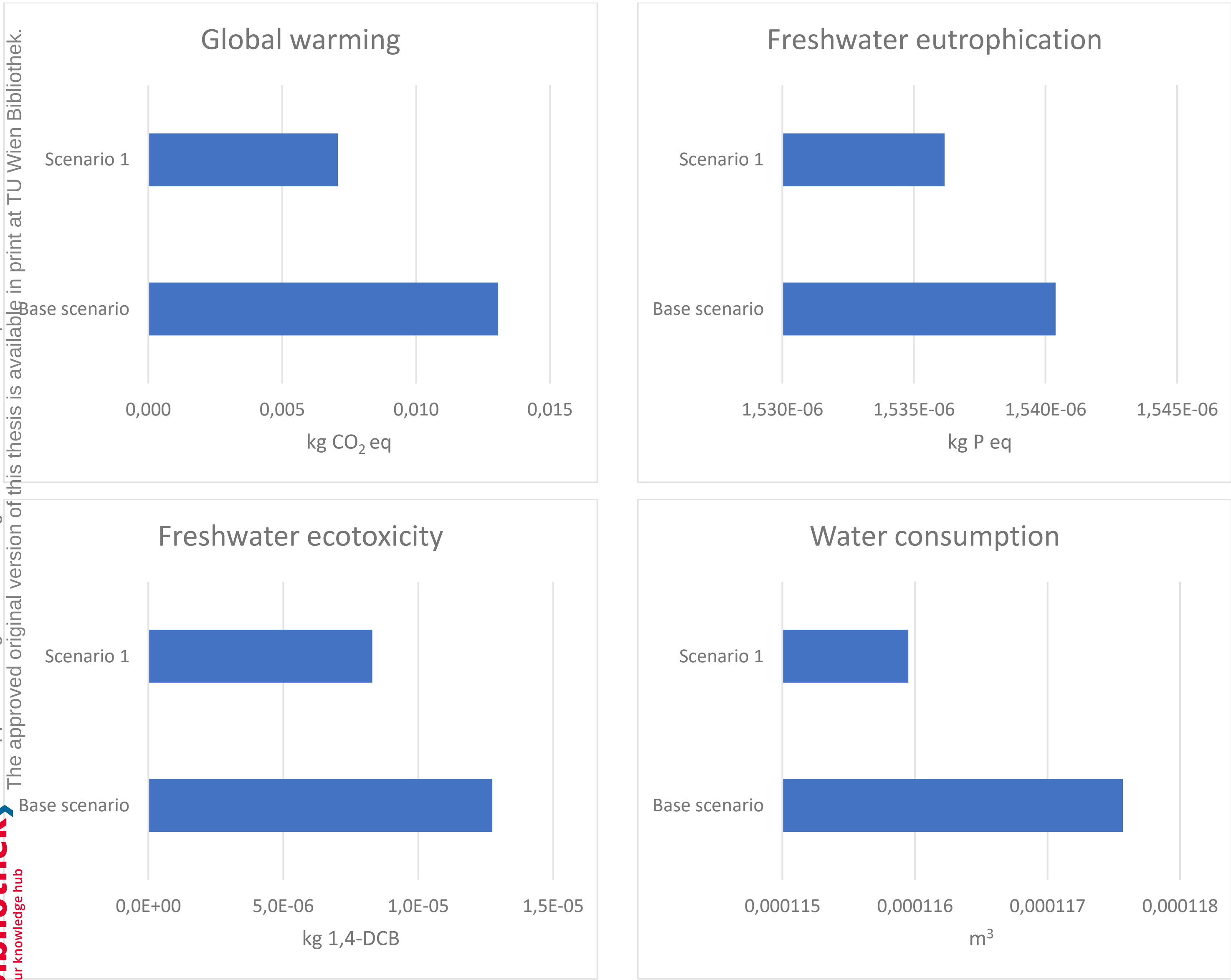


Figure 21: Sensitivity analysis for the material emission in step elution in case of item 500 IU/20 ml

The values of emission come from material are lower because the plastic waste has a positive sign in the emissions, so it will be added, and the recycling has a negative sign, it will be subtracted from the sum of all materials. It means some plastics are produced in this case, not consumed. So, the difference between the scenarios is this waste management step.

Table 21: Base scenario and one more scenario for the material emission in step elution in case of item 500 IU/20 ml

Impact category	Unit	Base Scenario	Scenario 1
Global warming	kg CO_2 eq.	0,0131	0,0071
Freshwater eutrophication	kg P eq.	1,540E-06	1,536E-06
Freshwater ecotoxicity	kg 1,4-DCB	1,3E-05	8,3E-06
Water consumption	m^3	0,000118	0,000116

The emissions in all impact categories are lower with recycling than with incineration waste management. Regarding CO_2-emission, almost the half of the emitted greenhouse gases could be saved with this treatment. Also, the ecotoxicity shows a larger difference, water consumption and eutrophication do not present a significant difference.

DISCUSSION

In this thesis a method was improved that is able to quantify the environmental impacts of pharmaceutical products from a manufacturing perspective look. This method contains data collection and evaluation, work with software, sensitivity analysis and the interpretation of the results. This method is based on a cradle-to-grave life cycle assessment but focused primarily on the core processes.

During the production of the examined product the following emissions were relevant: CO_2 emissions, water consumption, freshwater eutrophication and freshwater ecotoxicity. The greenhouse gas emission is one of the most significant problems these days, and the product has a large water demand during the production, therefore all related impact categories were studied. For quantifying these emissions, all material and water consumption and energy demand, waste and waste water treatment data, transportation data were collected, and the greenhouse gas emissions were distinguished by the three scopes: Scope 1 from company production facilities, Scope 2 from the purchased energy, and Scope 3 from all indirect emissions, from purchased goods and services, use of product, end-of-life treatment.

Finding an article which is similar to this work was difficult because of the type of the pharmaceutical product, the data collection from the company, the multi-purpose plant, and the product system.

Comparing the above-mentioned three LCAs of other pharmaceutical products, they discussed also different impact categories, beside the global warming potential, eutrophication and ecotoxicity, they also mentioned acidification, abiotic depletion, and photochemical formation oxidation potential. The concrete result of this LCA is not comparable to the three pharmaceutical products, since the type of LCA, the product system and therefore the system boundaries, the size of product, the pharmaceutical processes and also the functional units are different. Despite of these facts, the results of those study are presented to get some information about other LCAs and highlight the results of the impact categories which coincide with the examined impact categories of this thesis.

The first article was about a general pharmaceutical product, where the functional unit is one package, so 10 tablets of ibuprofen. In Figure 22 there are the results for all impact categories, the global warming potential of this product is 0.145 kg CO_2-eq.

Impact category	LCIA result
Abiotic depletion (ADP elements) [kg Sb-eq.]	3.45E-7
Abiotic depletion (ADP fossil) [MJ]	2.23
Global Warming (GWP) (excl. biogenic carbon) [kg CO_2-eq.]	0.145
Ecotoxicity (recommended and interim) [CTUe]	269
Human toxicity (cancer) (recommended and interim) [CTUh]	5.13E-9
Human toxicity (non-cancer) (recommended and interim) [CTUh]	1.08E-7

Figure 22: LCIA results for Eudorlin® Extra
(Siegert, et al., 2020)

Figure 23 shows the contribution of the life cycles (such as Use and EoL, Distribution and Production) to the impact categories.

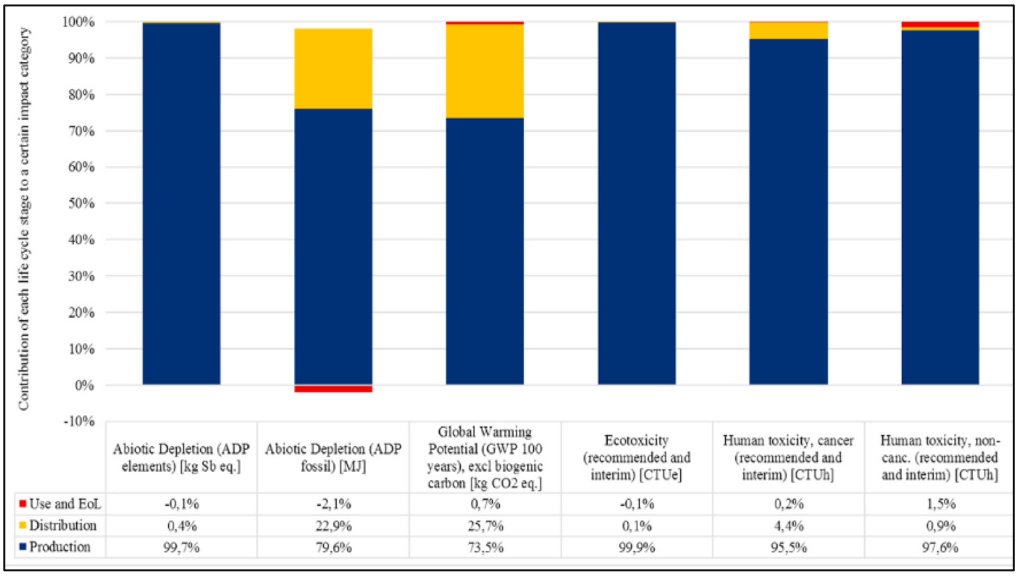


Figure 23: LCIA results for Eudorlin® Extra - The environmental profile illustrates the relative contribution of each life cycle stage to a certain impact category
(Siegert, et al., 2020)

The second article deals with three enzymes, the functional unit is 1 kg of them, the exact results are in Figure 24, where the greenhouse gas emissions are respectively 25, 16 and 17 kg CO_2-eq., and the eutrophication are 18, 12, and 14 kg P-eq. The diagrams also show the division after process steps.

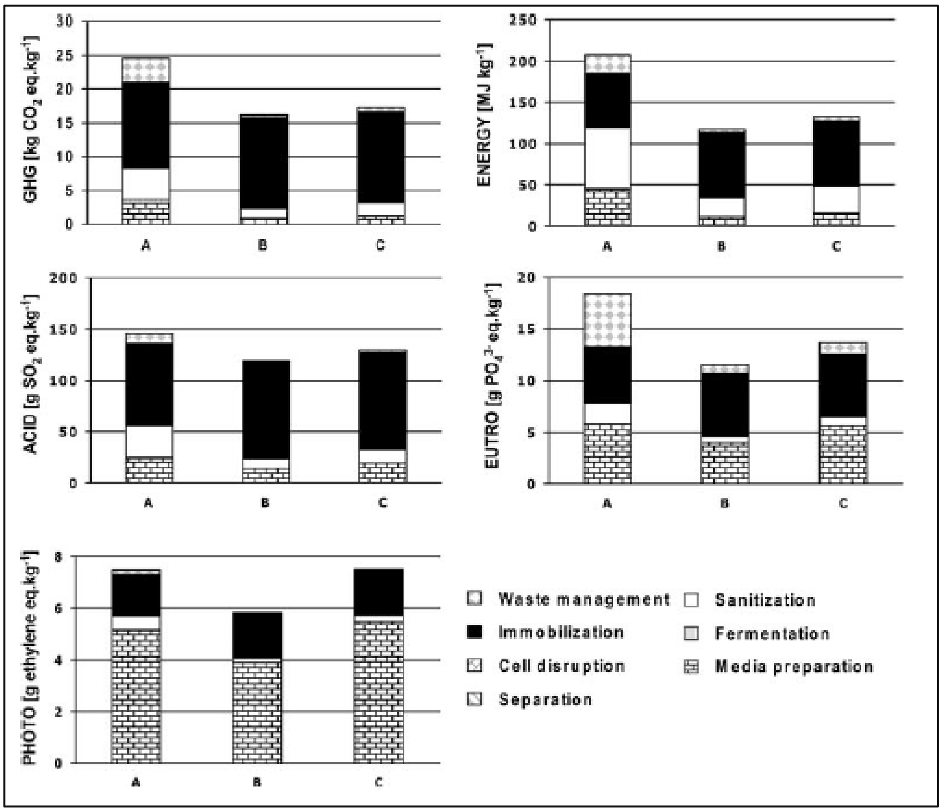


Figure 24: Selected environmental impacts associated with the immobilized enzyme production systems A, B, and C *(Kim, Jiménez-González, & Dale, 2009)*

Because of the same source of the product, the plasma-derived Albumin from Kedrion could be a frame of reference, however the pharmaceutical processes and the used protein are not the same, so they still have some discrepancies. Also, the functional unit is different, in this case is a 20 % solution in 50 ml volume. In Figure 25 the results of different impact categories are represented, as before, and the same categories are highlighted such as global warming potential, here is for one kit total 5.8 kg CO_2-eq. and eutrophication ($3.46 * 10^{-3}$ kg P eq.). Also, the water scarcity potential is 2.4 m^3 for this item.

		Unit			[redacted] EU	Total
Global warming potential (GWP)	Fossil	kg CO_2 eq	9.49E-01	4.70E+00	3.64E-02	**5.68E+00**
	Biogenic	kg CO_2 eq	4.48E-02	5.76E-02	3.65E-04	**1.03E-01**
	Land use and land transformation	kg CO_2 eq	1.08E-02	3.14E-04	8.90E-06	**1.12E-02**
	total	kg CO_2 eq	1.01E+00	4.75E+00	3.68E-02	**5.80E+00**
Depletion potential of the stratospheric ozone layer (ODP)		kg CFC 11 eq	3.34E-07	5.30E-07	2.24E-09	**8.66E-07**
Acidification potential (AP)		kg SO_2 eq	3.34E-03	6.43E-03	9.49E-05	**9.86E-03**
Eutrophication potential (EP)		kg PO_4^{3-} eq	1.26E-03	2.17E-03	3.00E-05	**3.46E-03**
Formation potential of tropospheric ozone (POFP)		kg NMVOCeq	3.09E-03	2.76E-02	1.22E-04	**3.08E-02**
Abiotic depletion potential – Elements		kg Sb eq	2.60E-06	1.08E-06	1.86E-08	**3.70E-06**
Abiotic depletion potential – Fossil resources		MJ net calorific value	2.12E+01	4.50E+01	1.91E-01	**6.64E+01**
Water scarcity potential		m^3 eq	5.24E-01	1.88E+00	2.66E-03	**2.40E+00**

Figure 25: Environmental Impact Potentials referred to the ALBUMIN 20% 50mL production system per FU (2017) *(Kedrion, 2018)*

Finding the relevant information sources was time-demanding because of the complexity of the production. The material and water consumption are recorded in an internal program of the company. The waste treatment is also documented. The emissions from company production facilities are already measured and as live data accessible. For owning the electricity data, the implementation of some measurement was necessary. The production of other materials and some transport data are from the Ecoinvent databases, since those data are industrial secrets of other companies, or it was not accomplishable to measure them. The above-mentioned LCAs also use data from company databases as well as from the general databases.

The execution of allocation was a challenging task in a multi-process and multi-product system. The starting material was the same for more products, so in the first steps of the production the allocation is necessary, because not all the emissions are from the studied product. In that case the allocation was accomplished according to the protein amount of the products. The company makes a profit based on the amount of protein in each product, so it is a mass and economic allocation at the same time. In the first factory level the products (and so the emissions) were distinguished, in the second factory only waste was produced no other product.

Breaking down the gathered data into process steps presented some difficulties because systems and databases typically focus on the product rather than the individual steps. Furthermore, the multi-product system of the production also made it more challenging as the allocation had to be taken into account per steps.

The method can estimate the environmental effects after modification of process steps; however it is needed to collect the data of the new process step, including materials and energy. In the software it is possible to compare the new step with the old one because a parameter setting is available, and also -as in the sensitivity analysis- it can be experienced the whole process chain with small changes.

Sensitivity analysis was essential, because various factors can contribute to uncertainty in the results of a life cycle assessment study. Unavoidable methodological choices as allocation method, cut-off rules or data collection method can cause uncertainty. In this case, most of them are considerable, e.g., due to complicated process flow and the complex allocation rules. Furthermore, the data collection method and used databases can also cause discrepancy from the real values. Some data were estimated as neglectable and brought under the cut-off rules, which may also contribute to the results.

But, in the sensitivity analysis parameter uncertainty was examined, which shows, changing some parameter how can affect the final values. The three presented cases with different scenarios describe well the importance of the sensitivity analysis. Changing the mean of transportation or the waste treatment of one type of material, or the steam production of the company for a general data from the database already modify some impact categories.

Conclusion

The environmental life cycle inventories and impacts of a plasma-derived product from the pharmaceutical industry were estimated in this thesis. The focus was on the production although the upstream and downstream processes were analysed as well. The system boundaries were defined from the plasmapheresis to the transported product to a distribution centre, the use and end-of-life stages are out of scope. The used materials for production and packaging, the electricity and heating/cooling, transportation of the raw materials and products are in the analysis, as well as the waste treatment during the production and the packaging materials by upstream processes. Testing during the production, transport of other materials and waste, cleaning materials and clothing for the production, such as lab coat, shoes, gloves were not studied.

Since this production is a multi-process and -product system, aside from the studied product, other products contribute to the emissions in the same steps. Therefore, a mass allocation was executed after protein amount of the products.

Four items were compared in the analysis according to four impact categories: global warming potential, freshwater eutrophication, freshwater ecotoxicity, and water consumption.

Some of the general conclusions obtained from this LCA are:

- in the largest amount used material in the production is water (in comparison to chemicals and other materials)
- the most emission come from the downstream processes because the transportation occurs by airplane
- Scope 3 has the largest effect on the environment, so the transport and materials contribute substantially
- item 2500 IU/50 ml has the major impact, and item 500 IU/10 ml the minor
- the main greenhouse gas sources are the steps sterile filling, freeze drying and ultra/diafiltration in the production
- among the plants the third factory has the highest CO_2 emission values

A few sensitivity-analysis were carried out with one or two different scenarios beside the basic scenarios. Changing the mean of transport by downstream processes could save a significantly amount of emission. Instead of incineration a recycling for used polymers would be a better solution, although it should be considered, that those polymers were in contact with the raw materials or product, so more washing steps are needed by the preparation.

So, the calculation includes the most important sources. Certainly, more data could be collected and analysed in a greater detail, but in summary, this method provides a comprehensive overview of the possible emissions in the studied impact categories.

Outlook

The aim of this study was to identify hotspots in environmental effects through one product and to create a monitoring for necessary data which can be a foundation for analysing other products henceforward.

Important question for the future, whether this method could work for the other products since they have different process and amount, and how can be eased and shorted the data collection step?

Avoiding the time demanding steps, in the future the process of this work will be automatized based on those experiences and the production will be evaluated for optimization also from an environmentally aspect avoiding the hotspots. Also, a scientific question can be, how can the digitalisation of this research be carried out?

Because of the aim of the greenhouse gas emission reduction, also new measuring instruments are needed, which may immediately digitize the measured values and make them readable a live data. Because of the huge amount of information, also software and computers should be designed with larger capacity.

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APPENDIX

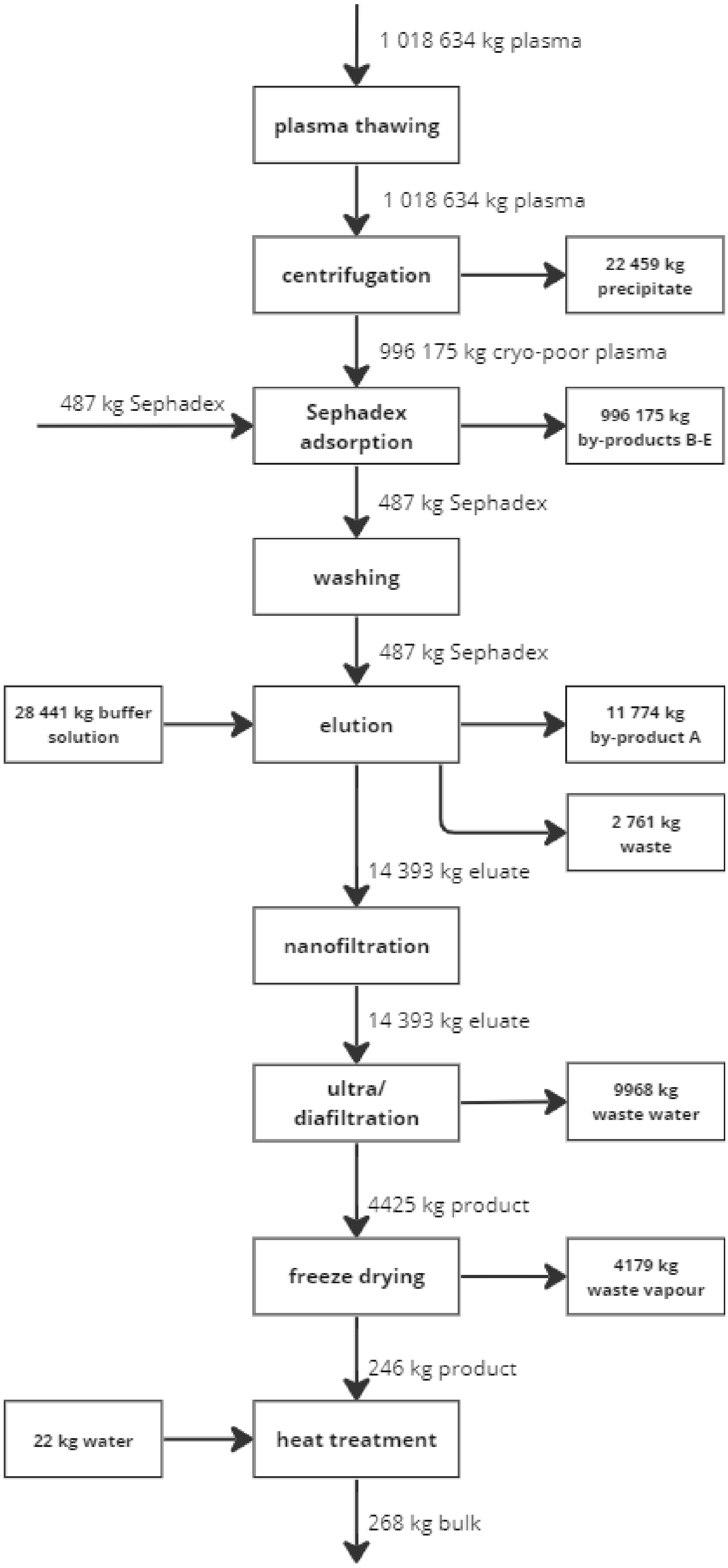

Figure 26: Mass flow for one year of production in the upstream process and in the first and second factories

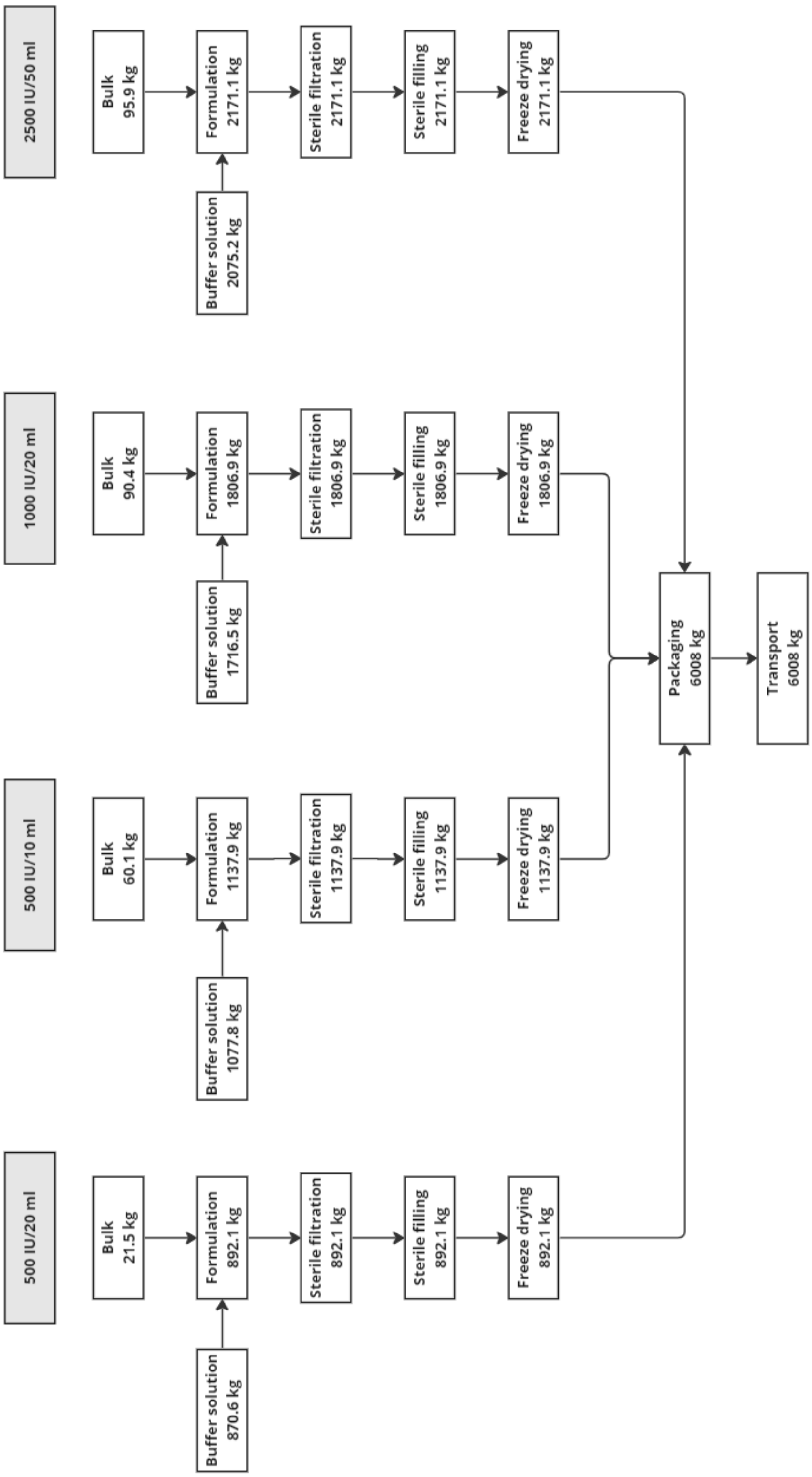

Figure 27: Mass flow for one year of production in the third factory and in downstream process

