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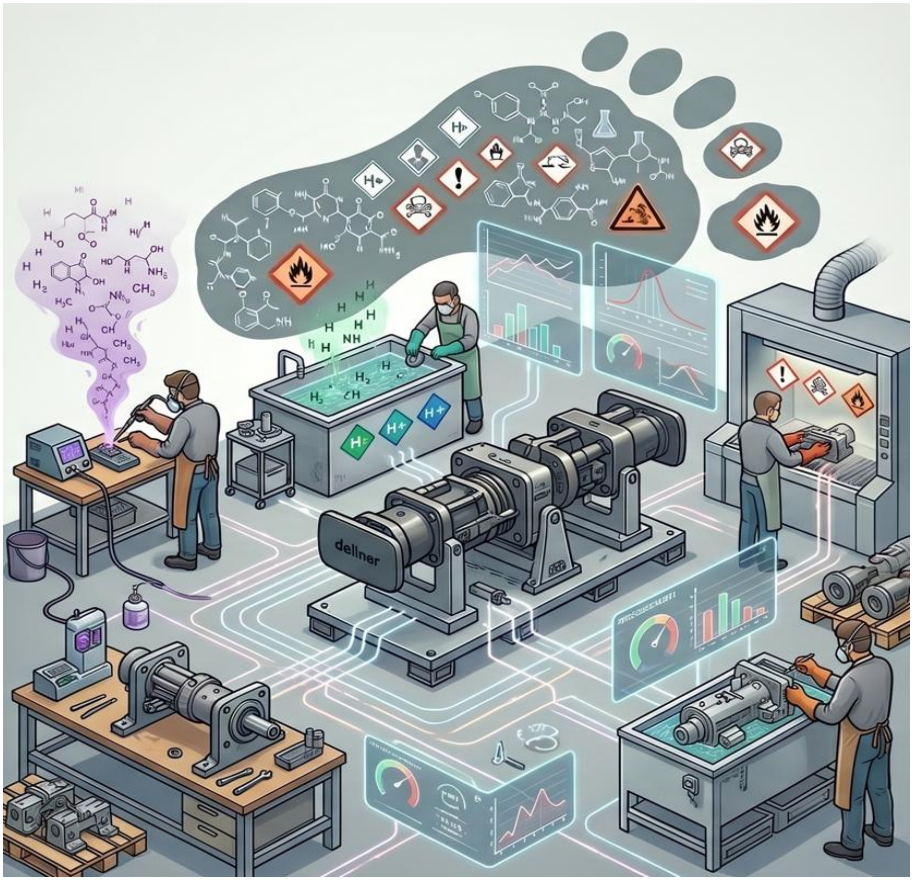

ProScale as a Tool for Organisational Chemical Footprint Assessment: A case study of Dellner Couplers AB

Master's thesis in Industrial Ecology

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SUMMARY

Current organisational chemical management practices lack harmonisation between actual toxicological impacts, regulation and operational feasibility. Existing approaches often maintain a narrow focus where the life cycle perspective is missing, increasing the risk of burden shifting. ProScale is a risk-based chemical footprinting tool which quantifies toxicity throughout a product's life cycle. In this study, the potential of ProScale as a tool for developing an organisational chemical footprint is investigated. The overall aim is to evaluate whether the ProScale method is a sufficiently simple yet informative tool to assess toxicity impact to be implemented by organisations to use for decision-making. Furthermore, the research explores whether this serves as a practical pathway away from current fragmented chemical management practices towards a science-based, organisational chemical footprint and whether this is useful to organisations.

To address these aims, a case study was conducted in which ProScale was applied to the chemical portfolio of Dellner, a train coupler manufacturer. While the results clearly demonstrate that ProScale successfully can be applied to quantify the chemical footprint of an organisation, the transition from a product-specific focus demanded several methodological adaptations to the tool. The findings indicate that a ProScale developed organisational chemical footprint indeed is useful for chemical management. However, the method needs further development to be practically feasible for internal use and decision-making support. The results indicate that the method used in the present study may have too many uncertainties regarding data collection and interpretations of inputs to yet be sufficiently rigid for external communication and comparison across organisations.

Keywords: Organisational chemical footprint, ProScale, Chemical management, Occupational toxicity.