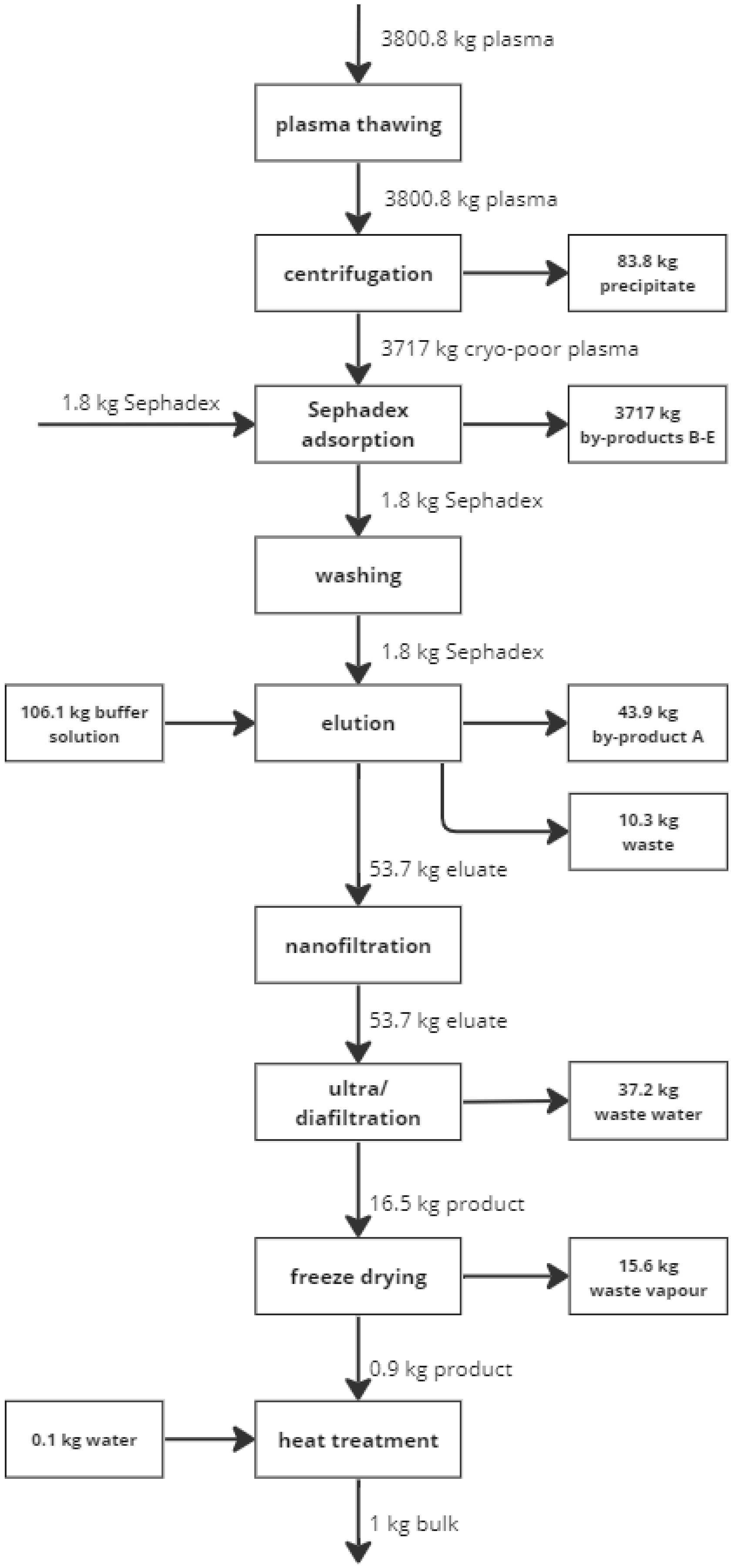

Figure 28: Mass flow for one kilogram product in the upstream process and in the first and second factories

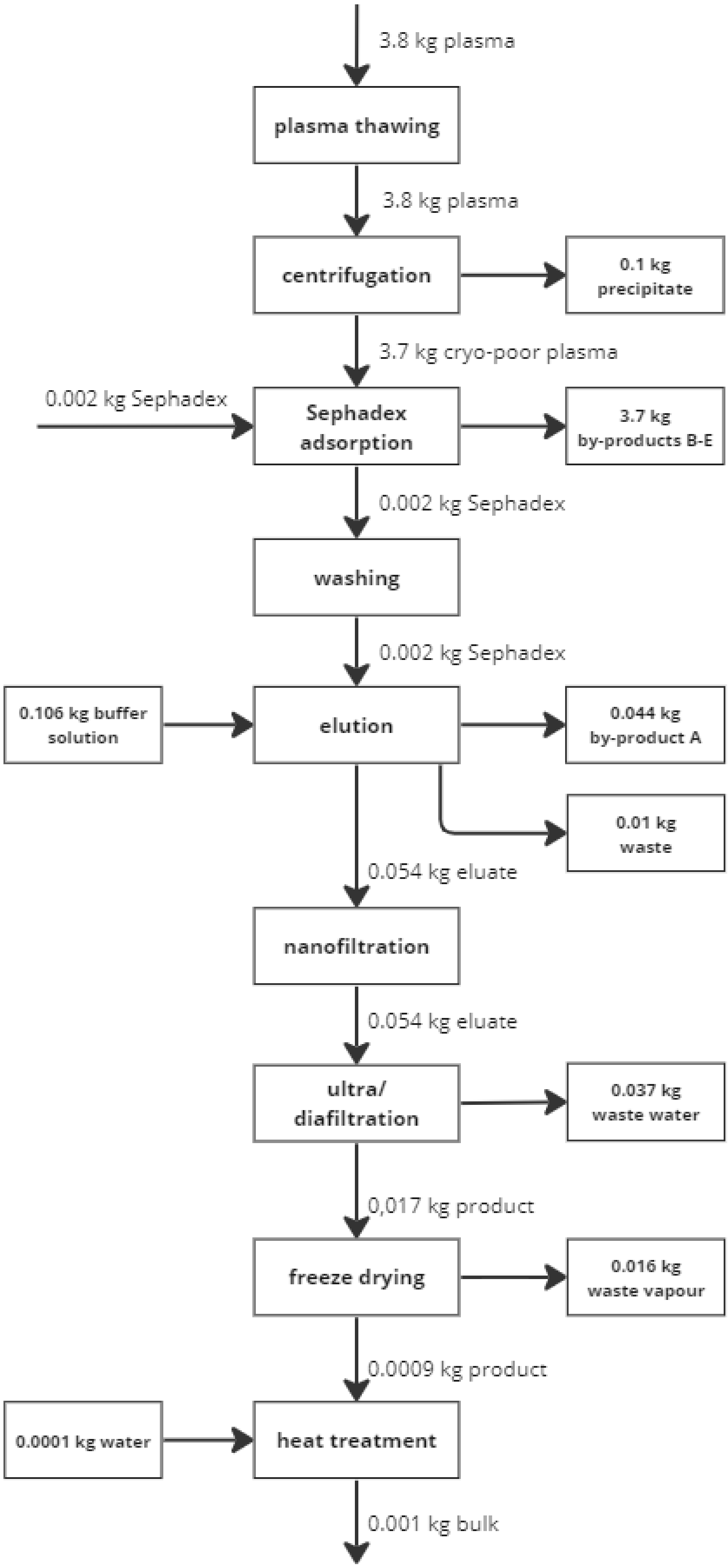

Figure 29: Mass flow for one gram product in the upstream process and in the first and second factories

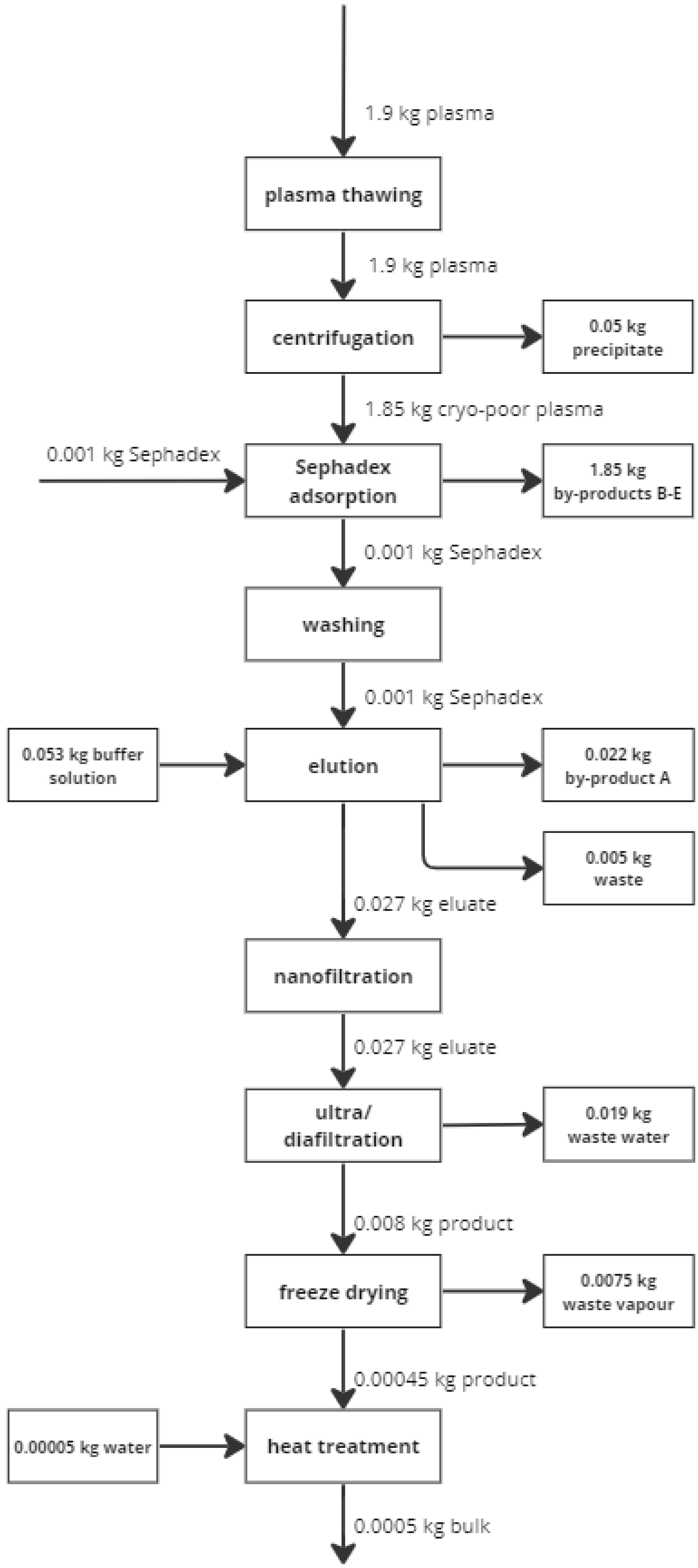

Figure 30: Mass flow for 0,5 gram product in the upstream process and in the first and second factories

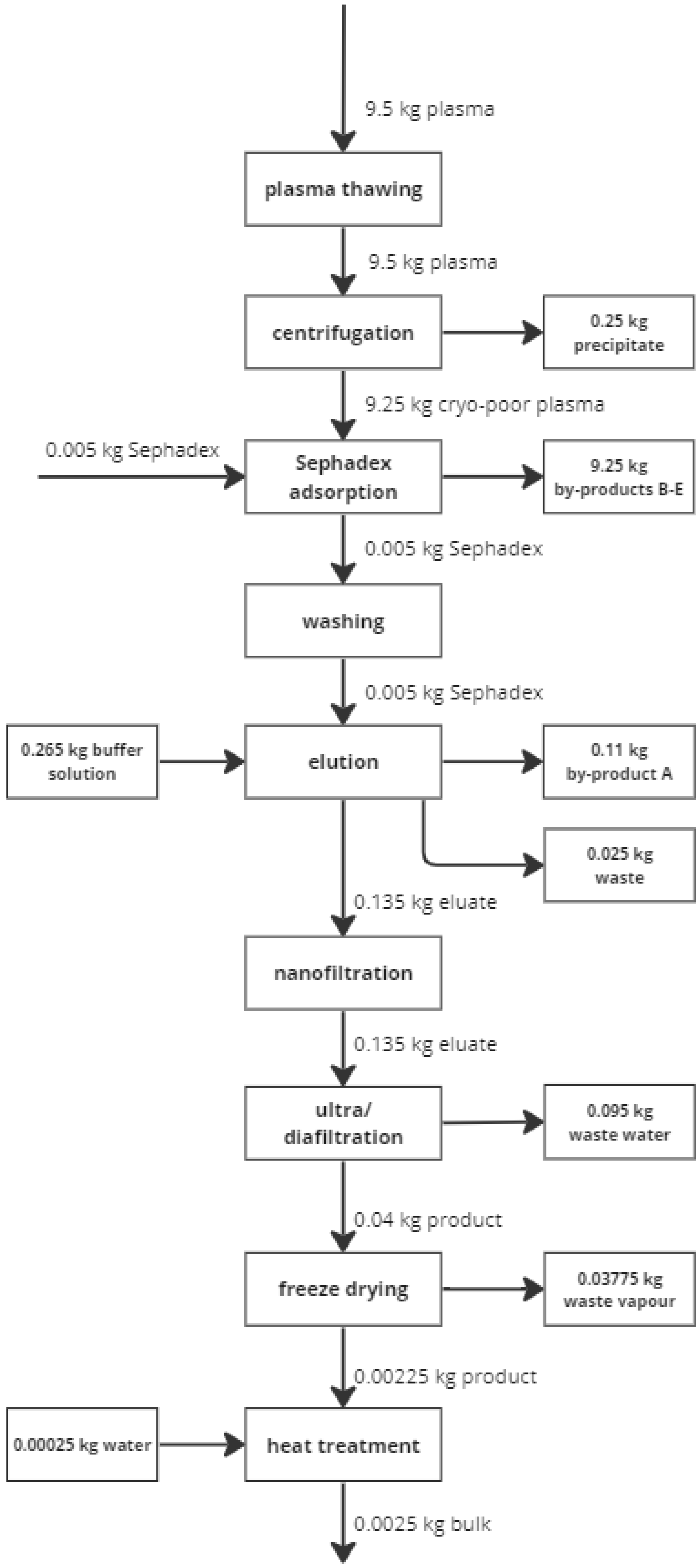

Figure 31: Mass flow for 2,5 gram product in the upstream process and in the first and second factories