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1 Introduction

Over the past 70 years, the chemical industry has experienced an approximate 50-fold increase in production and use (Persson et al., 2022). The trend expected to continue, as production and use of chemicals is projected to triple again by 2050. Persson et al. (2022) suggests that the planetary boundary for novel entities, defined as materials and substances that have been introduced to the environment by human activity, should be defined by the capacity to assess and monitor novel entities and conclude that this boundary is exceeded due to the insufficient monitoring and the growing number and complexity of new substances. There is a debt of persistent novel entities that will continue to pose risks to humans and the environment, even if all chemical production and use would be adequately assessed and monitored from here on (Persson et al., 2022). It should, however, be highlighted that chemicals have also been tremendously beneficial and played a key role in the development of modern society, and thus there is a need of developing and using chemicals in a way that does not harm the earth system and its biophysical processes which maintains the planetary stability (Persson et al. 2022; Sala & Goralczyk, 2013).

Rees et al. (1992) explains that one way to navigate and address complex environmental issues, such as the difficulty of assessing and monitoring novel entities, is by calculating environmental footprints. The concept of environmental footprints originally emerged in the 1990s with the Ecological Footprint. It was developed to visualize the impact of human society on the environment and geographically distant regions in a way that economic analysis could not (Rees, 1992). Since then, footprints have become a popular method to quantify human appropriation on natural resources (Čuček et al., 2012), aiming to represent the environmental burdens and impacts caused by human production and consumption (Sala & Goralczyk, 2013). During this time, Life Cycle Assessment (LCA) as an environmental assessment tool has also been developed and is widely used (Pelletier et al., 2014). Based on LCA methodology, the European Commission (EC) has developed methodologies for Product Environmental Footprints and Organisation Environmental Footprints for comparing products and organisations, respectively. The footprint and LCA tools are related, where footprints can be seen as partial results of an LCA. For example, the midpoint indicator of global warming in LCA is effectively a carbon footprint (Ran et al., 2024). Footprints based on LCA methodology are widely used in environmental management and constitute the basis of the Greenhouse Gas Protocol and Science-Based Targets initiative (SBTi) (Matuštík & Kočí, 2021). Footprints have further been used to assess how much of the safe operating space is taken up by individuals, countries or humanity, in relation to the planetary boundaries.

For the case of novel entities and chemicals, the use of footprints remains constrained as evaluating and comparing hazards and exposure along the life cycle is complex and time consuming (Andersson et al., 2024). While climate change is comparatively easy to quantify along the life cycle considering its global impact, toxicity is less straightforward. USEtox is a tool which aims to assess toxicity impacts along the life cycle by modelling fate in different media, exposure and toxicological effects, resulting in a characterization factor that can be multiplied with the emissions of the same chemical to yield the impact (Owsianiak et al., 2023). In the earliest versions of USEtox, human toxicity was only modelled by indirect exposure from chemicals emitted to the environment, and thus there was no assessment of the toxicity from direct exposure, particularly for workers.

To close this methodological gap, the risk-based chemical footprinting tool ProScale was developed as a collaboration between The Swedish Environmental Research Institute (IVL) and industrial partners (Lexén et al., 2017). It aims at providing a more practical way to combine hazard and exposure information across a chemical's life cycle for specific applications to evaluate risk along the life cycle and identify hotspots for improvements. The ProScale tool adds

additional layers of information and moves beyond standard regulatory requirements which often rely on hazard-based lists while disregarding the actual exposure of the specific situation and application (Lexén et al., 2017; Saling et al., 2019).

1.1 Aim and Research Questions

This thesis intends to investigate whether the ProScale method can be applied for developing an organisational chemical footprint and explores the extent to which ProScale can be used and adapted to represent the chemical footprint at an organisational level. By conducting a case study in collaboration with Dellner Couplers AB (in short: Dellner), the method's ability to identify hotspots and trade-offs, prioritise chemicals for substitution, and generally serve as a basis for corporate decision-making is tested. Furthermore, the study assesses whether ProScale offers a suitable balance between simplicity and informational value for organisational use. By exploring how ProScale can be adapted to an organisational level, the thesis intends to contribute to the methodological development of the tool, as well as the concept of organisational chemical footprints.

Based on this, the following research questions were derived:

1. How can the ProScale method be used to derive an organisational chemical footprint?
2. How can a ProScale-based organisational chemical footprint be used to identify relevant chemicals for management, substitution and decision making?
3. To what extent does the ProScale method balance simplicity and relevance to be useful and feasible for companies such as Dellner?

1.2 System under study

The case study is performed at Dellner, a train coupler manufacturer and service provider, whose chemical portfolio is analysed. However, the use and emissions of chemicals related to Dellner's products are not limited to the organisational gates. Chemicals are used and emitted both upstream and downstream throughout the manufacturing, use, service, and end-of-life of the train couplers. The appropriate system boundaries to capture the full organisational chemical footprint would include all activities related to all the products, including upstream and downstream activities. Due to the limited time and data available, this study only includes gate-to-gate activities. However, by showing the feasibility of the method within a narrow scope or one single company, it should in principle be applicable also for other companies upstream, enabling a life cycle-based organisational chemical footprint by extension given more time and effort.