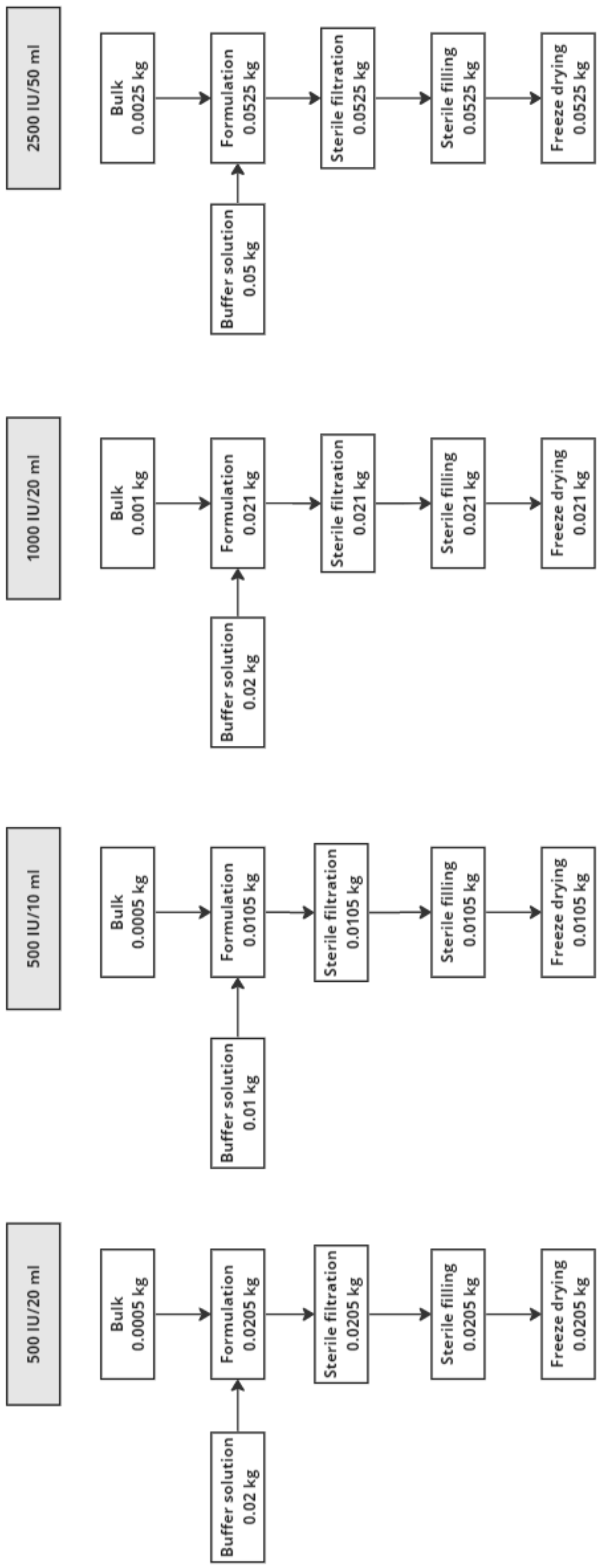

Figure 32: Mass flow for one vial of the 4 different items in the third factory

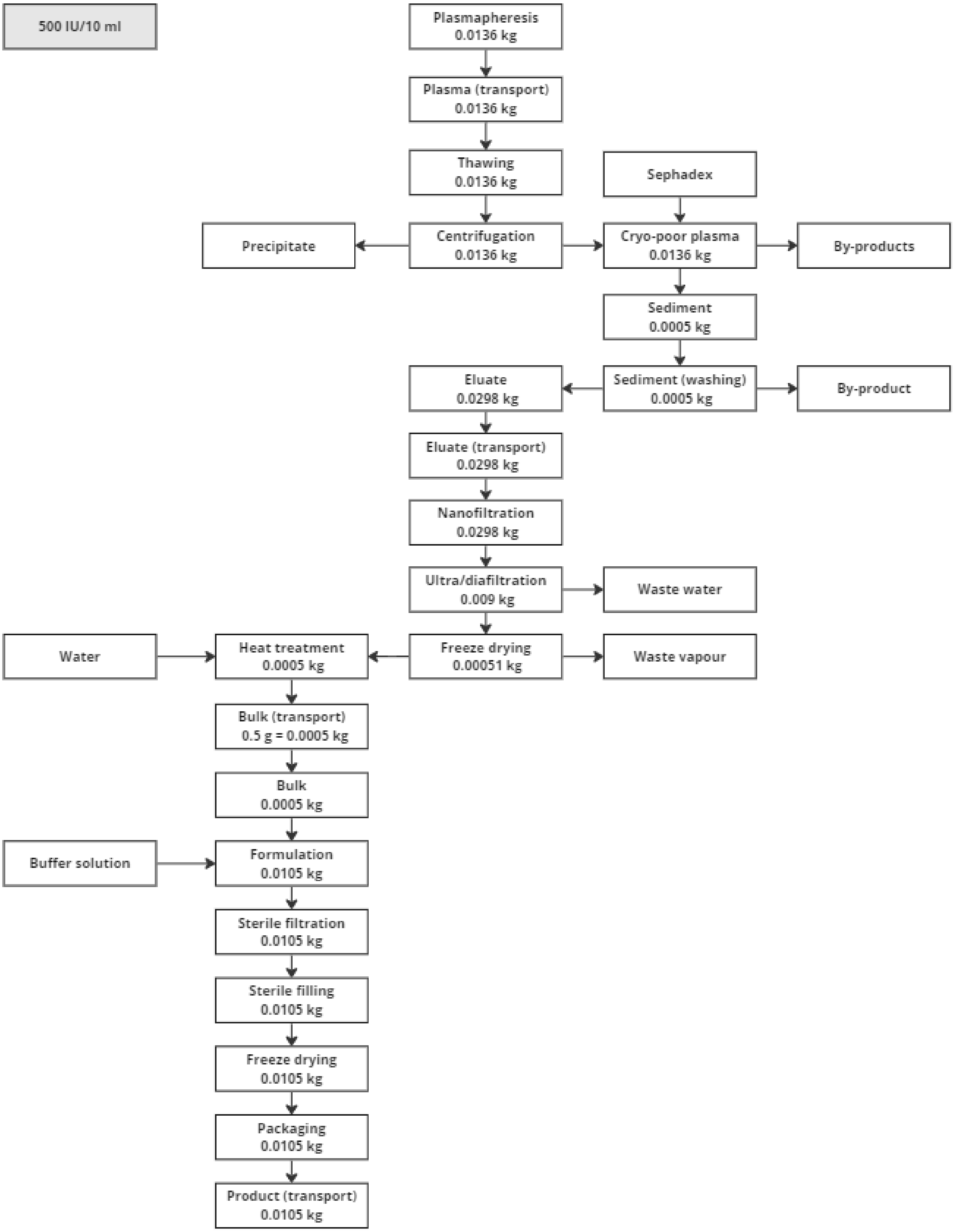

Figure 33: Mass flow according to allocation for product 500 IU/10 ml

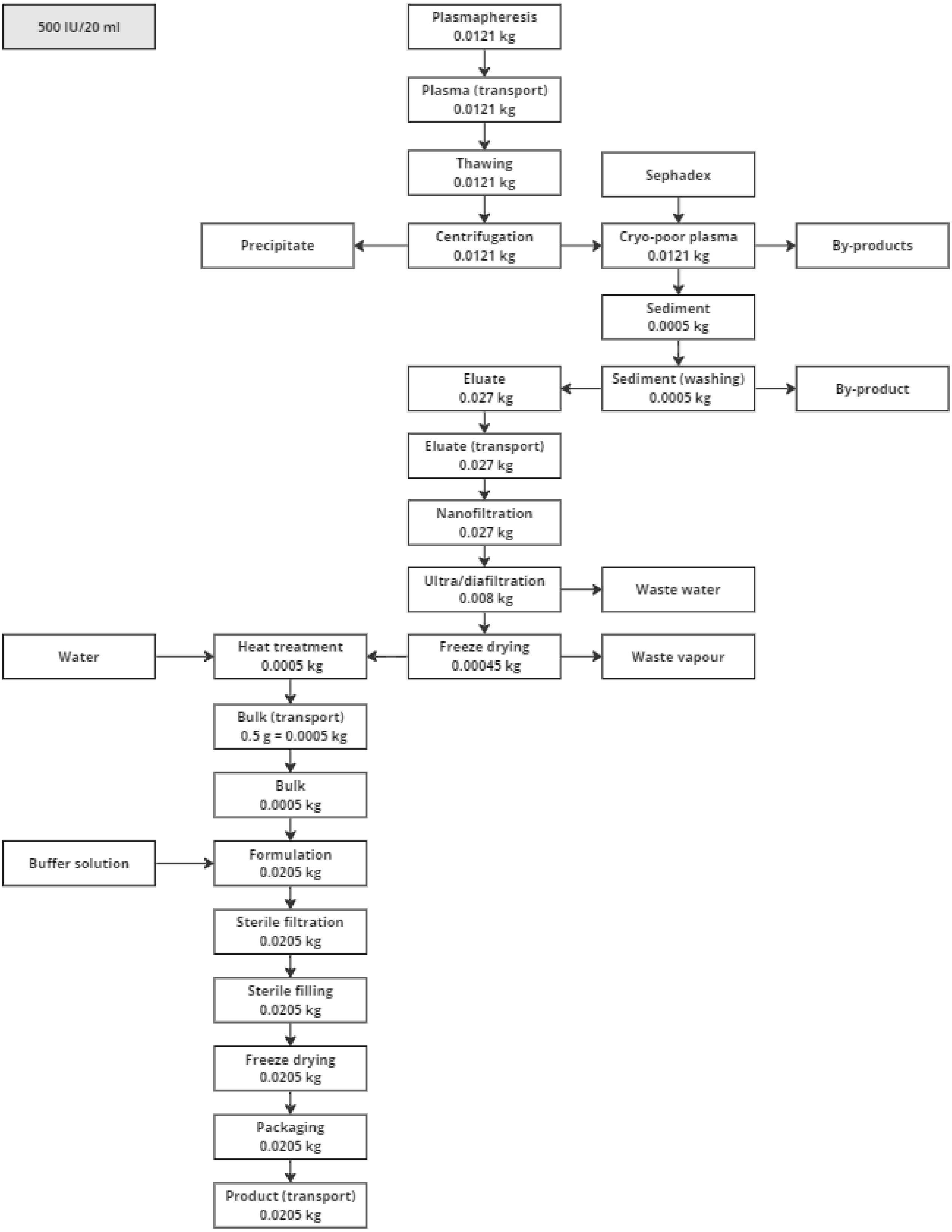

Figure 34: Mass flow according to allocation for product 500 IU/20 ml

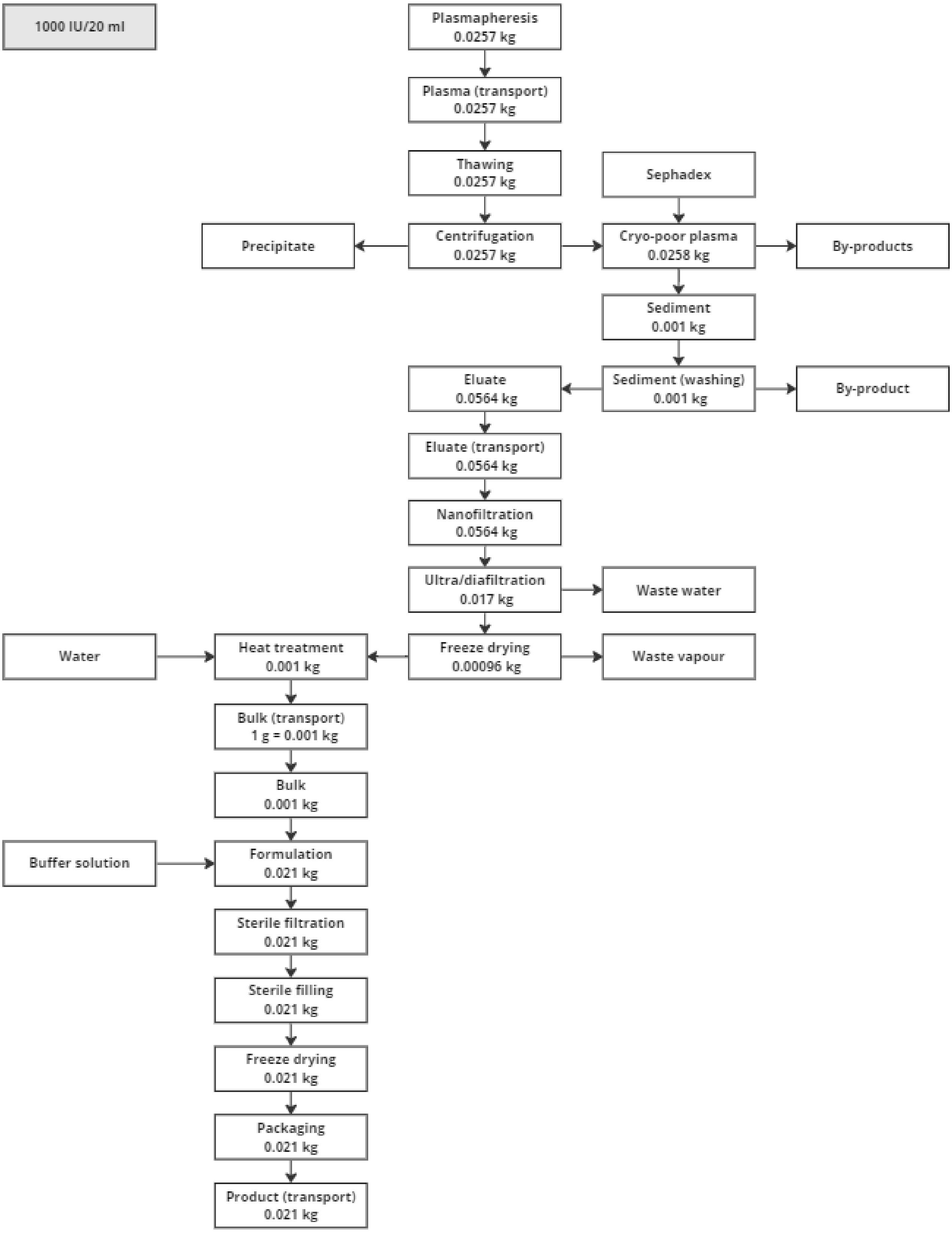

Figure 35: Mass flow according to allocation for product 1000 IU/20 ml

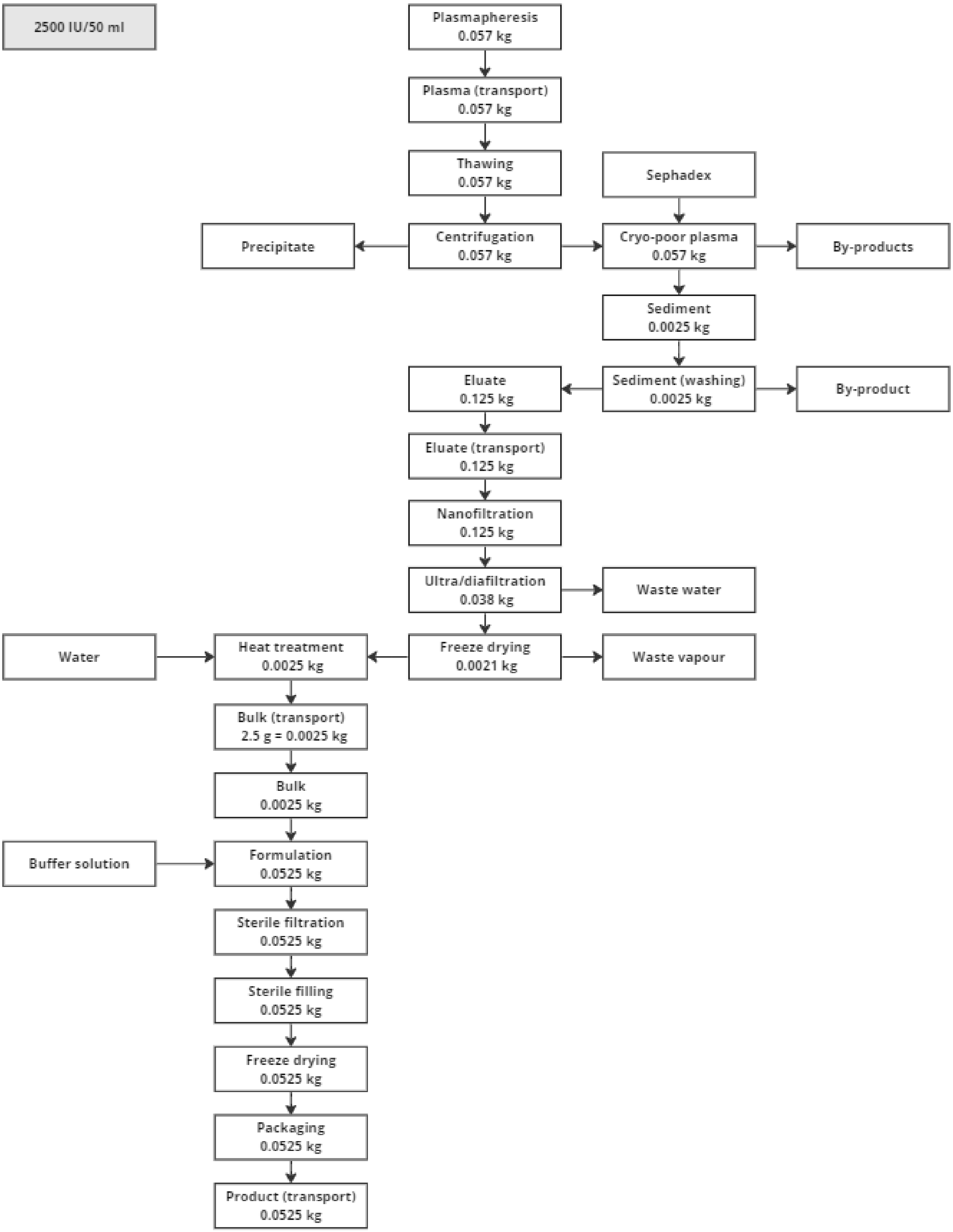

Figure 36: Mass flow according to allocation for product 2500 IU/50 ml

Table 22: The parameters of the analysis in Sima Pro for all steps showed for example 1 kg blood plasma

Calculation:	Analyse
Results:	Impact assessment
Product:	1 kg blood plasma
Method:	ReCiPe 2016 Midpoint (H) V1.05 / World (2010) H
Indicator:	Characterization
Skip categories:	Never
Exclude infrastructure processes:	Yes
Exclude long-term emissions:	Yes
Sorted on item:	Impact category
Sort order:	Ascending

Table 23: The emissions for 1 kg blood plasma

Impact category	Unit	Total	Blood plasma	Tap water
Global warming	kg CO_2 eq.	3,41E-04	0,00E+00	3,41E-04
Stratospheric ozone depletion	kg CFC11 eq.	1,48E-10	0,00E+00	1,48E-10
Ionizing radiation	kBq Co-60 eq.	7,68E-06	0,00E+00	7,68E-06
Ozone formation, Human health	kg NO_x eq.	8,06E-07	0,00E+00	8,06E-07
Fine particulate matter formation	kg $PM_{2.5}$ eq.	5,69E-07	0,00E+00	5,69E-07
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	8,29E-07	0,00E+00	8,29E-07
Terrestrial acidification	kg SO_2 eq.	1,27E-06	0,00E+00	1,27E-06
Freshwater eutrophication	kg P eq.	2,69E-08	0,00E+00	2,69E-08
Marine eutrophication	kg N eq.	2,92E-09	0,00E+00	2,92E-09
Terrestrial ecotoxicity	kg 1,4-DCB	7,49E-04	0,00E+00	7,49E-04
Freshwater ecotoxicity	kg 1,4-DCB	9,63E-07	0,00E+00	9,63E-07
Marine ecotoxicity	kg 1,4-DCB	1,91E-06	0,00E+00	1,91E-06
Human carcinogenic toxicity	kg 1,4-DCB	6,30E-05	0,00E+00	6,30E-05
Human non-carcinogenic toxicity	kg 1,4-DCB	9,95E-05	0,00E+00	9,95E-05
Land use	m^2a crop eq.	8,80E-06	0,00E+00	8,80E-06
Mineral resource scarcity	kg Cu eq.	3,95E-06	0,00E+00	3,95E-06
Fossil resource scarcity	kg oil eq.	9,04E-05	0,00E+00	9,04E-05
Water consumption	m^3	1,01E-03	0,00E+00	1,01E-03

Table 24: The emission for 1 kg blood plasma in step plasmapheresis

Impact category	Unit	Total	Corrugated board box	HDPE	PC	PVC	Steel	Extrusion of plastic sheets S	Extrusion, plastic pipes	Impact extrusion of steel	Printed paper	Board carton	Kraft paper	LDPE	PMMA	Blood plasma	Heat	Electricity	Hazardous waste	Inert waste
Global warming	kg CO_2 eq.	6,85E+00	2,56E-02	4,90E-02	6,20E-03	1,96E-01	2,03E-03	1,69E-01	3,94E-02	2,30E-04	1,50E-02	2,13E-02	2,95E-04	8,42E-03	1,16E+00	3,41E-04	1,22E+00	3,90E+00	3,24E-02	1,18E-03
Stratospheric ozone depletion	kg CFC11 eq.	2,07E-06	1,95E-08	8,21E-09	2,22E-09	1,49E-07	6,45E-10	6,61E-08	1,32E-08	8,80E-11	9,57E-09	9,97E-09	2,66E-10	1,40E-09	9,52E-09	1,48E-10	2,98E-07	1,48E-06	1,04E-08	8,60E-10
Ionizing radiation	kBq Co-60 eq.	1,02E-01	8,69E-05	1,53E-04	5,24E-07	9,89E-04	1,14E-05	1,55E-03	2,55E-04	2,99E-06	7,62E-05	1,35E-04	1,65E-06	2,88E-05	1,05E-04	7,68E-06	4,65E-03	9,37E-02	8,72E-05	1,63E-05
Ozone formation, Human health	kg NO_x eq.	9,42E-03	6,77E-05	1,13E-04	9,68E-06	4,21E-04	6,01E-06	3,64E-04	9,14E-05	4,95E-07	4,73E-05	7,24E-05	1,41E-06	2,00E-05	2,31E-03	8,06E-07	1,48E-03	4,38E-03	2,39E-05	1,03E-05
Fine particulate matter formation	kg $PM_{2.5}$ eq.	1,39E-02	3,47E-05	5,68E-05	5,81E-06	2,73E-04	8,01E-06	3,60E-04	8,62E-05	4,79E-07	3,16E-05	4,60E-05	6,45E-07	1,01E-05	1,39E-03	5,69E-07	9,36E-04	1,06E-02	1,45E-05	2,94E-06
Ozone formation	kg NO_x eq.	9,79E-03	6,92E-05	1,23E-04	1,00E-05	4,37E-04	6,10E-06	3,69E-04	9,24E-05	4,99E-07	4,90E-05	7,35E-05	1,47E-06	2,20E-05	2,52E-03	8,29E-07	1,52E-03	4,46E-03	2,43E-05	1,05E-05
Terrestrial acidification	kg SO_2 eq.	1,78E-02	7,63E-05	1,32E-04	1,47E-05	5,64E-04	8,78E-06	5,44E-04	1,45E-04	7,80E-07	5,47E-05	7,97E-05	1,39E-06	2,29E-05	4,45E-03	1,27E-06	2,77E-03	8,85E-03	3,16E-05	6,51E-06
Freshwater eutrophication	kg P eq.	4,12E-04	1,39E-06	1,17E-06	7,79E-08	6,83E-06	7,69E-08	8,74E-06	1,81E-06	1,39E-08	9,71E-07	1,15E-06	3,12E-08	2,16E-07	2,88E-05	2,69E-08	1,39E-05	3,46E-04	7,00E-07	1,26E-08
Marine eutrophication	kg N eq.	9,71E-05	1,01E-05	3,11E-07	2,54E-09	4,77E-06	1,58E-08	8,17E-07	1,43E-07	8,02E-10	1,17E-06	4,86E-07	4,53E-08	6,21E-08	6,43E-05	2,92E-09	6,79E-07	1,40E-05	1,59E-07	2,95E-09
Terrestrial ecotoxicity	kg 1,4-DCB	3,88E+00	5,72E-02	4,68E-02	2,00E-03	3,51E-01	6,65E-02	1,13E-01	3,63E-02	1,70E-04	3,54E-02	4,99E-02	3,82E-03	7,66E-03	1,88E-01	7,49E-04	1,75E+00	1,16E+00	1,88E-02	3,49E-03
Freshwater ecotoxicity	kg 1,4-DCB	3,49E-03	9,18E-05	2,84E-05	2,52E-06	1,77E-04	1,26E-05	8,02E-05	1,96E-05	9,82E-08	2,50E-05	2,19E-05	7,62E-07	4,85E-06	4,76E-04	9,63E-07	2,12E-04	2,18E-03	1,53E-04	1,34E-06
Marine ecotoxicity	kg 1,4-DCB	7,90E-03	1,19E-04	6,89E-05	4,13E-06	4,87E-04	4,57E-05	1,78E-04	4,85E-05	2,52E-07	4,11E-05	5,44E-05	3,63E-06	1,16E-05	7,49E-04	1,91E-06	2,52E-03	3,34E-03	2,22E-04	4,59E-06
Human carcinogenic T	kg 1,4-DCB	4,71E-02	3,09E-04	4,80E-04	3,35E-05	3,35E-03	1,16E-03	1,62E-03	6,37E-04	2,53E-06	1,62E-04	3,02E-04	5,98E-06	7,84E-05	6,50E-03	6,30E-05	3,92E-03	2,75E-02	9,34E-04	2,36E-05
Human non-carcinogenic T	kg 1,4-DCB	6,05E-01	5,28E-03	6,25E-03	1,19E-04	4,43E-02	1,60E-03	2,89E-02	6,64E-03	4,72E-05	3,91E-03	4,77E-03	8,66E-05	1,10E-03	1,76E-02	9,95E-05	6,16E-02	4,17E-01	5,84E-03	1,28E-04
Land use	m^{2}a crop eq.	1,45E-01	8,58E-03	4,42E-04	3,36E-06	3,20E-03	8,24E-05	2,33E-03	4,29E-03	3,70E-06	8,44E-03	2,72E-02	7,62E-04	7,85E-05	5,69E-04	8,80E-06	1,06E-02	7,79E-02	1,48E-04	1,88E-04
Mineral resource scarcity	kg Cu eq.	4,62E-03	4,73E-05	7,82E-05	4,56E-07	6,89E-04	2,28E-04	1,54E-04	5,50E-05	2,48E-07	3,54E-05	8,00E-05	5,47E-07	1,33E-05	1,41E-04	3,95E-06	2,86E-04	2,78E-03	2,11E-05	1,86E-06
Fossil resource scarcity	kg oil eq.	2,01E+00	6,60E-03	3,32E-02	1,59E-03	9,33E-02	4,78E-04	4,08E-02	9,56E-03	5,74E-05	4,17E-03	5,71E-03	7,36E-05	5,63E-03	3,71E-01	9,04E-05	4,10E-01	1,02E+00	3,36E-03	7,64E-04
Water consumption	m^3	3,59E-02	2,66E-04	5,77E-04	3,80E-05	2,69E-03	1,69E-05	1,16E-03	8,06E-04	1,93E-06	3,95E-04	1,59E-04	4,59E-06	1,06E-04	4,29E-03	1,01E-03	1,28E-03	2,30E-02	1,14E-04	3,57E-05

Table 25: The emissions of 1 kg transported plasma

Impact category	Unit	Total	Corrugated board box	LDPE	Printed paper	LDPE	PMMA	PVC	PMMA	PMMA	Extrusion of plastic sheets	Extrusion, plastic pipes	Transport, lorry with refrigeration machine,	Transport, sea, container ship with reefer, freezing	Plasma	Hazardous waste	Inert waste
Global warming	kg CO_2 eq.	9,51E+00	5,27E-03	3,59E-03	1,40E-04	1,33E-03	8,70E-03	7,92E-03	1,46E-02	4,14E-01	5,56E-02	1,62E-03	1,98E+00	1,53E-01	6,85E+00	8,41E-03	5,38E-04
Stratospheric ozone d.	kg CFC11 eq.	3,58E-06	4,02E-09	5,97E-10	8,85E-11	2,21E-10	7,12E-11	6,00E-09	1,20E-10	3,39E-09	2,18E-08	5,41E-10	1,34E-06	1,22E-07	2,07E-06	2,69E-09	3,34E-10
Ionizing radiation	kBq Co-60 eq.	1,17E-01	1,79E-05	1,23E-05	7,30E-07	4,55E-06	7,83E-07	3,99E-05	1,32E-06	3,73E-05	5,08E-04	1,00E-05	1,35E-02	9,93E-04	1,02E-01	2,34E-05	6,20E-06
Ozone formation, Human health	kg NO_x eq.	1,59E-02	1,40E-05	8,52E-06	4,50E-07	3,16E-06	1,72E-05	1,70E-05	2,90E-05	8,22E-04	1,20E-04	3,76E-06	2,78E-03	2,70E-03	9,42E-03	6,04E-06	4,14E-06
Fine particulate m.f	kg $PM_{2.5}$ eq.	1,70E-02	7,17E-06	4,33E-06	2,97E-07	1,60E-06	1,04E-05	1,10E-05	1,74E-05	4,94E-04	1,19E-04	3,55E-06	1,57E-03	8,11E-04	1,39E-02	3,68E-06	1,26E-06
Ozone formation	kg NO_x eq.	1,66E-02	1,43E-05	9,37E-06	4,66E-07	3,47E-06	1,89E-05	1,76E-05	3,17E-05	8,99E-04	1,22E-04	3,80E-06	2,92E-03	2,73E-03	9,79E-03	6,14E-06	4,23E-06
Terrestrial acidification	kg SO_2 eq.	2,53E-02	1,57E-05	9,78E-06	5,17E-07	3,62E-06	3,33E-05	2,28E-05	5,59E-05	1,59E-03	1,79E-04	5,93E-06	3,46E-03	2,15E-03	1,78E-02	8,09E-06	2,66E-06
Freshwater eutrophication	kg P eq.	4,45E-04	2,86E-07	9,20E-08	9,00E-09	3,41E-08	2,16E-07	2,76E-07	3,62E-07	1,03E-05	2,88E-06	7,33E-08	1,74E-05	9,37E-07	4,12E-04	1,82E-07	8,56E-09
Marine eutrophication	kg N eq.	1,30E-04	2,09E-06	2,65E-08	1,05E-08	9,80E-09	4,81E-07	1,92E-07	8,08E-07	2,29E-05	2,69E-07	5,83E-09	5,83E-06	6,56E-07	9,71E-05	4,11E-08	2,23E-09
Terrestrial ecotoxicity	kg 1,4-DCB	2,61E+01	1,18E-02	3,27E-03	3,50E-04	1,21E-03	1,41E-03	1,42E-02	2,36E-03	6,69E-02	3,71E-02	1,48E-03	2,18E+01	3,11E-01	3,88E+00	4,69E-03	1,49E-03
Freshwater ecotoxicity	kg 1,4-DCB	7,87E-03	1,89E-05	2,07E-06	2,45E-07	7,65E-07	3,56E-06	7,16E-06	5,97E-06	1,69E-04	2,64E-05	8,01E-07	3,99E-03	1,15E-04	3,49E-03	3,98E-05	5,94E-07
Marine ecotoxicity	kg 1,4-DCB	2,62E-02	2,46E-05	4,93E-06	4,36E-07	1,83E-06	5,61E-06	1,96E-05	9,41E-06	2,67E-04	5,87E-05	1,98E-06	1,74E-02	4,00E-04	7,90E-03	5,78E-05	1,91E-06
Human carcinogenic T	kg 1,4-DCB	8,26E-02	6,38E-05	3,34E-05	2,45E-06	1,24E-05	4,86E-05	1,35E-04	8,16E-05	2,31E-03	5,33E-04	2,59E-05	2,80E-02	3,97E-03	4,71E-02	2,43E-04	1,50E-05
Human non-carcinogenic T	kg 1,4-DCB	1,09E+00	1,09E-03	4,71E-04	3,98E-05	1,74E-04	1,32E-04	1,79E-03	2,21E-04	6,28E-03	9,54E-03	2,72E-04	4,46E-01	1,36E-02	6,05E-01	1,51E-03	6,58E-05
Land use	m^2a crop eq.	2,05E-01	1,77E-03	3,35E-05	7,66E-05	1,24E-05	4,25E-06	1,29E-04	7,14E-06	2,03E-04	7,69E-04	1,75E-04	5,59E-02	6,43E-04	1,45E-01	3,49E-05	1,50E-04
Mineral resource s.	kg Cu eq.	9,20E-03	9,75E-06	5,68E-06	4,58E-07	2,10E-06	1,06E-06	2,78E-05	1,78E-06	5,04E-05	5,07E-05	2,23E-06	4,08E-03	3,42E-04	4,62E-03	5,85E-06	1,55E-06
Fossil resource scarcity	kg oil eq.	2,83E+00	1,36E-03	2,40E-03	3,92E-05	8,88E-04	2,77E-03	3,77E-03	4,66E-03	1,32E-01	1,34E-02	3,92E-04	6,15E-01	4,53E-02	2,01E+00	8,68E-04	2,89E-04
Water consumption	m^3	4,16E-02	5,48E-05	4,51E-05	3,59E-06	1,67E-05	3,21E-05	1,09E-04	5,39E-05	1,53E-03	3,84E-04	3,26E-05	3,19E-03	1,81E-04	3,59E-02	2,95E-05	1,35E-05

Table 26: The emissions of 1 kg plasma in step thawing

Impact category	Unit	Total	HDPE	Extrusion of plastic sheets	Plasma (transported)	Electricity	Ventilation	Waste PE
Global warming	kg CO_2 eq.	9,61E+00	5,93E-04	3,22E-04	9,51E+00	3,85E-03	8,85E-02	9,00E-04
Stratospheric ozone depletion	kg CFC11 eq.	3,62E-06	7,63E-11	1,27E-10	3,58E-06	2,31E-09	3,91E-08	6,54E-11
Ionizing radiation	kBq Co-60 eq.	1,18E-01	2,60E-06	3,36E-06	1,17E-01	4,07E-05	5,23E-04	1,47E-08
Ozone formation, Human health	kg NO_x eq.	1,60E-02	1,09E-06	6,92E-07	1,59E-02	5,16E-06	9,36E-05	1,40E-07
Fine particulate matter formation	kg $PM_{2.5}$ eq.	1,70E-02	4,81E-07	6,84E-07	1,70E-02	2,52E-06	3,99E-05	2,03E-08
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	1,67E-02	1,20E-06	7,03E-07	1,66E-02	5,24E-06	9,56E-05	1,40E-07
Terrestrial acidification	kg SO_2 eq.	2,54E-02	1,36E-06	1,03E-06	2,53E-02	7,52E-06	1,15E-04	6,07E-08
Freshwater eutrophication	kg P eq.	4,59E-04	9,53E-09	1,66E-08	4,45E-04	4,68E-07	1,36E-05	1,03E-10
Marine eutrophication	kg N eq.	1,32E-04	2,38E-09	1,60E-09	1,30E-04	1,16E-08	1,27E-06	3,74E-10
Terrestrial ecotoxicity	kg 1,4-DCB	2,62E+01	2,82E-04	2,16E-04	2,61E+01	1,33E-03	1,84E-02	2,62E-03
Freshwater ecotoxicity	kg 1,4-DCB	7,89E-03	2,83E-07	1,54E-07	7,87E-03	1,21E-06	1,75E-05	5,24E-07
Marine ecotoxicity	kg 1,4-DCB	2,63E-02	6,66E-07	3,44E-07	2,62E-02	3,03E-06	1,13E-04	2,73E-06
Human carcinogenic toxicity	kg 1,4-DCB	8,33E-02	6,38E-06	3,12E-06	8,26E-02	4,01E-05	6,16E-04	1,22E-06
Human non-carcinogenic toxicity	kg 1,4-DCB	1,09E+00	5,04E-05	5,52E-05	1,09E+00	5,85E-04	7,46E-03	4,72E-05
Land use	m^2a crop eq.	2,06E-01	3,94E-06	4,47E-06	2,05E-01	1,15E-04	1,40E-03	1,28E-07
Mineral resource scarcity	kg Cu eq.	9,26E-03	9,43E-07	3,07E-07	9,20E-03	3,61E-06	5,51E-05	5,68E-08
Fossil resource scarcity	kg oil eq.	2,86E+00	4,69E-04	7,76E-05	2,83E+00	9,85E-04	2,83E-02	1,94E-06
Water consumption	m^3	4,29E-02	7,21E-06	2,25E-06	4,16E-02	8,15E-05	1,19E-03	8,28E-08

Table 27: The emission of 1 kg cryo-poor plasma in step centrifugation

Impact category	Unit	Total	PET	Extrusion of plastic sheets	Thawed plasma	Electricity	Ventilation	Waste plastic, mixture
Global warming	kg CO_2 eq.	9,60E+00	1,18E-03	4,26E-04	9,59E+00	4,14E-03	1,22E-04	9,31E-04
Stratospheric ozone depletion	kg CFC11 eq.	3,63E-06	7,80E-09	1,65E-10	3,62E-06	2,48E-09	5,38E-11	3,99E-10
Ionizing radiation	kBq Co-60 eq.	1,17E-01	5,21E-06	3,93E-06	1,17E-01	4,38E-05	7,19E-07	4,59E-08
Ozone formation, Human health	kg NO_x eq.	1,60E-02	2,33E-06	8,90E-07	1,60E-02	5,55E-06	1,29E-07	2,40E-07
Fine particulate matter formation	kg $PM_{2.5}$ eq.	1,70E-02	1,34E-06	9,07E-07	1,70E-02	2,71E-06	5,48E-08	3,94E-08
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	1,67E-02	2,45E-06	9,02E-07	1,67E-02	5,64E-06	1,31E-07	2,41E-07
Terrestrial acidification	kg SO_2 eq.	2,54E-02	3,15E-06	1,35E-06	2,54E-02	8,08E-06	1,58E-07	1,14E-07
Freshwater eutrophication	kg P eq.	4,60E-04	2,95E-08	2,21E-08	4,59E-04	5,04E-07	1,87E-08	2,50E-10
Marine eutrophication	kg N eq.	1,32E-04	1,77E-08	1,94E-09	1,32E-04	1,25E-08	1,74E-09	2,20E-09
Terrestrial ecotoxicity	kg 1,4-DCB	2,61E+01	2,46E-03	2,21E-04	2,61E+01	1,43E-03	2,53E-05	4,91E-04
Freshwater ecotoxicity	kg 1,4-DCB	7,88E-03	8,51E-07	1,67E-07	7,88E-03	1,30E-06	2,41E-08	1,09E-06
Marine ecotoxicity	kg 1,4-DCB	2,63E-02	2,83E-06	3,40E-07	2,63E-02	3,26E-06	1,55E-07	1,85E-06
Human carcinogenic toxicity	kg 1,4-DCB	8,32E-02	1,78E-05	1,85E-06	8,32E-02	4,31E-05	8,46E-07	3,79E-06
Human non-carcinogenic toxicity	kg 1,4-DCB	1,09E+00	2,09E-04	6,77E-05	1,09E+00	6,29E-04	1,02E-05	5,51E-05
Land use	m^2a crop eq.	2,06E-01	1,63E-05	3,91E-06	2,06E-01	1,24E-04	1,92E-06	3,05E-07
Mineral resource scarcity	kg Cu eq.	9,26E-03	4,20E-06	9,63E-08	9,25E-03	3,88E-06	7,57E-08	1,03E-07
Fossil resource scarcity	kg oil eq.	2,86E+00	6,11E-04	1,03E-04	2,86E+00	1,06E-03	3,88E-05	3,95E-06
Water consumption	m^3	4,30E-02	1,53E-05	2,91E-06	4,29E-02	8,76E-05	1,64E-06	1,38E-06

Table 28: The emissions of 1 kg sediment in step Sephadex adsorption

Impact category	Unit	Total	Cryo-poor plasma	Sephadex	Electricity
Global warming	kg CO_2 eq.	2,36E+02	2,36E+02	1,50E-02	3,49E-02
Stratospheric ozone depletion	kg CFC11 eq.	8,92E-05	8,91E-05	6,49E-08	2,09E-08
Ionizing radiation	kBq Co-60 eq.	2,88E+00	2,88E+00	8,85E-05	3,68E-04
Ozone formation, Human health	kg NO_x eq.	3,94E-01	3,94E-01	3,34E-05	4,68E-05
Fine particulate matter formation	kg $PM_{2.5}$ eq.	4,17E-01	4,17E-01	3,20E-05	2,28E-05
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	4,09E-01	4,09E-01	3,40E-05	4,75E-05
Terrestrial acidification	kg SO_2 eq.	6,24E-01	6,24E-01	1,23E-04	6,81E-05
Freshwater eutrophication	kg P eq.	1,13E-02	1,13E-02	1,14E-06	4,24E-06
Marine eutrophication	kg N eq.	3,25E-03	3,23E-03	1,45E-05	1,05E-07
Terrestrial ecotoxicity	kg 1,4-DCB	6,42E+02	6,42E+02	3,82E-02	1,21E-02
Freshwater ecotoxicity	kg 1,4-DCB	1,94E-01	1,93E-01	8,06E-05	1,10E-05
Marine ecotoxicity	kg 1,4-DCB	6,46E-01	6,46E-01	5,43E-05	2,75E-05
Human carcinogenic toxicity	kg 1,4-DCB	2,04E+00	2,04E+00	3,24E-04	3,63E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	2,69E+01	2,69E+01	-1,11E-02	5,30E-03
Land use	m^2a crop eq.	5,07E+00	5,06E+00	8,19E-03	1,04E-03
Mineral resource scarcity	kg Cu eq.	2,27E-01	2,27E-01	8,56E-05	3,27E-05
Fossil resource scarcity	kg oil eq.	7,02E+01	7,02E+01	3,79E-03	8,92E-03
Water consumption	m^3	1,06E+00	1,05E+00	3,44E-04	7,38E-04

Table 29: The emissions of 1 kg sediment in step washing

Impact category	Unit	Total	Sediment	NaCl	Na_3PO_4	WFI	Nylon	PET	Textile, non-woven polypropylene	Electricity	Ventilation	Wastewater	Waste plastic, mixture	Waste plastic, mixture
Global warming	kg CO_2 eq.	2,49E+02	2,36E+02	1,99E-01	1,50E+00	3,62E-01	1,41E-01	5,26E-02	9,33E-02	2,84E-01	1,07E+01	6,66E-02	3,91E-02	3,91E-02
Stratospheric ozone depletion	kg CFC11 eq.	9,54E-05	8,92E-05	7,30E-08	3,56E-07	1,79E-07	1,33E-07	3,28E-07	2,07E-08	1,70E-07	4,75E-06	1,71E-07	1,67E-08	1,67E-08
Ionizing radiation	kBq Co-60 eq.	2,97E+00	2,88E+00	1,36E-03	7,27E-03	1,10E-02	5,55E-06	2,04E-04	4,85E-04	2,99E-03	6,35E-02	3,16E-04	1,93E-06	1,93E-06
Ozone formation, Human health	kg NO_x eq.	4,11E-01	3,94E-01	4,89E-04	3,02E-03	6,63E-04	2,39E-04	1,12E-04	1,95E-04	3,80E-04	1,13E-02	2,47E-04	1,01E-05	1,01E-05
Fine particulate matter formation	kg $PM_{2.5}$ eq.	4,28E-01	4,17E-01	4,32E-04	4,40E-03	5,19E-04	1,22E-04	6,39E-05	1,14E-04	1,85E-04	4,84E-03	1,84E-04	1,66E-06	1,66E-06
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	4,26E-01	4,09E-01	4,95E-04	3,07E-03	6,73E-04	2,47E-04	1,17E-04	2,05E-04	3,86E-04	1,16E-02	2,51E-04	1,01E-05	1,01E-05
Terrestrial acidification	kg SO_2 eq.	6,55E-01	6,24E-01	7,77E-04	1,33E-02	1,25E-03	3,97E-04	1,46E-04	2,57E-04	5,53E-04	1,40E-02	4,57E-04	4,79E-06	4,79E-06
Freshwater eutrophication	kg P eq.	1,86E-02	1,13E-02	1,40E-05	6,38E-05	5,38E-03	5,65E-06	1,27E-06	2,74E-06	3,45E-05	1,65E-03	1,12E-04	1,05E-08	1,05E-08
Marine eutrophication	kg N eq.	4,92E-03	3,25E-03	2,09E-05	1,37E-05	7,48E-04	4,02E-05	7,52E-07	7,46E-07	8,55E-07	1,54E-04	6,99E-04	9,25E-08	9,25E-08
Terrestrial ecotoxicity	kg 1,4-DCB	6,51E+02	6,42E+02	5,94E-01	5,96E+00	3,72E-01	1,58E-02	1,31E-01	8,90E-02	9,80E-02	2,24E+00	2,23E-01	2,06E-02	2,06E-02
Freshwater ecotoxicity	kg 1,4-DCB	2,03E-01	1,94E-01	3,38E-04	5,27E-03	3,02E-04	8,75E-05	4,07E-05	5,17E-05	8,90E-05	2,12E-03	1,27E-03	4,59E-05	4,59E-05
Marine ecotoxicity	kg 1,4-DCB	6,77E-01	6,46E-01	9,52E-04	1,30E-02	7,49E-04	1,22E-04	1,36E-04	1,28E-04	2,23E-04	1,37E-02	1,85E-03	7,77E-05	7,77E-05
Human carcinogenic toxicity	kg 1,4-DCB	2,33E+00	2,04E+00	8,99E-03	1,68E-01	1,61E-02	6,42E-04	7,83E-04	9,43E-04	2,95E-03	7,47E-02	1,14E-02	1,59E-04	1,59E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	2,98E+01	2,69E+01	1,24E-01	1,52E+00	7,48E-02	1,68E-03	9,37E-03	1,21E-02	4,31E-02	9,04E-01	3,02E-01	2,31E-03	2,31E-03
Land use	m^2a crop eq.	5,49E+00	5,07E+00	8,83E-03	2,15E-01	8,42E-03	3,06E-05	7,63E-04	9,82E-04	8,47E-03	1,70E-01	3,44E-03	1,28E-05	1,28E-05
Mineral resource scarcity	kg Cu eq.	2,74E-01	2,27E-01	2,27E-03	3,43E-02	1,31E-03	2,74E-05	1,79E-04	1,89E-04	2,65E-04	6,69E-03	1,08E-03	4,32E-06	4,32E-06
Fossil resource scarcity	kg oil eq.	7,43E+01	7,02E+01	4,53E-02	2,86E-01	9,13E-02	4,39E-02	2,63E-02	6,05E-02	7,25E-02	3,43E+00	1,47E-02	1,66E-04	1,66E-04
Water consumption	m^3	1,32E+00	1,06E+00	3,29E-03	7,45E-02	1,39E-01	3,72E-03	6,34E-04	9,37E-04	6,00E-03	1,45E-01	-1,07E-01	5,78E-05	5,78E-05

Table 30: The emissions of 1 kg eluate in step elution

Impact category	Unit	Total	washed sediment	WFI	NaCl	HDPE	Extrusion of plastic sheets and thermoforming	Electricity	Ventilation	Waste PE	Municipal solid waste
Global warming	kg CO_2 eq.	5,19E+00	4,64E+00	3,28E-03	5,24E-03	1,39E-01	7,57E-02	5,28E-03	5,95E-02	2,06E-01	5,49E-02
Stratospheric ozone depletion	kg CFC11 eq.	1,93E-06	1,77E-06	1,63E-09	2,33E-09	1,67E-08	2,96E-08	3,16E-09	2,63E-08	1,49E-08	5,65E-08
Ionizing radiation	kBq Co-60 eq.	5,76E-02	5,53E-02	9,97E-05	1,06E-04	1,02E-03	6,92E-04	5,57E-05	3,52E-04	3,35E-06	1,20E-05
Ozone formation, Human health	kg NO_x eq.	8,25E-03	7,64E-03	6,02E-06	1,22E-05	2,89E-04	1,63E-04	7,07E-06	6,29E-05	3,20E-05	3,35E-05
Fine particulate matter formation	kg $PM_{2.5}$ eq.	8,30E-03	7,96E-03	4,71E-06	9,24E-06	1,22E-04	1,62E-04	3,45E-06	2,68E-05	4,64E-06	6,43E-06
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	8,58E-03	7,93E-03	6,11E-06	1,24E-05	3,29E-04	1,66E-04	7,18E-06	6,43E-05	3,21E-05	3,37E-05
Terrestrial acidification	kg SO_2 eq.	1,29E-02	1,22E-02	1,14E-05	2,23E-05	3,38E-04	2,44E-04	1,03E-05	7,75E-05	1,39E-05	1,74E-05
Freshwater eutrophication	kg P eq.	4,12E-04	3,45E-04	4,89E-05	5,68E-07	3,61E-06	3,92E-06	6,41E-07	9,15E-06	2,35E-08	5,46E-08
Marine eutrophication	kg N eq.	1,02E-04	9,16E-05	6,79E-06	8,11E-07	1,18E-06	3,66E-07	1,59E-08	8,54E-07	8,55E-08	3,10E-07
Terrestrial ecotoxicity	kg 1,4-DCB	1,29E+01	1,21E+01	3,38E-03	2,10E-02	6,05E-02	5,05E-02	1,82E-03	1,24E-02	6,00E-01	2,42E-02
Freshwater ecotoxicity	kg 1,4-DCB	4,27E-03	3,78E-03	2,74E-06	1,21E-05	6,72E-05	3,60E-05	1,66E-06	1,18E-05	1,20E-04	2,34E-04
Marine ecotoxicity	kg 1,4-DCB	1,39E-02	1,26E-02	6,81E-06	3,52E-05	1,50E-04	8,00E-05	4,15E-06	7,59E-05	6,24E-04	3,33E-04
Human carcinogenic toxicity	kg 1,4-DCB	4,72E-02	4,33E-02	1,46E-04	3,39E-04	1,26E-03	7,25E-04	5,50E-05	4,14E-04	2,80E-04	7,01E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	6,13E-01	5,55E-01	6,79E-04	4,45E-03	1,39E-02	1,30E-02	8,02E-04	5,01E-03	1,08E-02	9,25E-03
Land use	m^2a crop eq.	1,06E-01	1,02E-01	7,65E-05	3,19E-04	1,14E-03	1,05E-03	1,58E-04	9,42E-04	2,94E-05	9,97E-05
Mineral resource scarcity	kg Cu eq.	5,57E-03	5,09E-03	1,19E-05	8,85E-05	2,28E-04	6,90E-05	4,94E-06	3,71E-05	1,30E-05	1,96E-05
Fossil resource scarcity	kg oil eq.	1,53E+00	1,38E+00	8,30E-04	1,23E-03	1,08E-01	1,83E-02	1,35E-03	1,90E-02	4,43E-04	7,82E-04
Water consumption	m^3	2,99E-02	2,46E-02	1,27E-03	1,46E-04	2,28E-03	5,22E-04	1,12E-04	8,02E-04	1,89E-05	1,23E-04

Table 31: The emissions of 1 kg eluate in step transport between the first and second plant

Impact category	Unit	Total	Transport, lorry	Eluate
Global warming	kg CO_2 eq.	5,19E+00	8,81E-04	5,19E+00
Stratospheric ozone depletion	kg CFC11 eq.	1,93E-06	5,62E-10	1,93E-06
Ionizing radiation	kBq Co-60 eq.	5,76E-02	7,35E-06	5,76E-02
Ozone formation, Human health	kg NO_x eq.	8,25E-03	1,26E-06	8,25E-03
Fine particulate matter formation	kg $PM_{2.5}$ eq.	8,30E-03	7,15E-07	8,30E-03
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	8,58E-03	1,34E-06	8,58E-03
Terrestrial acidification	kg SO_2 eq.	1,29E-02	1,63E-06	1,29E-02
Freshwater eutrophication	kg P eq.	4,12E-04	9,32E-09	4,12E-04
Marine eutrophication	kg N eq.	1,02E-04	2,67E-09	1,02E-04
Terrestrial ecotoxicity	kg 1,4-DCB	1,29E+01	9,73E-03	1,29E+01
Freshwater ecotoxicity	kg 1,4-DCB	4,27E-03	1,89E-06	4,27E-03
Marine ecotoxicity	kg 1,4-DCB	1,39E-02	8,00E-06	1,39E-02
Human carcinogenic toxicity	kg 1,4-DCB	4,73E-02	1,80E-05	4,72E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	6,14E-01	2,15E-04	6,13E-01
Land use	m^2a crop eq.	1,06E-01	2,61E-05	1,06E-01
Mineral resource scarcity	kg Cu eq.	5,57E-03	2,64E-06	5,57E-03
Fossil resource scarcity	kg oil eq.	1,53E+00	2,95E-04	1,53E+00
Water consumption	m^3	2,99E-02	1,92E-06	2,99E-02

Table 32: The emissions of 1 kg product in step nanofiltration

Impact category	Unit	Total	NaCl	PP	Thermo-forming	Extrusion	Cellulose fiber	Thermo-forming	Nylon 6-6	Thermo-forming	Transported eluate	WFI	Ventilation	Electricity	Waste plastic	Waste PP	Waste water
Global warming	kg CO_2 eq.	5,55E+00	1,55E-02	2,69E-03	6,94E-04	6,98E-04	1,10E-02	2,11E-02	3,07E-02	2,18E-03	5,19E+00	5,75E-03	1,53E-01	2,54E-02	8,90E-02	2,75E-03	9,29E-04
Stratospheric ozone depletion	kg CFC11 eq.	2,08E-06	6,23E-09	3,48E-10	2,61E-10	2,89E-10	4,76E-09	7,93E-09	2,91E-08	8,20E-10	1,93E-06	2,85E-09	4,24E-08	1,52E-08	3,81E-08	2,00E-10	2,70E-09
Ionizing radiation	kBq Co-60 eq.	5,87E-02	1,29E-04	5,23E-06	5,83E-06	6,32E-06	7,27E-05	1,77E-04	3,59E-07	1,83E-05	5,76E-02	1,75E-04	1,58E-04	2,69E-04	4,38E-06	4,77E-08	8,68E-06
Ozone formation, Human health	kg NO_x eq.	8,64E-03	5,01E-05	5,54E-06	1,50E-06	1,49E-06	4,46E-05	4,55E-05	5,17E-05	4,71E-06	8,25E-03	1,05E-05	1,17E-04	3,41E-05	2,29E-05	4,30E-07	3,49E-06
Fine particulate matter formation	kg $PM_{2.5}$ eq.	8,51E-03	3,25E-05	2,70E-06	1,45E-06	1,49E-06	2,44E-05	4,41E-05	2,64E-05	4,56E-06	8,30E-03	8,26E-06	3,70E-05	1,66E-05	3,77E-06	6,39E-08	2,43E-06
Ozone formation, T	kg NO_x eq.	8,99E-03	5,08E-05	5,89E-06	1,52E-06	1,51E-06	4,55E-05	4,63E-05	5,35E-05	4,79E-06	8,58E-03	1,07E-05	1,21E-04	3,46E-05	2,30E-05	4,31E-07	3,55E-06
Terrestrial acidification	kg SO_2 eq.	1,34E-02	6,38E-05	6,98E-06	2,22E-06	2,23E-06	5,33E-05	6,75E-05	8,63E-05	6,98E-06	1,29E-02	1,99E-05	9,57E-05	4,96E-05	1,09E-05	1,87E-07	6,81E-06
Freshwater eutrophication	kg P eq.	5,38E-04	9,97E-07	5,14E-08	3,38E-08	3,58E-08	3,34E-07	1,03E-06	1,23E-06	1,06E-07	4,12E-04	8,56E-05	3,12E-05	3,09E-06	2,39E-08	3,33E-10	1,78E-06
Marine eutrophication	kg N eq.	1,40E-04	1,44E-06	1,09E-08	3,91E-09	3,75E-09	2,71E-07	1,19E-07	8,77E-06	1,23E-08	1,02E-04	1,19E-05	4,36E-06	7,67E-08	2,10E-07	1,15E-09	1,11E-05
Terrestrial ecotoxicity	kg 1,4-DCB	1,31E+01	6,83E-02	2,60E-03	5,19E-04	5,32E-04	4,70E-02	1,58E-02	1,91E-03	1,63E-03	1,29E+01	5,92E-03	1,01E-02	8,79E-03	4,70E-02	8,02E-03	3,50E-03
Freshwater ecotoxicity	kg 1,4-DCB	4,50E-03	2,83E-05	1,45E-06	3,94E-07	3,70E-07	2,13E-05	1,20E-05	1,89E-05	1,24E-06	4,27E-03	4,81E-06	1,19E-05	7,98E-06	1,04E-04	1,61E-06	2,01E-05
Marine ecotoxicity	kg 1,4-DCB	1,46E-02	8,74E-05	3,63E-06	8,57E-07	8,21E-07	5,71E-05	2,61E-05	2,55E-05	2,70E-06	1,39E-02	1,19E-05	2,74E-04	2,00E-05	1,77E-04	8,34E-06	2,95E-05
Human carcinogenic toxicity	kg 1,4-DCB	5,06E-02	6,83E-04	2,42E-05	9,18E-06	7,97E-06	5,75E-04	2,79E-04	1,38E-04	2,89E-05	4,73E-02	2,56E-04	5,20E-04	2,65E-04	3,62E-04	3,87E-06	1,82E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	6,51E-01	8,99E-03	3,16E-04	1,28E-04	1,19E-04	5,50E-03	3,88E-03	3,40E-04	4,01E-04	6,14E-01	1,19E-03	2,05E-03	3,86E-03	5,26E-03	1,44E-04	4,80E-03
Land use	m^2a crop eq.	1,08E-01	7,13E-04	2,12E-05	9,70E-06	1,03E-05	2,42E-04	2,95E-04	2,30E-06	3,05E-05	1,06E-01	1,34E-04	1,63E-04	7,59E-04	2,92E-05	4,12E-07	5,45E-05
Mineral resource scarcity	kg Cu eq.	6,04E-03	1,62E-04	5,50E-06	1,18E-06	8,16E-07	1,41E-04	3,60E-05	5,85E-06	3,73E-06	5,57E-03	2,09E-05	4,57E-05	2,38E-05	9,84E-06	1,87E-07	1,73E-05
Fossil resource scarcity	kg oil eq.	1,62E+00	3,80E-03	1,95E-03	1,63E-04	1,66E-04	2,76E-03	4,95E-03	9,55E-03	5,12E-04	1,53E+00	1,45E-03	5,91E-02	6,50E-03	3,77E-04	6,07E-06	1,99E-04
Water consumption	m^3	3,32E-02	2,37E-04	2,36E-05	4,52E-06	4,77E-06	7,14E-05	1,37E-04	8,11E-04	1,42E-05	2,99E-02	2,22E-03	8,87E-04	5,38E-04	1,32E-04	1,80E-07	-1,70E-03