2 Background

To understand how an organisational chemical footprint can be developed and applied, organisational environmental assessments, regulatory chemicals data and the organisational context need to be understood. This chapter presents the relevant organisational environmental assessment methods, regulatory frameworks and introduces Dellner.

2.1 Organisational Environmental Assessment

The assessment of the environmental impacts associated with an organisation can be useful since it focuses on impacts at the operational level where high-impact decisions are made (Pelletier et al., 2014). Until recently, organisational environmental assessment has largely been gate-to-gate operations, neglecting the life cycle perspective, or focused on single impacts, such as water use or greenhouse gas emissions (UNEP-SETAC, 2015).

One method applying a gate-to-gate perspective is environmental management systems (EMS), where environmental goals and legal requirements of the organisation are reviewed and analysed, and environmental objectives and targets are set. The idea is that increased control will improve the environmental performance of the organisation (UNEP-SETAC, 2015). However, EMS typically focuses on internal operations and thus risks burden-shifting impacts to another part of the life cycle.

The most used single-impact indicator approach for organisational assessments is the Greenhouse Gas Protocol. The reporting standard of this protocol defines scopes 1-3 that are used to ensure that both direct and indirect GHG emissions are accounted for (UNEP-SETAC, 2015). The standards in the GHG Protocol are applied by SBTi, which is a voluntary initiative that enables corporations to set goals for GHG emission reduction that are then validated by the SBTi. According to the SBTi, setting emission reduction goals results not only in climate impact reduction, but also in competitive advantages, improved reputation and risk mitigation (SBTi, 2025). However, neither the GHG protocol nor the SBTi considers toxicity impacts.

Two specific methodologies have been developed to assess the environmental impacts of organisations across the entire life cycle and for multiple impacts (Rimano et al., 2019), including toxicity. These are organisational life cycle assessment (O-LCA) and organisation environmental footprint (OEF), as described in the following sections.

2.1.1 Organisational Life Cycle Assessment

O-LCA is used to capture the full potential environmental impacts of the organisation across the life cycle tools (UNEP-SETAC, 2015). This includes the product portfolio as well as other organisational activities. The potential applications can be analytical, managerial or societal. Examples of analytical goals of O-LCA are identifying environmental hotspots, understanding risks and impact reduction opportunities, and tracking environmental performance over time. Managerial goals could be to support strategic decisions and inform corporate sustainability reporting. The analytical and managerial goals could help addressing societal goals, namely reducing pressure on the environment and motivating other stakeholders to use environmental tools (UNEP-SETAC, 2015).

O-LCA follows the methodology of product LCA closely, but with some important exceptions. Most notably, the scope differs between product LCA and O-LCA, affecting the definition of the unit of reference, and the delimitation of the system boundary. In O-LCA, the activities of the upstream and downstream organisations must be accounted for in addition to the flows relating to the product portfolio (UNEP-SETAC, 2015).

2.1.2 Organisation environmental footprint

OEF was developed by the EC with the goal of allowing comparison of environmental performance between similar organisations (Pelletier et al., 2014). This is in contrast with O-LCA, which explicitly prohibits comparison between organisations, since their unit of analysis will always be different (UNEP-SETAC, 2015). This means that the OEF has been developed with very strict requirements to ensure comparability across studies, and thus the methodology allows for limited flexibility (Rimano et al., 2019). An OEF should include 16 impact categories (climate change; ozone depletion; human toxicity, cancer and non-cancer; particulate matter; ionising radiation; photochemical ozone radiation; acidification; eutrophication, terrestrial, freshwater and marine; ecotoxicity, freshwater; land use; water use; resource use, minerals and materials, and fossils) assessed with pre-determined models (Damiani, Ferrara & Ardente, 2022). Exclusions of any of these impact categories need to be justified (Pelletier et al., 2014).

2.2 Existing chemical regulation data within organisations

The European Union, EU, has an extensive chemical regulation. Most prominently, the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation aims to protect humans and the environment from risks from chemicals (European Union, 2006). Manufacturers, importers and downstream users operating in the EU must identify and manage the risks associated with the substances they produce and sell. If a product cannot be used safely, the specific use or substance can be regulated (European Union, 2006).

The Globally Harmonised System of Classification and Labelling of Chemicals (GHS) is an initiative by the United Nations to develop internationally recognizable classes and labels for physical hazards and toxicity of chemicals (United Nations, 2023). This means that chemical hazards should be classified according to harmonized criteria and that communication elements such as labels and safety data sheets (SDS) are harmonized. For mixtures, all ingredients that are hazardous within the meaning of GHS need to be stated in the SDS, if they are present above their cut-off levels. Typically, the cut-off level is 1%, with the exception of respiratory/skin sensitization, germ cell mutagenicity (category 1 & 2), carcinogenicity and reproductive toxicity, where the cut-off level is 0.1% (United Nations, 2023).