Table 33: The emissions of 1 kg product in step ultra/diafiltration

Impact category	Unit	Total	Nano-filtered p.	PVDC	PP	Thermo-forming	Extrusion	WFI	NaCl	Citrate	Ventila-tion	Electricity	Waste PP	Waste plastic, mixture	Waste PVDC	Waste water	Waste water
Global warming	kg CO_2 eq.	2,16E+01	1,81E+01	1,41E-02	6,27E-03	3,24E-03	1,17E-03	8,36E-03	3,69E-03	1,90E-02	2,80E+00	6,46E-01	6,41E-03	4,84E-03	5,29E-03	1,10E-03	1,35E-03
Stratospheric ozone depletion	kg CFC11 eq.	8,16E-06	6,76E-06	1,50E-07	8,12E-10	1,22E-09	4,83E-10	4,14E-09	1,48E-09	6,99E-08	7,75E-07	3,87E-07	4,66E-10	2,07E-09	1,02E-09	3,20E-09	3,92E-09
Ionizing radiation	kBq Co-60 eq.	2,01E-01	1,91E-01	3,93E-06	1,22E-05	2,72E-05	1,06E-05	2,54E-04	3,05E-05	1,99E-04	2,90E-03	6,82E-03	1,11E-07	2,38E-07	4,72E-06	1,03E-05	1,26E-05
Ozone formation, Human health	kg NO_x eq.	3,12E-02	2,81E-02	2,83E-05	1,29E-05	6,97E-06	2,49E-06	1,53E-05	1,19E-05	3,97E-05	2,13E-03	8,65E-04	1,00E-06	1,25E-06	2,38E-06	4,13E-06	5,07E-06
Fine particulate matter formation	kg $PM_{2.5}$ eq.	2,89E-02	2,77E-02	2,32E-05	6,30E-06	6,75E-06	2,49E-06	1,20E-05	7,71E-06	3,18E-05	6,77E-04	4,22E-04	1,49E-07	2,05E-07	1,10E-06	2,88E-06	3,53E-06
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	3,25E-02	2,92E-02	2,97E-05	1,37E-05	7,09E-06	2,52E-06	1,56E-05	1,21E-05	4,04E-05	2,21E-03	8,78E-04	1,00E-06	1,25E-06	2,41E-06	4,20E-06	5,16E-06
Terrestrial acidification	kg SO_2 eq.	4,69E-02	4,36E-02	5,90E-05	1,63E-05	1,03E-05	3,73E-06	2,90E-05	1,51E-05	1,13E-04	1,75E-03	1,26E-03	4,36E-07	5,93E-07	2,46E-06	8,06E-06	9,89E-06
Freshwater eutrophication	kg P eq.	2,53E-03	1,75E-03	4,11E-08	1,20E-07	1,58E-07	5,98E-08	1,24E-04	2,36E-07	1,97E-06	5,70E-04	7,85E-05	7,75E-10	1,30E-09	1,88E-08	2,10E-06	2,58E-06
Marine eutrophication	kg N eq.	5,95E-04	4,56E-04	1,63E-08	2,54E-08	1,82E-08	6,27E-09	1,73E-05	3,43E-07	9,47E-06	7,98E-05	1,95E-06	2,69E-09	1,14E-08	1,99E-08	1,32E-05	1,61E-05
Terrestrial ecotoxicity	kg 1,4-DCB	4,32E+01	4,27E+01	4,69E-03	6,06E-03	2,42E-03	8,90E-04	8,60E-03	1,62E-02	3,48E-02	1,84E-01	2,23E-01	1,87E-02	2,55E-03	5,44E-03	4,15E-03	5,09E-03
Freshwater ecotoxicity	kg 1,4-DCB	1,53E-02	1,47E-02	3,86E-05	3,38E-06	1,84E-06	6,18E-07	6,98E-06	6,72E-06	6,94E-05	2,17E-04	2,03E-04	3,74E-06	5,68E-06	8,68E-06	2,38E-05	2,93E-05
Marine ecotoxicity	kg 1,4-DCB	5,34E-02	4,76E-02	5,58E-05	8,47E-06	4,00E-06	1,37E-06	1,73E-05	2,07E-05	7,74E-05	5,02E-03	5,08E-04	1,94E-05	9,62E-06	1,57E-05	3,48E-05	4,28E-05
Human carcinogenic toxicity	kg 1,4-DCB	1,83E-01	1,65E-01	7,17E-04	5,64E-05	4,28E-05	1,33E-05	3,72E-04	1,62E-04	2,92E-04	9,51E-03	6,72E-03	9,02E-06	1,97E-05	4,27E-05	2,15E-04	2,64E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	2,28E+00	2,12E+00	2,15E-03	7,37E-04	5,94E-04	1,99E-04	1,73E-03	2,13E-03	5,27E-03	3,74E-02	9,81E-02	3,36E-04	2,86E-04	7,26E-04	5,68E-03	6,97E-03
Land use	m^2a crop eq.	3,80E-01	3,53E-01	1,26E-05	4,95E-05	4,52E-05	1,72E-05	1,95E-04	1,69E-04	4,24E-03	2,99E-03	1,93E-02	9,60E-07	1,59E-06	2,63E-05	6,45E-05	7,91E-05
Mineral resource scarcity	kg Cu eq.	2,13E-02	1,97E-02	3,30E-06	1,28E-05	5,52E-06	1,36E-06	3,03E-05	3,84E-05	6,14E-05	8,36E-04	6,04E-04	4,35E-07	5,35E-07	4,08E-06	2,05E-05	2,51E-05
Fossil resource scarcity	kg oil eq.	6,54E+00	5,28E+00	3,77E-03	4,54E-03	7,59E-04	2,77E-04	2,11E-03	9,02E-04	5,04E-03	1,08E+00	1,65E-01	1,41E-05	2,05E-05	1,79E-04	2,35E-04	2,89E-04
Water consumption	m^3	1,38E-01	1,08E-01	1,51E-04	5,49E-05	2,11E-05	7,98E-06	3,22E-03	5,62E-05	9,27E-04	1,62E-02	1,37E-02	4,18E-07	7,16E-06	2,33E-04	-2,02E-03	-2,47E-03

Table 34: The emissions of 1 kg product in step freeze drying

Impact category	Unit	Total	Ultra/diafiltered product	Silicone	Extrusion	Electricity	Waste plastic, mixture	Waste water
Global warming	kg CO_2 eq.	5,89E+02	5,20E+02	4,74E-01	8,69E-02	6,83E+01	3,61E-01	9,46E-03
Stratospheric ozone depletion	kg CFC11 eq.	4,32E-04	3,90E-04	4,48E-07	3,60E-08	4,10E-05	1,54E-07	2,43E-08
Ionizing radiation	kBq Co-60 eq.	5,47E+00	4,75E+00	3,45E-03	7,87E-04	7,21E-01	1,78E-05	4,49E-05
Ozone formation, Human health	kg NO_x eq.	9,75E-01	8,82E-01	1,08E-03	1,86E-04	9,15E-02	9,30E-05	3,51E-05
Fine particulate matter formation	kg $PM_{2.5}$ eq.	8,33E-01	7,87E-01	6,53E-04	1,85E-04	4,46E-02	1,53E-05	2,61E-05
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	1,00E+00	9,08E-01	1,12E-03	1,88E-04	9,29E-02	9,33E-05	3,56E-05
Terrestrial acidification	kg SO_2 eq.	1,51E+00	1,38E+00	1,51E-03	2,78E-04	1,33E-01	4,42E-05	6,49E-05
Freshwater eutrophication	kg P eq.	6,02E-02	5,19E-02	1,53E-05	4,45E-06	8,30E-03	9,69E-08	1,59E-05
Marine eutrophication	kg N eq.	1,31E-02	1,28E-02	2,45E-06	4,67E-07	2,06E-04	8,53E-07	9,92E-05
Terrestrial ecotoxicity	kg 1,4-DCB	1,05E+03	1,03E+03	3,89E-01	6,63E-02	2,36E+01	1,90E-01	3,16E-02
Freshwater ecotoxicity	kg 1,4-DCB	4,20E-01	3,98E-01	3,79E-04	4,60E-05	2,14E-02	4,23E-04	1,80E-04
Marine ecotoxicity	kg 1,4-DCB	1,36E+00	1,31E+00	9,30E-04	1,02E-04	5,38E-02	7,17E-04	2,63E-04
Human carcinogenic toxicity	kg 1,4-DCB	6,36E+00	5,64E+00	3,81E-03	9,92E-04	7,11E-01	1,47E-03	1,62E-03
Human non-carcinogenic toxicity	kg 1,4-DCB	8,77E+01	7,71E+01	7,11E-02	1,49E-02	1,04E+01	2,13E-02	4,29E-02
Land use	m^2a crop eq.	1,17E+01	9,65E+00	1,49E-02	1,28E-03	2,04E+00	1,18E-04	4,88E-04
Mineral resource scarcity	kg Cu eq.	9,02E-01	8,37E-01	8,84E-04	1,02E-04	6,39E-02	3,99E-05	1,53E-04
Fossil resource scarcity	kg oil eq.	1,69E+02	1,51E+02	1,69E-01	2,07E-02	1,75E+01	1,53E-03	2,09E-03
Water consumption	m^3	2,37E+01	2,22E+01	1,93E-02	5,94E-04	1,44E+00	5,34E-04	-1,52E-02

Table 35: The emissions of 1 kg product in step heat treatment

Impact category	Unit	Total	Freeze dried product	WFI	PE	Thermo-forming	Extrusion	HDPE	Extrusion	Ventilation	Electricity	Waste PE	Waste plastic, mixture
Global warming	kg CO_2 eq.	4,58E+02	4,19E+02	2,48E-04	2,85E-03	7,28E-04	5,87E-02	4,07E-01	9,47E-02	3,28E+01	4,52E+00	5,03E-01	2,43E-01
Stratospheric ozone depletion	kg CFC11 eq.	1,85E-04	1,72E-04	1,23E-10	4,88E-10	2,73E-10	2,43E-08	6,97E-08	3,92E-08	9,09E-06	2,71E-06	3,66E-08	1,04E-07
Ionizing radiation	kBq Co-60 eq.	4,07E+00	3,98E+00	7,53E-06	6,90E-06	6,11E-06	5,31E-04	9,86E-04	8,57E-04	3,40E-02	4,78E-02	8,21E-06	1,20E-05
Ozone formation, Human health	kg NO_x eq.	6,33E-01	6,00E-01	4,55E-07	6,16E-06	1,57E-06	1,25E-04	8,80E-04	2,02E-04	2,50E-02	6,06E-03	7,83E-05	6,27E-05
Fine particulate matter formation	kg $PM_{2.5}$ eq.	5,29E-01	5,18E-01	3,56E-07	3,01E-06	1,52E-06	1,25E-04	4,30E-04	2,02E-04	7,94E-03	2,95E-03	1,14E-05	1,03E-05
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	6,55E-01	6,21E-01	4,62E-07	6,60E-06	1,59E-06	1,27E-04	9,42E-04	2,05E-04	2,59E-02	6,15E-03	7,85E-05	6,29E-05
Terrestrial acidification	kg SO_2 eq.	9,27E-01	8,96E-01	8,60E-07	7,47E-06	2,33E-06	1,87E-04	1,07E-03	3,03E-04	2,05E-02	8,82E-03	3,40E-05	2,98E-05
Freshwater eutrophication	kg P eq.	5,66E-02	4,94E-02	3,69E-06	5,63E-08	3,54E-08	3,00E-06	8,05E-06	4,85E-06	6,69E-03	5,50E-04	5,75E-08	6,54E-08
Marine eutrophication	kg N eq.	1,10E-02	1,00E-02	5,13E-07	1,13E-08	4,10E-09	3,15E-07	1,61E-06	5,09E-07	9,36E-04	1,36E-05	2,09E-07	5,75E-07
Terrestrial ecotoxicity	kg 1,4-DCB	7,41E+02	7,35E+02	2,55E-04	3,05E-03	5,44E-04	4,47E-02	4,35E-01	7,22E-02	2,16E+00	1,56E+00	1,47E+00	1,28E-01
Freshwater ecotoxicity	kg 1,4-DCB	2,77E-01	2,72E-01	2,07E-07	1,69E-06	4,13E-07	3,11E-05	2,41E-04	5,02E-05	2,54E-03	1,42E-03	2,93E-04	2,85E-04
Marine ecotoxicity	kg 1,4-DCB	9,98E-01	9,32E-01	5,14E-07	4,24E-06	8,98E-07	6,89E-05	6,05E-04	1,11E-04	5,88E-02	3,56E-03	1,53E-03	4,83E-04
Human carcinogenic toxicity	kg 1,4-DCB	3,84E+00	3,68E+00	1,10E-05	3,14E-05	9,62E-06	6,69E-04	4,48E-03	1,08E-03	1,12E-01	4,71E-02	6,84E-04	9,90E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	4,84E+01	4,72E+01	5,13E-05	3,40E-04	1,34E-04	1,00E-02	4,86E-02	1,62E-02	4,39E-01	6,87E-01	2,64E-02	1,44E-02
Land use	m^2a crop eq.	8,32E+00	8,14E+00	5,78E-06	2,38E-05	1,02E-05	8,65E-04	3,40E-03	1,40E-03	3,51E-02	1,35E-01	7,18E-05	7,97E-05
Mineral resource scarcity	kg Cu eq.	4,25E-01	4,11E-01	9,00E-07	4,66E-06	1,24E-06	6,86E-05	6,66E-04	1,11E-04	9,81E-03	4,23E-03	3,18E-05	2,69E-05
Fossil resource scarcity	kg oil eq.	1,38E+02	1,24E+02	6,27E-05	2,00E-03	1,71E-04	1,39E-02	2,86E-01	2,25E-02	1,27E+01	1,16E+00	1,08E-03	1,03E-03
Water consumption	m^3	3,90E+00	3,61E+00	9,57E-05	2,85E-05	4,73E-06	4,01E-04	4,07E-03	6,47E-04	1,90E-01	9,57E-02	4,63E-05	3,60E-04

Table 36: The emissions of 1 kg bulk in step transport between the second and third plant

Impact category	Unit	Total	Corrugated board box	Transport, lorry	Bulk
Global warming	kg CO_2 eq.	4,09E+02	1,32E-01	6,27E-04	4,09E+02
Stratospheric ozone depletion	kg CFC11 eq.	1,48E-04	1,17E-07	4,00E-10	1,48E-04
Ionizing radiation	kBq Co-60 eq.	3,41E+00	9,99E-04	5,23E-06	3,41E+00
Ozone formation, Human health	kg NO_x eq.	9,62E-01	3,66E-04	9,00E-07	9,62E-01
Fine particulate matter formation	kg $PM_{2.5}$ eq.	6,22E-01	1,51E-04	5,09E-07	6,22E-01
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	9,87E-01	3,74E-04	9,52E-07	9,87E-01
Terrestrial acidification	kg SO_2 eq.	1,22E+00	3,91E-04	1,16E-06	1,22E+00
Freshwater eutrophication	kg P eq.	4,50E-02	8,40E-06	6,63E-09	4,50E-02
Marine eutrophication	kg N eq.	9,80E-03	5,56E-05	1,90E-09	9,74E-03
Terrestrial ecotoxicity	kg 1,4-DCB	7,85E+02	3,39E-01	6,92E-03	7,85E+02
Freshwater ecotoxicity	kg 1,4-DCB	2,58E-01	3,49E-04	1,34E-06	2,58E-01
Marine ecotoxicity	kg 1,4-DCB	9,98E-01	5,13E-04	5,70E-06	9,98E-01
Human carcinogenic toxicity	kg 1,4-DCB	3,49E+00	1,66E-03	1,28E-05	3,49E+00
Human non-carcinogenic toxicity	kg 1,4-DCB	3,87E+01	1,90E-02	1,53E-04	3,86E+01
Land use	m^2a crop eq.	6,20E+00	5,15E-02	1,86E-05	6,15E+00
Mineral resource scarcity	kg Cu eq.	4,08E-01	2,75E-04	1,88E-06	4,08E-01
Fossil resource scarcity	kg oil eq.	1,28E+02	3,64E-02	2,10E-04	1,28E+02
Water consumption	m^3	2,40E+00	1,66E-03	1,37E-06	2,40E+00

Table 37: The emissions of 1 kg bulk in step formulation for item 500 IU/20 ml

Impact category	Unit	Total	NaCl	Citrat	HCl	HDPE	Thermo-forming	Ni	PC	Thermo-forming	Transported bulk	WFI	Waste PE	Waste plastic, mixture
Global warming	kg CO_2 eq.	9,88E+00	1,30E-03	7,71E-03	4,71E-04	4,28E-04	1,09E-04	1,43E-03	9,08E-03	6,42E-04	9,85E+00	2,95E-03	5,43E-04	2,51E-03
Stratospheric ozone depletion	kg CFC11 eq.	3,61E-06	4,78E-10	2,83E-08	5,18E-10	7,33E-11	4,10E-11	1,58E-09	3,25E-09	2,41E-10	3,57E-06	1,46E-09	3,94E-11	1,07E-09
Ionizing radiation	kBq Co-60 eq.	8,24E-02	8,88E-06	8,07E-05	1,00E-05	1,04E-06	9,17E-07	3,89E-05	7,67E-07	5,39E-06	8,22E-02	8,95E-05	8,84E-09	1,23E-07
Ozone formation, Human health	kg NO_x eq.	2,32E-02	3,20E-06	1,61E-05	1,07E-06	9,25E-07	2,35E-07	7,43E-06	1,42E-05	1,38E-06	2,32E-02	5,41E-06	8,44E-08	6,46E-07
Fine particulate matter formation	kg $PM_{2.5}$ eq.	1,51E-02	2,83E-06	1,29E-05	1,04E-06	4,52E-07	2,28E-07	4,46E-05	8,51E-06	1,34E-06	1,50E-02	4,23E-06	1,22E-08	1,06E-07
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	2,38E-02	3,24E-06	1,64E-05	1,09E-06	9,91E-07	2,40E-07	7,56E-06	1,47E-05	1,41E-06	2,38E-02	5,49E-06	8,47E-08	6,48E-07
Terrestrial acidification	kg SO_2 eq.	2,96E-02	5,08E-06	4,58E-05	2,77E-06	1,12E-06	3,49E-07	1,50E-04	2,15E-05	2,05E-06	2,94E-02	1,02E-05	3,66E-08	3,07E-07
Freshwater eutrophication	kg P eq.	1,13E-03	9,14E-08	7,99E-07	3,72E-08	8,46E-09	5,32E-09	1,42E-07	1,14E-07	3,13E-08	1,08E-03	4,39E-05	6,20E-11	6,74E-10
Marine eutrophication	kg N eq.	2,46E-04	1,37E-07	3,84E-06	1,12E-08	1,69E-09	6,16E-10	1,72E-07	3,72E-09	3,62E-09	2,36E-04	6,10E-06	2,25E-10	5,93E-09
Terrestrial ecotoxicity	kg 1,4-DCB	1,90E+01	3,89E-03	1,41E-02	1,62E-03	4,58E-04	8,17E-05	3,58E-02	2,93E-03	4,80E-04	1,89E+01	3,04E-03	1,58E-03	1,32E-03
Freshwater ecotoxicity	kg 1,4-DCB	6,27E-03	2,21E-06	2,81E-05	7,55E-07	2,53E-07	6,21E-08	4,42E-06	3,69E-06	3,65E-07	6,22E-03	2,46E-06	3,16E-07	2,94E-06
Marine ecotoxicity	kg 1,4-DCB	2,41E-02	6,23E-06	3,14E-05	2,31E-06	6,37E-07	1,35E-07	2,02E-05	6,04E-06	7,93E-07	2,41E-02	6,11E-06	1,64E-06	4,98E-06
Human carcinogenic toxicity	kg 1,4-DCB	8,45E-02	5,88E-05	1,18E-04	1,39E-05	4,71E-06	1,45E-06	3,70E-05	4,91E-05	8,49E-06	8,41E-02	1,31E-04	7,37E-07	1,02E-05
Human non-carcinogenic toxicity	kg 1,4-DCB	9,37E-01	8,08E-04	2,14E-03	2,20E-04	5,11E-05	2,01E-05	8,26E-04	1,75E-04	1,18E-04	9,32E-01	6,10E-04	2,84E-05	1,48E-04
Land use	m^2a crop eq.	1,51E-01	5,78E-05	1,72E-03	1,74E-05	3,57E-06	1,53E-06	6,55E-05	4,92E-06	8,97E-06	1,49E-01	6,87E-05	7,74E-08	8,22E-07
Mineral resource scarcity	kg Cu eq.	1,04E-02	1,48E-05	2,49E-05	3,27E-06	7,00E-07	1,86E-07	5,45E-04	6,68E-07	1,10E-06	9,83E-03	1,07E-05	3,43E-08	2,77E-07
Fossil resource scarcity	kg oil eq.	3,09E+00	2,97E-04	2,04E-03	1,51E-04	3,01E-04	2,56E-05	5,45E-04	2,34E-03	1,51E-04	3,09E+00	7,45E-04	1,17E-06	1,06E-05
Water consumption	m^3	5,96E-02	2,15E-05	3,76E-04	1,73E-05	4,28E-06	7,11E-07	1,74E-04	5,56E-05	4,18E-06	5,78E-02	1,14E-03	4,99E-08	3,71E-06

Table 38: The emissions of 1 kg bulk in step formulation for item 500 IU/10 ml

Impact category	Unit	Total	NaCl	Citrat	HCl	HDPE	Thermo-forming	Ni	PC	Thermo-forming	Transported bulk	WFI	Waste PE	Waste plastic, mixture
Global warming	kg CO_2 eq.	2,16E+01	6,28E-04	3,70E-03	1,04E-03	8,40E-04	2,14E-04	2,86E-03	1,67E-02	1,18E-03	2,16E+01	2,86E-03	1,06E-03	4,60E-03
Stratospheric ozone depletion	kg CFC11 eq.	7,85E-06	2,30E-10	1,36E-08	1,14E-09	1,44E-10	8,04E-11	3,16E-09	5,97E-09	4,42E-10	7,82E-06	1,42E-09	7,72E-11	1,97E-09
Ionizing radiation	kBq Co-60 eq.	1,80E-01	4,27E-06	3,87E-05	2,21E-05	2,03E-06	1,80E-06	7,80E-05	1,41E-06	9,89E-06	1,80E-01	8,69E-05	1,73E-08	2,27E-07
Ozone formation, Human health	kg NO_x eq.	5,09E-02	1,54E-06	7,72E-06	2,36E-06	1,81E-06	4,61E-07	1,49E-05	2,60E-05	2,54E-06	5,08E-02	5,25E-06	1,65E-07	1,19E-06
Fine particulate matter formation	kg $PM_{2.5}$ eq.	3,30E-02	1,36E-06	6,18E-06	2,31E-06	8,86E-07	4,47E-07	8,94E-05	1,56E-05	2,46E-06	3,28E-02	4,11E-06	2,40E-08	1,95E-07
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	5,22E-02	1,56E-06	7,86E-06	2,41E-06	1,94E-06	4,69E-07	1,51E-05	2,70E-05	2,58E-06	5,21E-02	5,33E-06	1,66E-07	1,19E-06
Terrestrial acidification	kg SO_2 eq.	6,48E-02	2,44E-06	2,20E-05	6,10E-06	2,20E-06	6,85E-07	3,01E-04	3,95E-05	3,77E-06	6,44E-02	9,92E-06	7,18E-08	5,64E-07
Freshwater eutrophication	kg P eq.	2,42E-03	4,39E-08	3,84E-07	8,20E-08	1,66E-08	1,04E-08	2,84E-07	2,09E-07	5,74E-08	2,38E-03	4,26E-05	1,21E-10	1,24E-09
Marine eutrophication	kg N eq.	5,26E-04	6,58E-08	1,84E-06	2,48E-08	3,32E-09	1,21E-09	3,45E-07	6,83E-09	6,64E-09	5,17E-04	5,92E-06	4,42E-10	1,09E-08
Terrestrial ecotoxicity	kg 1,4-DCB	4,16E+01	1,87E-03	6,78E-03	3,57E-03	8,97E-04	1,60E-04	7,16E-02	5,38E-03	8,81E-04	4,15E+01	2,95E-03	3,10E-03	2,43E-03
Freshwater ecotoxicity	kg 1,4-DCB	1,37E-02	1,06E-06	1,35E-05	1,67E-06	4,96E-07	1,22E-07	8,85E-06	6,78E-06	6,69E-07	1,36E-02	2,39E-06	6,20E-07	5,40E-06
Marine ecotoxicity	kg 1,4-DCB	5,28E-02	3,00E-06	1,51E-05	5,10E-06	1,25E-06	2,64E-07	4,05E-05	1,11E-05	1,45E-06	5,27E-02	5,93E-06	3,22E-06	9,14E-06
Human carcinogenic toxicity	kg 1,4-DCB	1,85E-01	2,83E-05	5,68E-05	3,07E-05	9,23E-06	2,83E-06	7,41E-05	9,00E-05	1,56E-05	1,84E-01	1,27E-04	1,44E-06	1,87E-05
Human non-carcinogenic toxicity	kg 1,4-DCB	2,05E+00	3,89E-04	1,03E-03	4,85E-04	1,00E-04	3,93E-05	1,65E-03	3,21E-04	2,16E-04	2,04E+00	5,92E-04	5,57E-05	2,72E-04
Land use	m^2a crop eq.	3,29E-01	2,78E-05	8,25E-04	3,84E-05	7,00E-06	2,99E-06	1,31E-04	9,02E-06	1,65E-05	3,27E-01	6,67E-05	1,52E-07	1,51E-06
Mineral resource scarcity	kg Cu eq.	2,27E-02	7,14E-06	1,19E-05	7,22E-06	1,37E-06	3,65E-07	1,09E-03	1,23E-06	2,01E-06	2,15E-02	1,04E-05	6,72E-08	5,09E-07
Fossil resource scarcity	kg oil eq.	6,77E+00	1,43E-04	9,80E-04	3,32E-04	5,90E-04	5,02E-05	1,09E-03	4,28E-03	2,76E-04	6,77E+00	7,23E-04	2,29E-06	1,95E-05
Water consumption	m^3	1,29E-01	1,04E-05	1,80E-04	3,82E-05	8,39E-06	1,39E-06	3,49E-04	1,02E-04	7,66E-06	1,27E-01	1,10E-03	9,78E-08	6,80E-06

Table 39: The emissions of 1 kg bulk in step formulation for item 1000 IU/20 ml

Impact category	Unit	Total	NaCl	Citrat	HCl	HDPE	Thermo-forming	Ni	PC	Thermo-forming	Transported bulk	WFI	Waste PE	Waste plastic, mixture
Global warming	kg CO_2 eq.	2,29E+01	7,22E-04	4,20E-03	3,59E-04	4,23E-04	1,08E-04	1,46E-03	8,44E-03	5,97E-04	2,29E+01	2,87E-03	5,36E-04	2,33E-03
Stratospheric ozone depletion	kg CFC11 eq.	9,26E-06	2,64E-10	1,54E-08	3,95E-10	7,24E-11	4,05E-11	1,61E-09	3,02E-09	2,24E-10	9,24E-06	1,42E-09	3,89E-11	9,98E-10
Ionizing radiation	kBq Co-60 eq.	2,04E-01	4,91E-06	4,39E-05	7,61E-06	1,02E-06	9,06E-07	3,97E-05	7,13E-07	5,01E-06	2,04E-01	8,71E-05	8,73E-09	1,15E-07
Ozone formation, Human health	kg NO_x eq.	3,17E-02	1,77E-06	8,75E-06	8,16E-07	9,14E-07	2,32E-07	7,58E-06	1,32E-05	1,29E-06	3,17E-02	5,26E-06	8,34E-08	6,01E-07
Fine particulate matter formation	kg $PM_{2,5}$ eq.	2,66E-02	1,56E-06	7,01E-06	7,96E-07	4,46E-07	2,25E-07	4,55E-05	7,91E-06	1,25E-06	2,65E-02	4,12E-06	1,21E-08	9,88E-08
Ozone formation, T	kg NO_x eq.	3,28E-02	1,79E-06	8,91E-06	8,30E-07	9,79E-07	2,36E-07	7,71E-06	1,37E-05	1,31E-06	3,28E-02	5,34E-06	8,36E-08	6,03E-07
Terrestrial acidification	kg SO_2 eq.	4,66E-02	2,81E-06	2,49E-05	2,11E-06	1,11E-06	3,45E-07	1,53E-04	2,00E-05	1,91E-06	4,64E-02	9,95E-06	3,62E-08	2,86E-07
Freshwater eutrophication	kg P eq.	2,88E-03	5,05E-08	4,35E-07	2,83E-08	8,36E-09	5,25E-09	1,45E-07	1,06E-07	2,91E-08	2,83E-03	4,27E-05	6,12E-11	6,26E-10
Marine eutrophication	kg N eq.	5,60E-04	7,57E-08	2,09E-06	8,56E-09	1,67E-09	6,08E-10	1,76E-07	3,46E-09	3,36E-09	5,51E-04	5,94E-06	2,23E-10	5,51E-09
Terrestrial ecotoxicity	kg 1,4-DCB	3,72E+01	2,15E-03	7,68E-03	1,23E-03	4,52E-04	8,07E-05	3,65E-02	2,73E-03	4,46E-04	3,71E+01	2,96E-03	1,56E-03	1,23E-03
Freshwater ecotoxicity	kg 1,4-DCB	1,39E-02	1,22E-06	1,53E-05	5,75E-07	2,50E-07	6,13E-08	4,50E-06	3,43E-06	3,39E-07	1,39E-02	2,40E-06	3,12E-07	2,73E-06
Marine ecotoxicity	kg 1,4-DCB	5,00E-02	3,45E-06	1,71E-05	1,76E-06	6,29E-07	1,33E-07	2,06E-05	5,62E-06	7,37E-07	4,99E-02	5,95E-06	1,62E-06	4,63E-06
Human carcinogenic t.	kg 1,4-DCB	1,93E-01	3,25E-05	6,44E-05	1,06E-05	4,65E-06	1,43E-06	3,77E-05	4,56E-05	7,90E-06	1,92E-01	1,28E-04	7,28E-07	9,49E-06
Human non-carcinogenic t.	kg 1,4-DCB	2,43E+00	4,47E-04	1,16E-03	1,68E-04	5,05E-05	1,98E-05	8,43E-04	1,63E-04	1,10E-04	2,42E+00	5,94E-04	2,81E-05	1,38E-04
Land use	m^2a crop eq.	4,20E-01	3,20E-05	9,35E-04	1,33E-05	3,53E-06	1,51E-06	6,68E-05	4,57E-06	8,34E-06	4,19E-01	6,69E-05	7,65E-08	7,64E-07
Mineral resource scarcity	kg Cu eq.	2,19E-02	8,21E-06	1,35E-05	2,49E-06	6,91E-07	1,84E-07	5,56E-04	6,21E-07	1,02E-06	2,13E-02	1,04E-05	3,38E-08	2,58E-07
Fossil resource scarcity	kg oil eq.	6,92E+00	1,64E-04	1,11E-03	1,15E-04	2,97E-04	2,53E-05	5,56E-04	2,17E-03	1,40E-04	6,92E+00	7,25E-04	1,15E-06	9,89E-06
Water consumption	m^3	1,97E-01	1,19E-05	2,04E-04	1,32E-05	4,23E-06	7,02E-07	1,77E-04	5,17E-05	3,88E-06	1,95E-01	1,11E-03	4,93E-08	3,45E-06

Table 40: The emissions of 1 kg bulk in step formulation for item 2500 IU/50 ml

Impact category	Unit	Total	NaCl	Citrat	HCl	HDPE	Thermo-forming	Ni	PC	Thermo-forming	Transported bulk	WFI	Waste plastic, mixture	Waste PE
Global warming	kg CO_2 eq.	2,02E+01	7,63E-04	4,49E-03	4,07E-04	4,40E-04	1,12E-04	1,51E-04	8,73E-04	6,17E-05	2,02E+01	2,89E-03	2,41E-04	5,57E-04
Stratospheric ozone depletion	kg CFC11 eq.	8,18E-06	2,79E-10	1,65E-08	4,47E-10	7,53E-11	4,22E-11	1,67E-10	3,13E-10	2,32E-11	8,16E-06	1,43E-09	1,03E-10	4,05E-11
Ionizing radiation	kBq Co-60 eq.	1,80E-01	5,19E-06	4,70E-05	8,63E-06	1,07E-06	9,42E-07	4,12E-06	7,37E-08	5,18E-07	1,80E-01	8,77E-05	1,19E-08	9,09E-09
Ozone formation, Human health	kg NO_x eq.	2,80E-02	1,87E-06	9,36E-06	9,24E-07	9,51E-07	2,42E-07	7,87E-07	1,36E-06	1,33E-07	2,80E-02	5,30E-06	6,22E-08	8,67E-08
Fine particulate matter formation	kg $PM_{2,5}$ eq.	2,34E-02	1,65E-06	7,50E-06	9,02E-07	4,64E-07	2,34E-07	4,72E-06	8,19E-07	1,29E-07	2,34E-02	4,15E-06	1,02E-08	1,26E-08
Ozone formation, T	kg NO_x eq.	2,90E-02	1,89E-06	9,53E-06	9,41E-07	1,02E-06	2,46E-07	8,01E-07	1,41E-06	1,35E-07	2,89E-02	5,38E-06	6,23E-08	8,70E-08
Terrestrial acidification	kg SO_2 eq.	4,10E-02	2,97E-06	2,66E-05	2,39E-06	1,15E-06	3,59E-07	1,59E-05	2,07E-06	1,97E-07	4,10E-02	1,00E-05	2,95E-08	3,76E-08
Freshwater eutrophication	kg P eq.	2,55E-03	5,34E-08	4,65E-07	3,21E-08	8,69E-09	5,47E-09	1,50E-08	1,10E-08	3,01E-09	2,50E-03	4,30E-05	6,48E-11	6,37E-11
Marine eutrophication	kg N eq.	4,95E-04	8,00E-08	2,23E-06	9,70E-09	1,74E-09	6,33E-10	1,82E-08	3,58E-10	3,48E-10	4,87E-04	5,98E-06	5,70E-10	2,32E-10
Terrestrial ecotoxicity	kg 1,4-DCB	3,28E+01	2,27E-03	8,21E-03	1,40E-03	4,70E-04	8,39E-05	3,79E-03	2,82E-04	4,61E-05	3,28E+01	2,97E-03	1,27E-04	1,62E-03
Freshwater ecotoxicity	kg 1,4-DCB	1,23E-02	1,29E-06	1,64E-05	6,52E-07	2,60E-07	6,37E-08	4,68E-07	3,55E-07	3,51E-08	1,23E-02	2,41E-06	2,83E-07	3,25E-07
Marine ecotoxicity	kg 1,4-DCB	4,41E-02	3,64E-06	1,82E-05	2,00E-06	6,54E-07	1,39E-07	2,14E-06	5,81E-07	7,62E-08	4,41E-02	5,99E-06	4,79E-07	1,69E-06
Human carcinogenic toxicity	kg 1,4-DCB	1,70E-01	3,44E-05	6,89E-05	1,20E-05	4,84E-06	1,48E-06	3,92E-06	4,72E-06	8,17E-07	1,70E-01	1,28E-04	9,81E-07	7,57E-07
Human non-carcinogenic toxicity	kg 1,4-DCB	2,14E+00	4,73E-04	1,24E-03	1,90E-04	5,25E-05	2,06E-05	8,75E-05	1,68E-05	1,13E-05	2,14E+00	5,97E-04	1,43E-05	2,92E-05
Land use	m^2a crop eq.	3,71E-01	3,38E-05	1,00E-03	1,50E-05	3,67E-06	1,57E-06	6,93E-06	4,73E-07	8,62E-07	3,70E-01	6,73E-05	7,90E-08	7,95E-08
Mineral resource scarcity	kg Cu eq.	1,89E-02	8,68E-06	1,45E-05	2,82E-06	7,19E-07	1,91E-07	5,77E-05	6,43E-08	1,05E-07	1,88E-02	1,05E-05	2,67E-08	3,52E-08
Fossil resource scarcity	kg oil eq.	6,11E+00	1,73E-04	1,19E-03	1,30E-04	3,09E-04	2,63E-05	5,77E-05	2,25E-04	1,45E-05	6,11E+00	7,30E-04	1,02E-06	1,20E-06
Water consumption	m^3	1,74E-01	1,26E-05	2,19E-04	1,49E-05	4,40E-06	7,30E-07	1,84E-05	5,34E-06	4,02E-07	1,72E-01	1,11E-03	3,57E-07	5,13E-08

Table 41: The emissions of 1 kg bulk in step sterile filtration for item 500 IU/20 ml

Impact category	Unit	Total	Formulated bulk	Glass fibre	PP	Glass fibre reinforced plastic	Extrusion	Nylon 6-6	Thermo-forming	PP	Injection moulding	PC	Thermo-forming	Poly-sulfone	Thermo-forming	Waste plastic, mixture	Waste PP
Global warming	kg CO_2 eq.	1,62E+02	1,61E+02	6,98E-03	6,88E-03	5,11E-02	1,68E-03	5,57E-02	3,96E-03	2,33E-01	9,44E-02	1,45E-02	2,05E-03	4,83E-03	3,62E-04	3,74E-02	2,58E-01
Stratospheric ozone depletion	kg CFC11 eq.	6,93E-05	6,91E-05	9,93E-09	8,91E-10	4,78E-08	6,95E-10	5,28E-08	1,49E-09	3,02E-08	4,22E-08	5,19E-09	7,69E-10	1,58E-09	1,36E-10	1,60E-08	1,88E-08
Ionizing radiation	kBq Co-60 eq.	6,08E-01	6,04E-01	4,67E-05	1,34E-05	1,39E-04	1,52E-05	2,20E-06	3,32E-05	4,53E-04	2,30E-03	1,22E-06	1,72E-05	2,16E-05	3,04E-06	1,84E-06	4,47E-06
Ozone formation, Human health	kg NO_x eq.	2,86E-01	2,85E-01	2,69E-05	1,42E-05	8,34E-05	3,59E-06	9,46E-05	8,53E-06	4,79E-04	1,67E-04	2,26E-05	4,41E-06	1,16E-05	7,80E-07	9,63E-06	4,03E-05
Fine particulate matter formation	kg $PM_{2.5}$ eq.	6,25E-01	6,25E-01	1,44E-05	6,91E-06	4,95E-05	3,59E-06	4,82E-05	8,26E-06	2,34E-04	1,17E-04	1,36E-05	4,27E-06	8,15E-06	7,55E-07	1,58E-06	5,99E-06
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	2,95E-01	2,94E-01	2,72E-05	1,51E-05	8,64E-05	3,63E-06	9,80E-05	8,68E-06	5,10E-04	1,76E-04	2,34E-05	4,49E-06	1,27E-05	7,93E-07	9,66E-06	4,04E-05
Terrestrial acidification	kg SO_2 eq.	1,98E+00	1,98E+00	3,42E-05	1,78E-05	1,45E-04	5,37E-06	1,57E-04	1,27E-05	6,04E-04	3,00E-04	3,43E-05	6,55E-06	1,51E-05	1,16E-06	4,58E-06	1,76E-05
Freshwater eutrophication	kg P eq.	4,38E-03	4,36E-03	2,18E-07	1,31E-07	6,17E-07	8,61E-08	2,24E-06	1,93E-07	4,45E-06	6,76E-06	1,82E-07	9,98E-08	2,22E-07	1,76E-08	1,00E-08	3,12E-08
Marine eutrophication	kg N eq.	2,36E-03	2,34E-03	5,46E-08	2,79E-08	1,07E-05	9,03E-09	1,59E-05	2,23E-08	9,45E-07	4,24E-07	5,94E-09	1,15E-08	1,10E-07	2,04E-09	8,83E-08	1,08E-07
Terrestrial ecotoxicity	kg 1,4-DCB	4,91E+02	4,90E+02	3,89E-02	6,65E-03	9,69E-03	1,28E-03	6,27E-03	2,96E-03	2,25E-01	7,21E-02	4,68E-03	1,53E-03	6,81E-03	2,71E-04	1,97E-02	7,52E-01
Freshwater ecotoxicity	kg 1,4-DCB	1,33E-01	1,32E-01	8,39E-06	3,71E-06	4,14E-05	8,90E-07	3,46E-05	2,25E-06	1,25E-04	6,13E-05	5,89E-06	1,16E-06	7,60E-06	2,06E-07	4,38E-05	1,51E-04
Marine ecotoxicity	kg 1,4-DCB	3,96E-01	3,95E-01	3,60E-05	9,29E-06	6,31E-05	1,98E-06	4,83E-05	4,89E-06	3,15E-04	1,91E-04	9,64E-06	2,53E-06	9,92E-06	4,47E-07	7,42E-05	7,82E-04
Human carcinogenic toxicity	kg 1,4-DCB	1,27E+00	1,26E+00	1,17E-04	6,20E-05	3,23E-04	1,92E-05	2,54E-04	5,24E-05	2,10E-03	1,08E-03	7,83E-05	2,71E-05	6,04E-05	4,79E-06	1,52E-04	3,63E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	1,58E+01	1,57E+01	8,95E-03	8,09E-04	1,61E-03	2,87E-04	6,64E-04	7,28E-04	2,74E-02	1,51E-02	2,79E-04	3,76E-04	1,58E-03	6,65E-05	2,21E-03	1,35E-02
Land use	m^2a crop eq.	1,10E+00	1,09E+00	7,00E-05	5,43E-05	3,45E-04	2,48E-05	1,21E-05	5,53E-05	1,84E-03	5,56E-03	7,85E-06	2,86E-05	7,43E-05	5,06E-06	1,22E-05	3,87E-05
Mineral resource scarcity	kg Cu eq.	6,15E+00	6,15E+00	2,46E-05	1,41E-05	2,35E-05	1,97E-06	1,08E-05	6,76E-06	4,76E-04	3,12E-04	1,07E-06	3,50E-06	1,00E-05	6,17E-07	4,13E-06	1,75E-05
Fossil resource scarcity	kg oil eq.	3,85E+01	3,83E+01	1,94E-03	4,99E-03	1,55E-02	4,00E-04	1,74E-02	9,29E-04	1,69E-01	3,39E-02	3,73E-03	4,81E-04	2,41E-03	8,49E-05	1,58E-04	5,69E-04
Water consumption	m^3	2,72E+00	2,71E+00	5,12E-05	6,03E-05	1,23E-03	1,15E-05	1,47E-03	2,58E-05	2,04E-03	1,63E-03	8,87E-05	1,33E-05	8,14E-05	2,36E-06	5,52E-05	1,68E-05

Table 42: The emissions of 1 kg bulk in step sterile filtration for item 500 IU/10 ml

Impact category	Unit	Total	Glass fibre	PP	Glass fibre reinforced plastic	Extrusion	Formulated bulk	Nylon 6-6	Thermo-forming	Poly-sulfone	Thermo-forming	PP	Injection moulding	PC	Thermo-forming	Waste PP	Waste plastic, mixture
Global warming	kg CO_2 eq.	3,17E+02	3,15E+02	1,35E-02	1,33E-02	9,87E-02	3,22E-03	1,11E-01	7,87E-03	1,07E-02	8,03E-04	4,52E-01	1,83E-01	5,45E-02	7,71E-03	5,04E-01	9,12E-02
Stratospheric ozone depletion	kg CFC11 eq.	1,35E-04	1,35E-04	1,92E-08	1,72E-09	9,22E-08	1,33E-09	1,05E-07	2,96E-09	3,51E-09	3,02E-10	5,86E-08	8,20E-08	1,95E-08	2,90E-09	3,66E-08	3,90E-08
Ionizing radiation	kBq Co-60 eq.	1,20E+00	1,19E+00	9,00E-05	2,58E-05	2,69E-04	2,92E-05	4,37E-06	6,61E-05	4,80E-05	6,74E-06	8,78E-04	4,47E-03	4,61E-06	6,47E-05	8,73E-06	4,49E-06
Ozone formation, Human health	kg NO_x eq.	5,62E-01	5,60E-01	5,19E-05	2,73E-05	1,61E-04	6,89E-06	1,88E-04	1,70E-05	2,57E-05	1,73E-06	9,30E-04	3,25E-04	8,52E-05	1,66E-05	7,87E-05	2,35E-05
Fine particulate matter formation	kg $PM_{2.5}$ eq.	1,22E+00	1,22E+00	2,78E-05	1,33E-05	9,56E-05	6,87E-06	9,57E-05	1,64E-05	1,81E-05	1,68E-06	4,54E-04	2,28E-04	5,11E-05	1,61E-05	1,17E-05	3,86E-06
Ozone formation, Terrestrial es	kg NO_x eq.	5,78E-01	5,76E-01	5,26E-05	2,91E-05	1,67E-04	6,96E-06	1,95E-04	1,73E-05	2,82E-05	1,76E-06	9,90E-04	3,41E-04	8,82E-05	1,69E-05	7,89E-05	2,36E-05
Terrestrial acidification	kg SO_2 eq.	3,84E+00	3,84E+00	6,61E-05	3,44E-05	2,79E-04	1,03E-05	3,12E-04	2,52E-05	3,34E-05	2,57E-06	1,17E-03	5,83E-04	1,29E-04	2,46E-05	3,43E-05	1,12E-05
Freshwater eutrophication	kg P eq.	8,73E-03	8,70E-03	4,22E-07	2,54E-07	1,19E-06	1,65E-07	4,44E-06	3,83E-07	4,91E-07	3,91E-08	8,63E-06	1,31E-05	6,85E-07	3,75E-07	6,09E-08	2,45E-08
Marine eutrophication	kg N eq.	4,64E-03	4,58E-03	1,05E-07	5,39E-08	2,06E-05	1,73E-08	3,16E-05	4,44E-08	2,43E-07	4,53E-09	1,83E-06	8,23E-07	2,24E-08	4,34E-08	2,11E-07	2,16E-07
Terrestrial ecotoxicity	kg 1,4-DCB	9,58E+02	9,56E+02	7,51E-02	1,28E-02	1,87E-02	2,46E-03	1,25E-02	5,88E-03	1,51E-02	6,00E-04	4,37E-01	1,40E-01	1,76E-02	5,76E-03	1,47E+00	4,81E-02
Freshwater ecotoxicity	kg 1,4-DCB	2,60E-01	2,59E-01	1,62E-05	7,15E-06	7,98E-05	1,71E-06	6,88E-05	4,47E-06	1,69E-05	4,56E-07	2,43E-04	1,19E-04	2,22E-05	4,38E-06	2,94E-04	1,07E-04
Marine ecotoxicity	kg 1,4-DCB	7,75E-01	7,72E-01	6,95E-05	1,79E-05	1,22E-04	3,79E-06	9,60E-05	9,72E-06	2,20E-05	9,92E-07	6,11E-04	3,71E-04	3,63E-05	9,52E-06	1,53E-03	1,81E-04
Human carcinogenic toxicity	kg 1,4-DCB	2,48E+00	2,47E+00	2,25E-04	1,20E-04	6,23E-04	3,68E-05	5,05E-04	1,04E-04	1,34E-04	1,06E-05	4,07E-03	2,11E-03	2,95E-04	1,02E-04	7,09E-04	3,71E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	3,08E+01	3,07E+01	1,73E-02	1,56E-03	3,10E-03	5,51E-04	1,32E-03	1,45E-03	3,51E-03	1,48E-04	5,31E-02	2,93E-02	1,05E-03	1,42E-03	2,64E-02	5,39E-03
Land use	m^2a crop eq.	2,17E+00	2,15E+00	1,35E-04	1,05E-04	6,66E-04	4,75E-05	2,41E-05	1,10E-04	1,65E-04	1,12E-05	3,57E-03	1,08E-02	2,95E-05	1,08E-04	7,54E-05	2,99E-05
Mineral resource scarcity	kg Cu eq.	1,19E+01	1,19E+01	4,74E-05	2,72E-05	4,53E-05	3,77E-06	2,16E-05	1,34E-05	2,22E-05	1,37E-06	9,25E-04	6,06E-04	4,01E-06	1,32E-05	3,42E-05	1,01E-05
Fossil resource scarcity	kg oil eq.	7,56E+01	7,51E+01	3,75E-03	9,62E-03	3,00E-02	7,66E-04	3,45E-02	1,85E-03	5,35E-03	1,88E-04	3,28E-01	6,59E-02	1,40E-02	1,81E-03	1,11E-03	3,87E-04
Water consumption	m^3	5,29E+00	5,28E+00	9,88E-05	1,16E-04	2,37E-03	2,20E-05	2,92E-03	5,12E-05	1,81E-04	5,23E-06	3,96E-03	3,16E-03	3,34E-04	5,02E-05	3,29E-05	1,35E-04

Table 43: The emissions of 1 kg bulk in step sterile filtration for item 1000 IU/20 ml

Impact category	Unit	Total	Formulated bulk	Glass fiber	PP	Glass fiber reinforced plastic	Extrusion	Nylon 6-6	Thermo-forming	PP	Injection moulding	PC	Thermo-forming	Poly-sulfone	Thermo-forming	Waste PP	Waste plastic, mixture
Global warming	kg CO_2 eq.	1,68E+02	1,68E+02	6,76E-03	6,66E-03	4,95E-02	1,63E-03	5,55E-02	3,95E-03	2,27E-01	9,19E-02	1,36E-02	1,92E-03	5,40E-03	4,05E-04	2,51E-01	3,66E-02
Stratospheric ozone depletion	kg CFC11 eq.	7,14E-05	7,11E-05	9,62E-09	8,63E-10	4,63E-08	6,74E-10	5,26E-08	1,48E-09	2,94E-08	4,11E-08	4,87E-09	7,22E-10	1,77E-09	1,52E-10	1,83E-08	1,57E-08
Ionizing radiation	kBq Co-60 eq.	6,82E-01	6,79E-01	4,52E-05	1,29E-05	1,35E-04	1,47E-05	2,19E-06	3,31E-05	4,40E-04	2,24E-03	1,15E-06	1,61E-05	2,42E-05	3,40E-06	4,35E-06	1,80E-06
Ozone formation, Human health	kg NO_x eq.	3,04E-01	3,03E-01	2,61E-05	1,37E-05	8,08E-05	3,48E-06	9,42E-05	8,50E-06	4,67E-04	1,63E-04	2,12E-05	4,14E-06	1,30E-05	8,72E-07	3,92E-05	9,44E-06
Fine particulate matter formation	kg $PM_{2.5}$ eq.	6,25E-01	6,25E-01	1,40E-05	6,70E-06	4,80E-05	3,47E-06	4,80E-05	8,23E-06	2,28E-04	1,14E-04	1,27E-05	4,01E-06	9,11E-06	8,44E-07	5,83E-06	1,55E-06
Ozone formation, T.e	kg NO_x eq.	3,13E-01	3,12E-01	2,64E-05	1,46E-05	8,37E-05	3,52E-06	9,76E-05	8,65E-06	4,96E-04	1,71E-04	2,20E-05	4,21E-06	1,42E-05	8,87E-07	3,93E-05	9,47E-06
Terrestrial acidification	kg SO_2 eq.	1,96E+00	1,96E+00	3,32E-05	1,73E-05	1,40E-04	5,20E-06	1,56E-04	1,26E-05	5,88E-04	2,92E-04	3,22E-05	6,14E-06	1,68E-05	1,29E-06	1,71E-05	4,49E-06
Freshwater eutrophication	kg P eq.	5,46E-03	5,44E-03	2,12E-07	1,27E-07	5,98E-07	8,34E-08	2,23E-06	1,92E-07	4,33E-06	6,58E-06	1,71E-07	9,36E-08	2,48E-07	1,97E-08	3,04E-08	9,84E-09
Marine eutrophication	kg N eq.	2,56E-03	2,53E-03	5,28E-08	2,70E-08	1,03E-05	8,75E-09	1,58E-05	2,22E-08	9,20E-07	4,13E-07	5,57E-09	1,08E-08	1,23E-07	2,28E-09	1,05E-07	8,66E-08
Terrestrial ecotoxicity	kg 1,4-DCB	4,99E+02	4,98E+02	3,77E-02	6,44E-03	9,38E-03	1,24E-03	6,25E-03	2,95E-03	2,19E-01	7,02E-02	4,39E-03	1,44E-03	7,61E-03	3,02E-04	7,32E-01	1,93E-02
Freshwater ecotoxicity	kg 1,4-DCB	1,36E-01	1,36E-01	8,13E-06	3,59E-06	4,01E-05	8,63E-07	3,45E-05	2,24E-06	1,22E-04	5,97E-05	5,53E-06	1,09E-06	8,50E-06	2,30E-07	1,47E-04	4,30E-05
Marine ecotoxicity	kg 1,4-DCB	4,12E-01	4,11E-01	3,49E-05	9,00E-06	6,11E-05	1,91E-06	4,81E-05	4,87E-06	3,06E-04	1,86E-04	9,04E-06	2,37E-06	1,11E-05	5,00E-07	7,61E-04	7,27E-05
Human carcinogenic t	kg 1,4-DCB	1,32E+00	1,32E+00	1,13E-04	6,00E-05	3,13E-04	1,86E-05	2,53E-04	5,22E-05	2,04E-03	1,06E-03	7,34E-05	2,54E-05	6,76E-05	5,35E-06	3,53E-04	1,49E-04
Human non-carcinogenic t	kg 1,4-DCB	1,64E+01	1,63E+01	8,66E-03	7,83E-04	1,55E-03	2,78E-04	6,61E-04	7,25E-04	2,66E-02	1,47E-02	2,62E-04	3,53E-04	1,77E-03	7,43E-05	1,32E-02	2,16E-03
Land use	m^2a crop eq.	1,24E+00	1,23E+00	6,78E-05	5,26E-05	3,34E-04	2,40E-05	1,21E-05	5,51E-05	1,79E-03	5,41E-03	7,36E-06	2,68E-05	8,31E-05	5,65E-06	3,76E-05	1,20E-05
Mineral resource scarcity	kg Cu eq.	6,00E+00	6,00E+00	2,38E-05	1,36E-05	2,27E-05	1,90E-06	1,08E-05	6,73E-06	4,64E-04	3,04E-04	1,00E-06	3,28E-06	1,12E-05	6,90E-07	1,71E-05	4,05E-06
Fossil resource scarcity	kg oil eq.	4,09E+01	4,07E+01	1,88E-03	4,83E-03	1,51E-02	3,87E-04	1,73E-02	9,25E-04	1,64E-01	3,30E-02	3,50E-03	4,51E-04	2,70E-03	9,49E-05	5,54E-04	1,55E-04
Water consumption	m^3	2,71E+00	2,70E+00	4,96E-05	5,84E-05	1,19E-03	1,11E-05	1,46E-03	2,57E-05	1,99E-03	1,59E-03	8,32E-05	1,25E-05	9,10E-05	2,63E-06	1,64E-05	5,41E-05

Table 44: The emissions of 1 kg bulk in step sterile filtration for item 2500 IU/50 ml

Impact category	Unit	Total	Formulated bulk	Glass fiber	PP	Glass fiber reinforced plastic	Extrusion	Nylon 6-6	Thermo-forming	Poly-sulfone	Thermo-forming	PP	Injection moulding	PC	Thermo-forming	Waste plastic, mixture	Waste PP
Global warming	kg CO_2 eq.	7,77E+01	7,73E+01	7,06E-03	6,96E-03	5,17E-02	1,69E-03	5,77E-02	4,10E-03	5,62E-03	4,21E-04	9,12E-02	3,70E-02	1,43E-02	2,02E-03	3,81E-02	1,06E-01
Stratospheric ozone depletion	kg CFC11 eq.	3,24E-05	3,22E-05	1,00E-08	9,01E-10	4,83E-08	6,98E-10	5,46E-08	1,54E-09	1,84E-09	1,58E-10	1,18E-08	1,65E-08	5,12E-09	7,59E-10	1,63E-08	7,68E-09
Ionizing radiation	kBq Co-60 eq.	3,57E-01	3,55E-01	4,72E-05	1,35E-05	1,41E-04	1,53E-05	2,27E-06	3,44E-05	2,52E-05	3,53E-06	1,77E-04	9,01E-04	1,21E-06	1,70E-05	1,88E-06	1,83E-06
Ozone formation, Human health	kg NO_x eq.	1,46E-01	1,45E-01	2,72E-05	1,43E-05	8,43E-05	3,61E-06	9,79E-05	8,83E-06	1,35E-05	9,07E-07	1,88E-04	6,56E-05	2,23E-05	4,35E-06	9,83E-06	1,65E-05
Fine particulate matter formation	kg $PM_{2.5}$ eq.	2,67E-01	2,66E-01	1,46E-05	6,99E-06	5,01E-05	3,60E-06	4,98E-05	8,55E-06	9,47E-06	8,78E-07	9,17E-05	4,60E-05	1,34E-05	4,22E-06	1,62E-06	2,45E-06
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	1,50E-01	1,49E-01	2,75E-05	1,52E-05	8,74E-05	3,65E-06	1,01E-04	8,98E-06	1,48E-05	9,23E-07	2,00E-04	6,88E-05	2,31E-05	4,43E-06	9,86E-06	1,66E-05
Terrestrial acidification	kg SO_2 eq.	8,17E-01	8,16E-01	3,46E-05	1,81E-05	1,46E-04	5,39E-06	1,62E-04	1,31E-05	1,75E-05	1,35E-06	2,37E-04	1,18E-04	3,39E-05	6,46E-06	4,67E-06	7,19E-06
Freshwater eutrophication	kg P eq.	3,31E-03	3,30E-03	2,21E-07	1,33E-07	6,25E-07	8,65E-08	2,31E-06	2,00E-07	2,58E-07	2,05E-08	1,74E-06	2,65E-06	1,79E-07	9,84E-08	1,02E-08	1,28E-08
Marine eutrophication	kg N eq.	1,29E-03	1,26E-03	5,52E-08	2,82E-08	1,08E-05	9,07E-09	1,64E-05	2,31E-08	1,28E-07	2,37E-09	3,70E-07	1,66E-07	5,86E-09	1,14E-08	9,02E-08	4,43E-08
Terrestrial ecotoxicity	kg 1,4-DCB	2,20E+02	2,19E+02	3,94E-02	6,73E-03	9,80E-03	1,29E-03	6,49E-03	3,06E-03	7,91E-03	3,15E-04	8,82E-02	2,83E-02	4,62E-03	1,51E-03	2,01E-02	3,08E-01
Freshwater ecotoxicity	kg 1,4-DCB	6,11E-02	6,09E-02	8,49E-06	3,75E-06	4,18E-05	8,94E-07	3,58E-05	2,33E-06	8,84E-06	2,39E-07	4,91E-05	2,40E-05	5,81E-06	1,15E-06	4,47E-05	6,17E-05
Marine ecotoxicity	kg 1,4-DCB	1,90E-01	1,89E-01	3,64E-05	9,40E-06	6,38E-05	1,98E-06	5,00E-05	5,06E-06	1,15E-05	5,20E-07	1,23E-04	7,48E-05	9,51E-06	2,49E-06	7,58E-05	3,20E-04
Human carcinogenic toxicity	kg 1,4-DCB	6,18E-01	6,15E-01	1,18E-04	6,27E-05	3,27E-04	1,93E-05	2,63E-04	5,42E-05	7,03E-05	5,57E-06	8,21E-04	4,25E-04	7,72E-05	2,67E-05	1,55E-04	1,49E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	7,54E+00	7,49E+00	9,05E-03	8,18E-04	1,62E-03	2,89E-04	6,87E-04	7,53E-04	1,84E-03	7,73E-05	1,07E-02	5,92E-03	2,75E-04	3,71E-04	2,26E-03	5,54E-03
Land use	m^2a crop eq.	6,47E-01	6,44E-01	7,08E-05	5,49E-05	3,49E-04	2,49E-05	1,25E-05	5,72E-05	8,65E-05	5,88E-06	7,20E-04	2,18E-03	7,74E-06	2,82E-05	1,25E-05	1,58E-05
Mineral resource scarcity	kg Cu eq.	2,43E+00	2,42E+00	2,49E-05	1,42E-05	2,37E-05	1,97E-06	1,12E-05	6,99E-06	1,16E-05	7,18E-07	1,87E-04	1,22E-04	1,05E-06	3,45E-06	4,22E-06	7,18E-06
Fossil resource scarcity	kg oil eq.	1,96E+01	1,95E+01	1,97E-03	5,04E-03	1,57E-02	4,01E-04	1,80E-02	9,61E-04	2,81E-03	9,87E-05	6,61E-02	1,33E-02	3,67E-03	4,74E-04	1,62E-04	2,33E-04
Water consumption	m^3	1,15E+00	1,15E+00	5,18E-05	6,10E-05	1,24E-03	1,15E-05	1,52E-03	2,67E-05	9,47E-05	2,74E-06	8,00E-04	6,39E-04	8,75E-05	1,31E-05	5,64E-05	6,90E-06

Table 45: 1 kg bulk in step sterile filling for item 500 IU/20 ml

Impact category	Unit	Total	Sterile filtered bulk	Synthetic rubber	Thermoforming	Glass tube	Tempering, glass
Global warming	kg CO_2 eq.	1,68E+02	1,62E+02	3,38E-01	7,38E-02	5,56E+00	4,26E-01
Stratospheric ozone depletion	kg CFC11 eq.	7,15E-05	6,93E-05	1,50E-07	2,77E-08	1,91E-06	9,56E-08
Ionizing radiation	kBq Co-60 eq.	6,43E-01	6,08E-01	4,10E-03	6,20E-04	2,90E-02	1,39E-03
Ozone formation, Human health	kg NO_x eq.	3,18E-01	2,86E-01	8,86E-04	1,59E-04	2,95E-02	1,30E-03
Fine particulate matter formation	kg $PM_{2.5}$ eq.	6,39E-01	6,25E-01	5,79E-04	1,54E-04	1,22E-02	6,83E-04
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	3,27E-01	2,95E-01	9,61E-04	1,62E-04	2,98E-02	1,32E-03
Terrestrial acidification	kg SO_2 eq.	2,01E+00	1,98E+00	1,24E-03	2,36E-04	2,90E-02	2,06E-03
Freshwater eutrophication	kg P eq.	4,59E-03	4,38E-03	1,09E-05	3,60E-06	1,95E-04	5,02E-06
Marine eutrophication	kg N eq.	2,39E-03	2,36E-03	1,31E-06	4,16E-07	2,37E-05	1,61E-06
Terrestrial ecotoxicity	kg 1,4-DCB	5,02E+02	4,91E+02	6,77E-01	5,52E-02	9,48E+00	3,71E-01
Freshwater ecotoxicity	kg 1,4-DCB	1,40E-01	1,33E-01	4,85E-04	4,19E-05	6,01E-03	1,16E-04
Marine ecotoxicity	kg 1,4-DCB	4,12E-01	3,96E-01	1,22E-03	9,12E-05	1,43E-02	7,84E-04
Human carcinogenic toxicity	kg 1,4-DCB	1,41E+00	1,27E+00	6,45E-03	9,77E-04	1,36E-01	2,24E-03
Human non-carcinogenic toxicity	kg 1,4-DCB	1,72E+01	1,58E+01	7,70E-02	1,36E-02	1,30E+00	2,71E-02
Land use	m^2a crop eq.	1,58E+00	1,10E+00	1,03E-02	1,03E-03	4,65E-01	7,36E-03
Mineral resource scarcity	kg Cu eq.	6,18E+00	6,15E+00	1,35E-03	1,26E-04	2,62E-02	6,09E-04
Fossil resource scarcity	kg oil eq.	4,04E+01	3,85E+01	2,10E-01	1,73E-02	1,47E+00	1,27E-01
Water consumption	m^3	2,76E+00	2,72E+00	5,55E-03	4,80E-04	3,66E-02	1,75E-03

Table 46: 1 kg bulk in step sterile filling for item 500 IU/10 ml

Impact category	Unit	Total	Sterile filtered bulk	Synthetic rubber	Thermoforming	Glass tube	Tempering, glass
Global warming	kg CO_2 eq.	3,21E+02	3,17E+02	6,56E-01	1,43E-01	3,52E+00	2,70E-01
Stratospheric ozone depletion	kg CFC11 eq.	1,37E-04	1,35E-04	2,92E-07	5,39E-08	1,21E-06	6,06E-08
Ionizing radiation	kBq Co-60 eq.	1,23E+00	1,20E+00	7,96E-03	1,20E-03	1,84E-02	8,83E-04
Ozone formation, Human health	kg NO_x eq.	5,83E-01	5,62E-01	1,72E-03	3,09E-04	1,87E-02	8,26E-04
Fine particulate matter formation	kg $PM_{2.5}$ eq.	1,23E+00	1,22E+00	1,12E-03	2,99E-04	7,75E-03	4,33E-04
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	6,00E-01	5,78E-01	1,87E-03	3,14E-04	1,89E-02	8,34E-04
Terrestrial acidification	kg SO_2 eq.	3,87E+00	3,84E+00	2,41E-03	4,58E-04	1,84E-02	1,30E-03
Freshwater eutrophication	kg P eq.	8,88E-03	8,73E-03	2,11E-05	6,98E-06	1,23E-04	3,18E-06
Marine eutrophication	kg N eq.	4,66E-03	4,64E-03	2,55E-06	8,08E-07	1,50E-05	1,02E-06
Terrestrial ecotoxicity	kg 1,4-DCB	9,66E+02	9,58E+02	1,32E+00	1,07E-01	6,01E+00	2,35E-01
Freshwater ecotoxicity	kg 1,4-DCB	2,64E-01	2,60E-01	9,43E-04	8,14E-05	3,81E-03	7,34E-05
Marine ecotoxicity	kg 1,4-DCB	7,87E-01	7,75E-01	2,36E-03	1,77E-04	9,04E-03	4,97E-04
Human carcinogenic toxicity	kg 1,4-DCB	2,58E+00	2,48E+00	1,25E-02	1,90E-03	8,64E-02	1,42E-03
Human non-carcinogenic toxicity	kg 1,4-DCB	3,19E+01	3,08E+01	1,49E-01	2,63E-02	8,26E-01	1,72E-02
Land use	m^2a crop eq.	2,49E+00	2,17E+00	2,01E-02	2,00E-03	2,95E-01	4,66E-03
Mineral resource scarcity	kg Cu eq.	1,20E+01	1,19E+01	2,62E-03	2,45E-04	1,66E-02	3,86E-04
Fossil resource scarcity	kg oil eq.	7,71E+01	7,56E+01	4,08E-01	3,36E-02	9,33E-01	8,07E-02
Water consumption	m^3	5,33E+00	5,29E+00	1,08E-02	9,33E-04	2,32E-02	1,11E-03

Table 47: 1 kg bulk in step sterile filling for item 1000 IU/20 ml

Impact category	Unit	Total	Sterile filtered bulk	Synthetic rubber	Glass tube	Tempering, glass	Thermoforming
Global warming	kg CO_2 eq.	1,75E+02	1,68E+02	3,29E-01	5,41E+00	4,15E-01	7,19E-02
Stratospheric ozone depletion	kg CFC11 eq.	7,35E-05	7,14E-05	1,46E-07	1,86E-06	9,31E-08	2,70E-08
Ionizing radiation	kBq Co-60 eq.	7,16E-01	6,82E-01	3,99E-03	2,83E-02	1,36E-03	6,03E-04
Ozone formation, Human health	kg NO_x eq.	3,35E-01	3,04E-01	8,62E-04	2,88E-02	1,27E-03	1,55E-04
Fine particulate matter formation	kg $PM_{2.5}$ eq.	6,38E-01	6,25E-01	5,64E-04	1,19E-02	6,65E-04	1,50E-04
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	3,45E-01	3,13E-01	9,36E-04	2,90E-02	1,28E-03	1,58E-04
Terrestrial acidification	kg SO_2 eq.	1,99E+00	1,96E+00	1,21E-03	2,83E-02	2,00E-03	2,30E-04
Freshwater eutrophication	kg P eq.	5,67E-03	5,46E-03	1,06E-05	1,90E-04	4,89E-06	3,50E-06
Marine eutrophication	kg N eq.	2,59E-03	2,56E-03	1,28E-06	2,31E-05	1,57E-06	4,05E-07
Terrestrial ecotoxicity	kg 1,4-DCB	5,09E+02	4,99E+02	6,60E-01	9,23E+00	3,61E-01	5,37E-02
Freshwater ecotoxicity	kg 1,4-DCB	1,43E-01	1,36E-01	4,73E-04	5,85E-03	1,13E-04	4,08E-05
Marine ecotoxicity	kg 1,4-DCB	4,28E-01	4,12E-01	1,18E-03	1,39E-02	7,64E-04	8,88E-05
Human carcinogenic toxicity	kg 1,4-DCB	1,47E+00	1,32E+00	6,28E-03	1,33E-01	2,18E-03	9,51E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	1,78E+01	1,64E+01	7,49E-02	1,27E+00	2,64E-02	1,32E-02
Land use	m^2a crop eq.	1,71E+00	1,24E+00	1,01E-02	4,53E-01	7,16E-03	1,00E-03
Mineral resource scarcity	kg Cu eq.	6,03E+00	6,00E+00	1,31E-03	2,55E-02	5,93E-04	1,23E-04
Fossil resource scarcity	kg oil eq.	4,27E+01	4,09E+01	2,05E-01	1,43E+00	1,24E-01	1,69E-02
Water consumption	m^3	2,75E+00	2,71E+00	5,40E-03	3,57E-02	1,71E-03	4,68E-04

Table 48: 1 kg bulk in step sterile filling for item 2500 IU/50 ml

Impact category	Unit	Total	Sterile filtered bulk	Synthetic rubber	Thermoforming	Glass tube	Tempering, glass
Global warming	kg CO_2 eq.	8,22E+01	7,77E+01	1,32E-01	2,89E-02	4,00E+00	3,07E-01
Stratospheric ozone depletion	kg CFC11 eq.	3,39E-05	3,24E-05	5,89E-08	1,09E-08	1,37E-06	6,88E-08
Ionizing radiation	kBq Co-60 eq.	3,80E-01	3,57E-01	1,61E-03	2,43E-04	2,09E-02	1,00E-03
Ozone formation, Human health	kg NO_x eq.	1,68E-01	1,46E-01	3,47E-04	6,23E-05	2,13E-02	9,38E-04
Fine particulate matter formation	kg $PM_{2.5}$ eq.	2,76E-01	2,67E-01	2,27E-04	6,04E-05	8,79E-03	4,91E-04
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	1,73E-01	1,50E-01	3,77E-04	6,34E-05	2,14E-02	9,47E-04
Terrestrial acidification	kg SO_2 eq.	8,40E-01	8,17E-01	4,86E-04	9,25E-05	2,09E-02	1,48E-03
Freshwater eutrophication	kg P eq.	3,46E-03	3,31E-03	4,25E-06	1,41E-06	1,40E-04	3,61E-06
Marine eutrophication	kg N eq.	1,31E-03	1,29E-03	5,15E-07	1,63E-07	1,71E-05	1,16E-06
Terrestrial ecotoxicity	kg 1,4-DCB	2,27E+02	2,20E+02	2,65E-01	2,16E-02	6,82E+00	2,67E-01
Freshwater ecotoxicity	kg 1,4-DCB	6,58E-02	6,11E-02	1,90E-04	1,64E-05	4,33E-03	8,33E-05
Marine ecotoxicity	kg 1,4-DCB	2,01E-01	1,90E-01	4,77E-04	3,57E-05	1,03E-02	5,64E-04
Human carcinogenic toxicity	kg 1,4-DCB	7,20E-01	6,18E-01	2,53E-03	3,83E-04	9,81E-02	1,61E-03
Human non-carcinogenic toxicity	kg 1,4-DCB	8,53E+00	7,54E+00	3,02E-02	5,31E-03	9,38E-01	1,95E-02
Land use	m^2a crop eq.	9,92E-01	6,47E-01	4,05E-03	4,04E-04	3,35E-01	5,29E-03
Mineral resource scarcity	kg Cu eq.	2,45E+00	2,43E+00	5,28E-04	4,94E-05	1,88E-02	4,38E-04
Fossil resource scarcity	kg oil eq.	2,08E+01	1,96E+01	8,24E-02	6,79E-03	1,06E+00	9,16E-02
Water consumption	m^3	1,18E+00	1,15E+00	2,17E-03	1,88E-04	2,64E-02	1,26E-03

Table 49: 1 kg product in step freeze drying for item 500 IU/20 ml

Impact category	Unit	Total	Sterile filled product	Al	PP	Injection moulding
Global warming	kg CO_2 eq.	1,68E+02	1,68E+02	4,26E-02	4,50E-03	3,65E-03
Stratospheric ozone depletion	kg CFC11 eq.	7,15E-05	7,15E-05	9,27E-09	5,83E-10	1,63E-09
Ionizing radiation	kBq Co-60 eq.	6,43E-01	6,43E-01	5,69E-05	8,74E-06	8,89E-05
Ozone formation, Human health	kg NO_x eq.	3,18E-01	3,18E-01	1,11E-04	9,26E-06	6,47E-06
Fine particulate matter formation	kg $PM_{2.5}$ eq.	6,39E-01	6,39E-01	8,41E-05	4,52E-06	4,54E-06
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	3,27E-01	3,27E-01	1,12E-04	9,85E-06	6,79E-06
Terrestrial acidification	kg SO_2 eq.	2,01E+00	2,01E+00	1,86E-04	1,17E-05	1,16E-05
Freshwater eutrophication	kg P eq.	4,59E-03	4,59E-03	1,30E-06	8,59E-08	2,61E-07
Marine eutrophication	kg N eq.	2,39E-03	2,39E-03	8,48E-08	1,83E-08	1,64E-08
Terrestrial ecotoxicity	kg 1,4-DCB	5,02E+02	5,02E+02	2,39E-02	4,35E-03	2,79E-03
Freshwater ecotoxicity	kg 1,4-DCB	1,40E-01	1,40E-01	3,51E-05	2,42E-06	2,37E-06
Marine ecotoxicity	kg 1,4-DCB	4,13E-01	4,12E-01	6,58E-05	6,08E-06	7,38E-06
Human carcinogenic toxicity	kg 1,4-DCB	1,41E+00	1,41E+00	1,87E-03	4,05E-05	4,19E-05
Human non-carcinogenic toxicity	kg 1,4-DCB	1,72E+01	1,72E+01	1,83E-02	5,29E-04	5,84E-04
Land use	m^2a crop eq.	1,59E+00	1,58E+00	4,66E-04	3,55E-05	2,15E-04
Mineral resource scarcity	kg Cu eq.	6,18E+00	6,18E+00	4,54E-04	9,20E-06	1,21E-05
Fossil resource scarcity	kg oil eq.	4,04E+01	4,04E+01	8,76E-03	3,26E-03	1,31E-03
Water consumption	m^3	2,76E+00	2,76E+00	1,38E-04	3,94E-05	6,30E-05

Table 50: 1 kg product in step freeze drying for item 500 IU/10 ml

Impact category	Unit	Total	Sterile filled product	Al	PP	Injection moulding
Global warming	kg CO_2 eq.	3,21E+02	3,21E+02	8,05E-02	8,50E-03	6,90E-03
Stratospheric ozone depletion	kg CFC11 eq.	1,37E-04	1,37E-04	1,75E-08	1,10E-09	3,08E-09
Ionizing radiation	kBq Co-60 eq.	1,23E+00	1,23E+00	1,08E-04	1,65E-05	1,68E-04
Ozone formation, Human health	kg NO_x eq.	5,84E-01	5,83E-01	2,10E-04	1,75E-05	1,22E-05
Fine particulate matter formation	kg $PM_{2.5}$ eq.	1,23E+00	1,23E+00	1,59E-04	8,55E-06	8,58E-06
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	6,00E-01	6,00E-01	2,11E-04	1,86E-05	1,28E-05
Terrestrial acidification	kg SO_2 eq.	3,87E+00	3,87E+00	3,52E-04	2,21E-05	2,19E-05
Freshwater eutrophication	kg P eq.	8,89E-03	8,88E-03	2,45E-06	1,62E-07	4,94E-07
Marine eutrophication	kg N eq.	4,66E-03	4,66E-03	1,60E-07	3,45E-08	3,10E-08
Terrestrial ecotoxicity	kg 1,4-DCB	9,66E+02	9,66E+02	4,52E-02	8,22E-03	5,27E-03
Freshwater ecotoxicity	kg 1,4-DCB	2,65E-01	2,64E-01	6,64E-05	4,58E-06	4,48E-06
Marine ecotoxicity	kg 1,4-DCB	7,87E-01	7,87E-01	1,24E-04	1,15E-05	1,39E-05
Human carcinogenic toxicity	kg 1,4-DCB	2,58E+00	2,58E+00	3,53E-03	7,66E-05	7,92E-05
Human non-carcinogenic toxicity	kg 1,4-DCB	3,19E+01	3,19E+01	3,45E-02	1,00E-03	1,10E-03
Land use	m^2a crop eq.	2,49E+00	2,49E+00	8,81E-04	6,72E-05	4,06E-04
Mineral resource scarcity	kg Cu eq.	1,20E+01	1,20E+01	8,58E-04	1,74E-05	2,28E-05
Fossil resource scarcity	kg oil eq.	7,71E+01	7,71E+01	1,66E-02	6,16E-03	2,48E-03
Water consumption	m^3	5,33E+00	5,33E+00	2,60E-04	7,46E-05	1,19E-04

Table 51: 1 kg product in step freeze drying for item 1000 IU/20 ml

Impact category	Unit	Total	Sterile filled product	Al	PP	Injection moulding
Global warming	kg CO_2 eq.	1,75E+02	1,75E+02	4,08E-02	4,31E-03	3,50E-03
Stratospheric ozone depletion	kg CFC11 eq.	7,35E-05	7,35E-05	8,89E-09	5,58E-10	1,56E-09
Ionizing radiation	kBq Co-60 eq.	7,16E-01	7,16E-01	5,45E-05	8,38E-06	8,52E-05
Ozone formation, Human health	kg NO_x eq.	3,36E-01	3,35E-01	1,07E-04	8,87E-06	6,20E-06
Fine particulate matter formation	kg $PM_{2.5}$ eq.	6,39E-01	6,38E-01	8,06E-05	4,33E-06	4,35E-06
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	3,45E-01	3,45E-01	1,07E-04	9,44E-06	6,51E-06
Terrestrial acidification	kg SO_2 eq.	1,99E+00	1,99E+00	1,79E-04	1,12E-05	1,11E-05
Freshwater eutrophication	kg P eq.	5,67E-03	5,67E-03	1,24E-06	8,23E-08	2,50E-07
Marine eutrophication	kg N eq.	2,59E-03	2,59E-03	8,12E-08	1,75E-08	1,57E-08
Terrestrial ecotoxicity	kg 1,4-DCB	5,09E+02	5,09E+02	2,29E-02	4,17E-03	2,67E-03
Freshwater ecotoxicity	kg 1,4-DCB	1,43E-01	1,43E-01	3,37E-05	2,32E-06	2,27E-06
Marine ecotoxicity	kg 1,4-DCB	4,28E-01	4,28E-01	6,31E-05	5,82E-06	7,07E-06
Human carcinogenic toxicity	kg 1,4-DCB	1,47E+00	1,47E+00	1,79E-03	3,88E-05	4,02E-05
Human non-carcinogenic toxicity	kg 1,4-DCB	1,78E+01	1,78E+01	1,75E-02	5,07E-04	5,60E-04
Land use	m^2a crop eq.	1,71E+00	1,71E+00	4,46E-04	3,40E-05	2,06E-04
Mineral resource scarcity	kg Cu eq.	6,03E+00	6,03E+00	4,35E-04	8,82E-06	1,16E-05
Fossil resource scarcity	kg oil eq.	4,27E+01	4,27E+01	8,39E-03	3,12E-03	1,26E-03
Water consumption	m^3	2,75E+00	2,75E+00	1,32E-04	3,78E-05	6,04E-05

Table 52: 1 kg product in step freeze drying for item 2500 IU/50 ml

Impact category	Unit	Total	Sterile filled product	Al	PP	Injection moulding
Global warming	kg CO_2 eq.	8,22E+01	8,22E+01	4,22E-02	4,46E-03	3,62E-03
Stratospheric ozone depletion	kg CFC11 eq.	3,39E-05	3,39E-05	9,19E-09	5,77E-10	1,62E-09
Ionizing radiation	kBq Co-60 eq.	3,81E-01	3,80E-01	5,64E-05	8,66E-06	8,81E-05
Ozone formation, Human health	kg NO_x eq.	1,69E-01	1,68E-01	1,10E-04	9,18E-06	6,41E-06
Fine particulate matter formation	kg $PM_{2.5}$ eq.	2,76E-01	2,76E-01	8,33E-05	4,48E-06	4,50E-06
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	1,73E-01	1,73E-01	1,11E-04	9,76E-06	6,73E-06
Terrestrial acidification	kg SO_2 eq.	8,40E-01	8,40E-01	1,85E-04	1,16E-05	1,15E-05
Freshwater eutrophication	kg P eq.	3,46E-03	3,46E-03	1,29E-06	8,51E-08	2,59E-07
Marine eutrophication	kg N eq.	1,31E-03	1,31E-03	8,40E-08	1,81E-08	1,62E-08
Terrestrial ecotoxicity	kg 1,4-DCB	2,27E+02	2,27E+02	2,37E-02	4,31E-03	2,76E-03
Freshwater ecotoxicity	kg 1,4-DCB	6,58E-02	6,58E-02	3,48E-05	2,40E-06	2,35E-06
Marine ecotoxicity	kg 1,4-DCB	2,01E-01	2,01E-01	6,52E-05	6,02E-06	7,31E-06
Human carcinogenic toxicity	kg 1,4-DCB	7,22E-01	7,20E-01	1,85E-03	4,01E-05	4,15E-05
Human non-carcinogenic toxicity	kg 1,4-DCB	8,55E+00	8,53E+00	1,81E-02	5,24E-04	5,79E-04
Land use	m^2a crop eq.	9,93E-01	9,92E-01	4,62E-04	3,52E-05	2,13E-04
Mineral resource scarcity	kg Cu eq.	2,45E+00	2,45E+00	4,50E-04	9,12E-06	1,20E-05
Fossil resource scarcity	kg oil eq.	2,08E+01	2,08E+01	8,68E-03	3,23E-03	1,30E-03
Water consumption	m^3	1,18E+00	1,18E+00	1,37E-04	3,91E-05	6,24E-05

Table 53: 1 kg product in step packaging and transport for item 500 IU/20 ml

Impact category	Unit	Total	Core board	Kraft paper	Transport, aircraft	Freeze dried product
Global warming	kg CO_2 eq.	1,26E+02	2,26E+01	4,47E-01	8,32E+01	2,00E+01
Stratospheric ozone depletion	kg CFC11 eq.	6,60E-05	3,70E-05	4,87E-07	2,12E-05	7,37E-06
Ionizing radiation	kBq Co-60 eq.	9,47E-01	1,97E-01	6,38E-03	5,97E-01	1,46E-01
Ozone formation, Human health	kg NO_x eq.	5,81E-01	9,88E-02	2,27E-03	4,20E-01	6,01E-02
Fine particulate matter formation	kg $PM_{2.5}$ eq.	1,63E-01	4,85E-02	7,89E-04	8,27E-02	3,14E-02
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	5,87E-01	1,00E-01	2,40E-03	4,23E-01	6,12E-02
Terrestrial acidification	kg SO_2 eq.	4,34E-01	1,13E-01	2,21E-03	2,50E-01	6,95E-02
Freshwater eutrophication	kg P eq.	6,41E-03	4,31E-03	6,40E-05	1,28E-04	1,92E-03
Marine eutrophication	kg N eq.	9,25E-03	8,73E-03	8,61E-05	4,03E-05	3,85E-04
Terrestrial ecotoxicity	kg 1,4-DCB	2,94E+02	1,16E+02	7,79E+00	1,37E+02	3,32E+01
Freshwater ecotoxicity	kg 1,4-DCB	2,23E-01	1,78E-01	1,45E-03	2,97E-02	1,48E-02
Marine ecotoxicity	kg 1,4-DCB	3,47E-01	1,49E-01	7,27E-03	1,44E-01	4,61E-02
Human carcinogenic toxicity	kg 1,4-DCB	8,42E-01	3,78E-01	1,02E-02	1,83E-01	2,71E-01
Human non-carcinogenic toxicity	kg 1,4-DCB	3,02E+01	1,28E+01	1,50E-01	1,42E+01	2,91E+00
Land use	m^2a crop eq.	1,27E+01	1,05E+01	1,37E+00	1,58E-01	7,16E-01
Mineral resource scarcity	kg Cu eq.	1,29E-01	6,11E-02	1,01E-03	2,28E-02	4,43E-02
Fossil resource scarcity	kg oil eq.	3,89E+01	5,75E+00	1,20E-01	2,71E+01	5,97E+00
Water consumption	m^3	1,17E+00	9,62E-01	9,52E-03	3,24E-02	1,65E-01

Table 54: 1 kg product in step packaging and transport for item 500 IU/10 ml

Impact category	Unit	Total	Core board	Kraft paper	Transport, aircraft	Freeze dried product
Global warming	kg CO_2 eq.	3,73E+02	8,04E+01	8,67E-01	2,57E+02	3,42E+01
Stratospheric ozone depletion	kg CFC11 eq.	2,11E-04	1,32E-04	9,45E-07	6,54E-05	1,29E-05
Ionizing radiation	kBq Co-60 eq.	2,83E+00	7,03E-01	1,24E-02	1,85E+00	2,70E-01
Ozone formation, Human health	kg NO_x eq.	1,74E+00	3,52E-01	4,41E-03	1,30E+00	8,30E-02
Fine particulate matter formation	kg $PM_{2.5}$ eq.	4,78E-01	1,73E-01	1,53E-03	2,56E-01	4,84E-02
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	1,76E+00	3,57E-01	4,67E-03	1,31E+00	8,51E-02
Terrestrial acidification	kg SO_2 eq.	1,28E+00	4,02E-01	4,30E-03	7,72E-01	1,03E-01
Freshwater eutrophication	kg P eq.	1,97E-02	1,53E-02	1,24E-04	3,97E-04	3,83E-03
Marine eutrophication	kg N eq.	3,22E-02	3,11E-02	1,67E-04	1,25E-04	7,83E-04
Terrestrial ecotoxicity	kg 1,4-DCB	9,07E+02	4,12E+02	1,51E+01	4,23E+02	5,69E+01
Freshwater ecotoxicity	kg 1,4-DCB	7,50E-01	6,33E-01	2,81E-03	9,18E-02	2,27E-02
Marine ecotoxicity	kg 1,4-DCB	1,07E+00	5,30E-01	1,41E-02	4,47E-01	7,69E-02
Human carcinogenic toxicity	kg 1,4-DCB	2,31E+00	1,35E+00	1,98E-02	5,65E-01	3,74E-01
Human non-carcinogenic toxicity	kg 1,4-DCB	9,44E+01	4,58E+01	2,91E-01	4,41E+01	4,25E+00
Land use	m^2a crop eq.	4,13E+01	3,73E+01	2,67E+00	4,88E-01	8,26E-01
Mineral resource scarcity	kg Cu eq.	3,45E-01	2,18E-01	1,95E-03	7,04E-02	5,43E-02
Fossil resource scarcity	kg oil eq.	1,15E+02	2,05E+01	2,33E-01	8,37E+01	1,05E+01
Water consumption	m^3	3,84E+00	3,43E+00	1,85E-02	1,00E-01	2,96E-01

Table 55: 1 kg product in step packaging and transport for item 1000 IU/20 ml

Impact category	Unit	Total	Core board	Kraft paper	Transport, aircraft	Freeze dried product
Global warming	kg CO_2 eq.	1,37E+02	2,20E+01	4,35E-01	8,11E+01	3,35E+01
Stratospheric ozone depletion	kg CFC11 eq.	6,97E-05	3,60E-05	4,74E-07	2,06E-05	1,26E-05
Ionizing radiation	kBq Co-60 eq.	1,04E+00	1,92E-01	6,21E-03	5,82E-01	2,60E-01
Ozone formation, Human health	kg NO_x eq.	5,96E-01	9,62E-02	2,21E-03	4,09E-01	8,82E-02
Fine particulate matter formation	kg $PM_{2.5}$ eq.	1,78E-01	4,72E-02	7,68E-04	8,06E-02	4,94E-02
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	6,02E-01	9,77E-02	2,34E-03	4,12E-01	9,02E-02
Terrestrial acidification	kg SO_2 eq.	4,62E-01	1,10E-01	2,15E-03	2,43E-01	1,06E-01
Freshwater eutrophication	kg P eq.	8,05E-03	4,19E-03	6,23E-05	1,25E-04	3,67E-03
Marine eutrophication	kg N eq.	9,35E-03	8,50E-03	8,38E-05	3,92E-05	7,25E-04
Terrestrial ecotoxicity	kg 1,4-DCB	3,09E+02	1,13E+02	7,58E+00	1,33E+02	5,58E+01
Freshwater ecotoxicity	kg 1,4-DCB	2,26E-01	1,73E-01	1,41E-03	2,89E-02	2,28E-02
Marine ecotoxicity	kg 1,4-DCB	3,68E-01	1,45E-01	7,07E-03	1,41E-01	7,58E-02
Human carcinogenic toxicity	kg 1,4-DCB	9,49E-01	3,68E-01	9,92E-03	1,78E-01	3,93E-01
Human non-carcinogenic toxicity	kg 1,4-DCB	3,09E+01	1,25E+01	1,46E-01	1,39E+01	4,36E+00
Land use	m^2a crop eq.	1,26E+01	1,02E+01	1,34E+00	1,54E-01	9,41E-01
Mineral resource scarcity	kg Cu eq.	1,41E-01	5,95E-02	9,79E-04	2,22E-02	5,85E-02
Fossil resource scarcity	kg oil eq.	4,22E+01	5,60E+00	1,17E-01	2,64E+01	1,01E+01
Water consumption	m^3	1,26E+00	9,37E-01	9,26E-03	3,16E-02	2,83E-01

Table 56: 1 kg product in step packaging and transport for item 2500 IU/50 ml

Impact category	Unit	Total	Core board	Kraft paper	Transport, aircraft	Freeze dried product
Global warming	kg CO_2 eq.	1,00E+02	1,62E+01	1,75E-01	5,57E+01	2,83E+01
Stratospheric ozone depletion	kg CFC11 eq.	5,17E-05	2,66E-05	1,91E-07	1,42E-05	1,07E-05
Ionizing radiation	kBq Co-60 eq.	7,66E-01	1,42E-01	2,50E-03	4,00E-01	2,22E-01
Ozone formation, Human health	kg NO_x eq.	4,26E-01	7,11E-02	8,89E-04	2,81E-01	7,28E-02
Fine particulate matter formation	kg $PM_{2.5}$ eq.	1,32E-01	3,48E-02	3,09E-04	5,54E-02	4,13E-02
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	4,31E-01	7,21E-02	9,42E-04	2,83E-01	7,44E-02
Terrestrial acidification	kg SO_2 eq.	3,38E-01	8,12E-02	8,67E-04	1,67E-01	8,84E-02
Freshwater eutrophication	kg P eq.	6,42E-03	3,10E-03	2,51E-05	8,60E-05	3,21E-03
Marine eutrophication	kg N eq.	6,98E-03	6,28E-03	3,37E-05	2,70E-05	6,40E-04
Terrestrial ecotoxicity	kg 1,4-DCB	2,25E+02	8,32E+01	3,05E+00	9,16E+01	4,71E+01
Freshwater ecotoxicity	kg 1,4-DCB	1,67E-01	1,28E-01	5,67E-04	1,99E-02	1,89E-02
Marine ecotoxicity	kg 1,4-DCB	2,70E-01	1,07E-01	2,85E-03	9,67E-02	6,37E-02
Human carcinogenic toxicity	kg 1,4-DCB	7,21E-01	2,72E-01	3,99E-03	1,22E-01	3,23E-01
Human non-carcinogenic toxicity	kg 1,4-DCB	2,24E+01	9,24E+00	5,87E-02	9,54E+00	3,60E+00
Land use	m^2a crop eq.	8,93E+00	7,53E+00	5,38E-01	1,06E-01	7,56E-01
Mineral resource scarcity	kg Cu eq.	1,06E-01	4,40E-02	3,94E-04	1,52E-02	4,65E-02
Fossil resource scarcity	kg oil eq.	3,08E+01	4,14E+00	4,70E-02	1,81E+01	8,48E+00
Water consumption	m^3	9,58E-01	6,92E-01	3,73E-03	2,17E-02	2,41E-01

Table 57: Ventilation and electricity for 1 kg formulated product

Impact category	Unit	Total	Formulated bulk 2500/50	Formulated bulk 1000/20	Formulated bulk 500/10	Formulated bulk 500/20	Electricity	Ventilation
Global warming	kg CO_2 eq.	2,05E+01	0,00E+00	7,31E+00	6,90E+00	4,59E+00	1,64E+00	3,68E-03
Stratospheric ozone depletion	kg CFC11 eq.	8,26E-06	0,00E+00	2,95E-06	2,79E-06	1,85E-06	6,66E-07	2,21E-09
Ionizing radiation	kBq Co-60 eq.	1,82E-01	0,00E+00	6,50E-02	6,13E-02	4,07E-02	1,46E-02	3,88E-05
Ozone formation, Human health	kg NO_x eq.	2,83E-02	0,00E+00	1,01E-02	9,53E-03	6,34E-03	2,27E-03	4,93E-06
Fine particulate matter formation	kg $PM_{2.5}$ eq.	2,37E-02	0,00E+00	8,46E-03	7,99E-03	5,32E-03	1,91E-03	2,40E-06
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	2,93E-02	0,00E+00	1,05E-02	9,87E-03	6,57E-03	2,35E-03	5,00E-06
Terrestrial acidification	kg SO_2 eq.	4,16E-02	0,00E+00	1,48E-02	1,40E-02	9,35E-03	3,36E-03	7,17E-06
Freshwater eutrophication	kg P eq.	2,57E-03	0,00E+00	9,20E-04	8,65E-04	5,75E-04	2,09E-04	4,47E-07
Marine eutrophication	kg N eq.	5,00E-04	0,00E+00	1,79E-04	1,68E-04	1,12E-04	4,10E-05	1,11E-08
Terrestrial ecotoxicity	kg 1,4-DCB	3,31E+01	0,00E+00	1,18E+01	1,12E+01	7,44E+00	2,66E+00	1,27E-03
Freshwater ecotoxicity	kg 1,4-DCB	1,24E-02	0,00E+00	4,44E-03	4,18E-03	2,78E-03	1,00E-03	1,15E-06
Marine ecotoxicity	kg 1,4-DCB	4,46E-02	0,00E+00	1,59E-02	1,50E-02	1,00E-02	3,58E-03	2,90E-06
Human carcinogenic toxicity	kg 1,4-DCB	1,72E-01	0,00E+00	6,15E-02	5,80E-02	3,86E-02	1,38E-02	3,83E-05
Human non-carcinogenic toxicity	kg 1,4-DCB	2,16E+00	0,00E+00	7,74E-01	7,30E-01	4,85E-01	1,74E-01	5,59E-04
Land use	m^2a crop eq.	3,75E-01	0,00E+00	1,34E-01	1,26E-01	8,39E-02	3,02E-02	1,10E-04
Mineral resource scarcity	kg Cu eq.	1,95E-02	0,00E+00	6,83E-03	6,58E-03	4,47E-03	1,61E-03	3,44E-06
Fossil resource scarcity	kg oil eq.	6,18E+00	0,00E+00	2,21E+00	2,08E+00	1,39E+00	4,96E-01	9,40E-04
Water consumption	m^3	1,76E-01	0,00E+00	6,28E-02	5,92E-02	3,94E-02	1,42E-02	7,78E-05

Table 58: Ventilation and electricity for 1 kg sterile filtered product

Impact category	Unit	Total	Formulated bulk 2500/50	Formulated bulk 1000/20	Formulated bulk 500/10	Formulated bulk 500/20	Electricity
Global warming	kg CO_2 eq.	2,15E+01	7,47E+00	7,12E+00	4,88E+00	1,76E+00	2,26E-01
Stratospheric ozone depletion	kg CFC11 eq.	8,65E-06	3,02E-06	2,85E-06	1,94E-06	7,00E-07	1,36E-07
Ionizing radiation	kBq Co-60 eq.	1,87E-01	6,55E-02	6,22E-02	4,19E-02	1,50E-02	2,39E-03
Ozone formation, Human health	kg NO_x eq.	2,96E-02	1,03E-02	9,82E-03	6,71E-03	2,42E-03	3,03E-04
Fine particulate matter formation	kg $PM_{2,5}$ eq.	2,44E-02	8,57E-03	8,14E-03	5,52E-03	1,98E-03	1,48E-04
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	3,06E-02	1,07E-02	1,02E-02	6,95E-03	2,50E-03	3,08E-04
Terrestrial acidification	kg SO_2 eq.	4,34E-02	1,51E-02	1,44E-02	9,87E-03	3,56E-03	4,41E-04
Freshwater eutrophication	kg P eq.	2,61E-03	9,23E-04	8,70E-04	5,81E-04	2,12E-04	2,75E-05
Marine eutrophication	kg N eq.	5,34E-04	1,89E-04	1,77E-04	1,22E-04	4,52E-05	6,82E-07
Terrestrial ecotoxicity	kg 1,4-DCB	3,43E+01	1,20E+01	1,15E+01	7,87E+00	2,83E+00	7,81E-02
Freshwater ecotoxicity	kg 1,4-DCB	1,30E-02	4,54E-03	4,33E-03	2,97E-03	1,07E-03	7,10E-05
Marine ecotoxicity	kg 1,4-DCB	4,63E-02	1,62E-02	1,55E-02	1,06E-02	3,81E-03	1,78E-04
Human carcinogenic toxicity	kg 1,4-DCB	1,79E-01	6,24E-02	5,93E-02	4,03E-02	1,45E-02	2,35E-03
Human non-carcinogenic toxicity	kg 1,4-DCB	2,27E+00	7,89E-01	7,51E-01	5,13E-01	1,85E-01	3,43E-02
Land use	m^2a crop eq.	3,89E-01	1,35E-01	1,29E-01	8,69E-02	3,14E-02	6,75E-03
Mineral resource scarcity	kg Cu eq.	2,06E-02	6,98E-03	6,85E-03	4,81E-03	1,75E-03	2,12E-04
Fossil resource scarcity	kg oil eq.	6,48E+00	2,26E+00	2,16E+00	1,48E+00	5,33E-01	5,78E-02
Water consumption	m^3	1,88E-01	6,45E-02	6,12E-02	4,19E-02	1,52E-02	4,78E-03

Table 59: Ventilation and electricity for 1 kg sterile filled product

Impact category	Unit	Total	Formulated bulk 2500/50	Formulated bulk 1000/20	Formulated bulk 500/10	Formulated bulk 500/20	Electricity	Ventilation
Global warming	kg CO_2 eq.	2,68E+01	9,08E+00	9,00E+00	5,75E+00	2,71E+00	2,26E-01	6,56E-02
Stratospheric ozone depletion	kg CFC11 eq.	1,05E-05	3,56E-06	3,49E-06	2,25E-06	1,02E-06	1,36E-07	1,81E-08
Ionizing radiation	kBq Co-60 eq.	2,16E-01	7,41E-02	7,24E-02	4,73E-02	2,03E-02	2,39E-03	6,61E-05
Ozone formation, Human health	kg NO_x eq.	5,59E-02	1,85E-02	1,92E-02	1,08E-02	7,15E-03	3,03E-04	4,97E-05
Fine particulate matter formation	kg $PM_{2,5}$ eq.	3,57E-02	1,20E-02	1,21E-02	7,34E-03	4,01E-03	1,48E-04	1,53E-05
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	5,73E-02	1,89E-02	1,96E-02	1,11E-02	7,29E-03	3,08E-04	5,14E-05
Terrestrial acidification	kg SO_2 eq.	7,04E-02	2,34E-02	2,40E-02	1,41E-02	8,39E-03	4,41E-04	4,03E-05
Freshwater eutrophication	kg P eq.	2,80E-03	9,77E-04	9,33E-04	6,10E-04	2,44E-04	2,75E-05	1,15E-05
Marine eutrophication	kg N eq.	5,58E-04	1,96E-04	1,85E-04	1,26E-04	4,92E-05	6,82E-07	1,61E-06
Terrestrial ecotoxicity	kg 1,4-DCB	4,31E+01	1,47E+01	1,46E+01	9,32E+00	4,41E+00	7,81E-02	4,09E-03
Freshwater ecotoxicity	kg 1,4-DCB	1,85E-02	6,21E-03	6,28E-03	3,90E-03	2,06E-03	7,10E-05	4,88E-06
Marine ecotoxicity	kg 1,4-DCB	6,00E-02	2,03E-02	2,03E-02	1,29E-02	6,24E-03	1,78E-04	1,18E-04
Human carcinogenic toxicity	kg 1,4-DCB	3,00E-01	9,95E-02	1,02E-01	5,97E-02	3,62E-02	2,35E-03	2,14E-04
Human non-carcinogenic toxicity	kg 1,4-DCB	3,45E+00	1,15E+00	1,17E+00	7,06E-01	3,96E-01	3,43E-02	8,30E-04
Land use	m^2a crop eq.	7,88E-01	2,60E-01	2,70E-01	1,48E-01	1,03E-01	6,75E-03	6,64E-05
Mineral resource scarcity	kg Cu eq.	4,40E-02	1,42E-02	1,51E-02	8,57E-03	5,94E-03	2,12E-04	1,89E-05
Fossil resource scarcity	kg oil eq.	8,04E+00	2,70E+00	2,69E+00	1,75E+00	8,04E-01	5,78E-02	2,54E-02
Water consumption	m^3	2,25E-01	7,53E-02	7,42E-02	4,87E-02	2,18E-02	4,78E-03	3,32E-04

Table 60: Ventilation and electricity for 1 kg freeze dried product

Impact category	Unit	Total	Formulated bulk 2500/50	Formulated bulk 1000/20	Formulated bulk 500/10	Formulated bulk 500/20	Electricity	Ventilation
Global warming	kg CO_2 eq.	2,95E+01	9,10E+00	9,01E+00	5,77E+00	2,71E+00	1,42E+00	1,44E+00
Stratospheric ozone depletion	kg CFC11 eq.	1,16E-05	3,57E-06	3,50E-06	2,25E-06	1,03E-06	8,49E-07	3,99E-07
Ionizing radiation	kBq Co-60 eq.	2,31E-01	7,41E-02	7,25E-02	4,73E-02	2,03E-02	1,50E-02	1,45E-03
Ozone formation, Human health	kg NO_x eq.	5,87E-02	1,85E-02	1,92E-02	1,08E-02	7,17E-03	1,90E-03	1,09E-03
Fine particulate matter formation	kg $PM_{2,5}$ eq.	3,69E-02	1,21E-02	1,22E-02	7,37E-03	4,02E-03	9,25E-04	3,38E-04
Ozone formation, Terrestrial ecosystems	kg NO_x eq.	6,01E-02	1,90E-02	1,96E-02	1,11E-02	7,31E-03	1,93E-03	1,13E-03
Terrestrial acidification	kg SO_2 eq.	7,38E-02	2,35E-02	2,40E-02	1,42E-02	8,42E-03	2,76E-03	8,87E-04
Freshwater eutrophication	kg P eq.	3,19E-03	9,78E-04	9,33E-04	6,11E-04	2,44E-04	1,72E-04	2,52E-04
Marine eutrophication	kg N eq.	5,95E-04	1,96E-04	1,85E-04	1,26E-04	4,92E-05	4,27E-06	3,53E-05
Terrestrial ecotoxicity	kg 1,4-DCB	4,37E+01	1,47E+01	1,46E+01	9,33E+00	4,41E+00	4,89E-01	8,99E-02
Freshwater ecotoxicity	kg 1,4-DCB	1,90E-02	6,22E-03	6,29E-03	3,91E-03	2,07E-03	4,44E-04	1,07E-04
Marine ecotoxicity	kg 1,4-DCB	6,35E-02	2,04E-02	2,03E-02	1,29E-02	6,25E-03	1,11E-03	2,59E-03
Human carcinogenic toxicity	kg 1,4-DCB	3,19E-01	1,00E-01	1,03E-01	6,04E-02	3,65E-02	1,47E-02	4,70E-03
Human non-carcinogenic toxicity	kg 1,4-DCB	3,67E+00	1,15E+00	1,17E+00	7,13E-01	3,99E-01	2,15E-01	1,83E-02
Land use	m^2a crop eq.	8,26E-01	2,60E-01	2,71E-01	1,48E-01	1,03E-01	4,23E-02	1,46E-03
Mineral resource scarcity	kg Cu eq.	4,61E-02	1,43E-02	1,53E-02	8,74E-03	6,01E-03	1,33E-03	4,17E-04
Fossil resource scarcity	kg oil eq.	8,89E+00	2,71E+00	2,69E+00	1,76E+00	8,06E-01	3,62E-01	5,58E-01
Water consumption	m^3	2,58E-01	7,54E-02	7,43E-02	4,88E-02	2,19E-02	3,00E-02	7,30E-03