The EU has implemented an extension of GHS by the Classification, Labelling and Packaging (CLP) Regulation (EC) No 1272/2008 (European Chemicals Agency, 2024). Classification refers to determining whether a substance or mixture has the properties that lead to one or more hazard classifications. Classification must be included in the registration dossier for substances according to REACH and can result in the need for an exposure assessment and risk characterisation. Hazard classifications also mean the need for supplying a SDS according to REACH (European Chemicals Agency, 2024). Since chemicals in the EU cannot be used or sold in large quantities if they have not been registered according to REACH and CLP, hazard data is readily available for most chemicals used in organisations, which can be used for risk-based chemical footprinting.

2.2.1 Hazard Phrases

Hazard phrases, also referred to as hazard statements or H-phrases, are standardised phrases assigned to a specific hazard class and category, describing the nature of the substance or mix and its hazard (Lexén et al., 2017; United Nations, 2023). These classifications are widely accepted and available, and form a common and coherent approach for defining, classifying and communicating hazards. Hazard phrases are a core element of the GHS. Each hazard phrase is

identified by a unique alphanumerical code, beginning with the letter H for "hazard", followed by three digits. The first number refers to the type of hazard, 2 for physical hazards, 3 for health hazards and 4 for environmental hazards, as shown in Table 1. The last two digits corresponds to the intrinsic properties of the substance or mixture (United Nations, 2023).

Harmonized hazard phrases are official hazard assessments of the chemical substance that are legally binding under the EU CLP Regulation. These are defined by ECHA and agreed upon at EU level for the purpose of standardizing the communication of chemical risk across EU. If a substance has a harmonized hazard statement, this H-phrase must be used for classification and labelling.

Table 1. Description of hazard phrase classes (MSDS-Europe, n.d.)

Phrase	Type of hazard	Description	Examples
H2xx	Physical hazards	Refers to physical hazards such as explosivity and flammability.	H200 Unstable explosive H204 Fire or projection hazard H221 Flammable gas
H3xx	Health hazards	Refers to health hazards caused by exposure to a substance or mixture.	H300 Fatal if swallowed H311 Toxic in contact with skin H331 Toxic if inhaled
H4xx	Environmental hazards	Refers to the harmfulness of a substance or mixture to the environment.	H400 Very toxic to aquatic life H401 Toxic to aquatic life H402 Harmful to aquatic life
EUHx	EU hazard phrases	Additional phrases providing information on specific hazards not included in the regular H-phrases and describes hazards related to specific conditions and situations.	EUH001 Explosive when dry EUH019 May form explosive peroxides EUH031 Contact with acids liberates toxic gas

2.2.2 Occupational exposure limits, OEL

An occupational exposure limit, OEL, is an upper limit of the acceptable concentration of a hazardous substance in the air of a workplace, indicating levels of exposure that are considered safe (European Chemicals Agency, n.d.a). OELs are set at the national level and by the EC. At the European level, binding OELs set a minimum level of protection for all workers in the EU. However, nations can set stricter OELs. Indicative OELs set by the EC need to be considered by member states but are not binding.

2.3 Dellner Couplers AB

Dellner is an international manufacturer and service provider of train connection systems, including couplers, gangways and dampers. They sell their products and services to train builders and rail operators worldwide. Except for a product portfolio, they also provide related downstream customer support such as installation, maintenance and refurbishments. Both in the manufacturing stages of the coupler modules, as well as during service and end-of-life activities, chemical products are used and/or emitted. The chemical portfolio includes chemical product groups such as lubricants, paints, adhesives, corrosion protection, cleaning and marking agents.

2.3.1 The organisation, Globally and Dellner Vika

During a site visit to Dellner´s headquarters and production facility in Falun, the company presented its organisation, operations and market position. According to this presentation, Dellner has a global presence, with operation and service capabilities worldwide (Figure 1). At

the site in Vika, only one out of the three product categories in the company´s product portfolio is manufactured: train couplers. The production activities at this site are primarily final assembly, integrating pre-manufactured parts from other Dellner sites and suppliers into finished train couplers, as well as maintenance and service of couplers already in operation. In addition to servicing their own products, the site also services non-original equipment manufacturer, non-OEM, couplers. Service is offered both on- and off-site, the latter by means of a transportable field-service container with basis at the site in Vika (J. Lexen, H. Garbergs, personal communication, 10 March 2026).

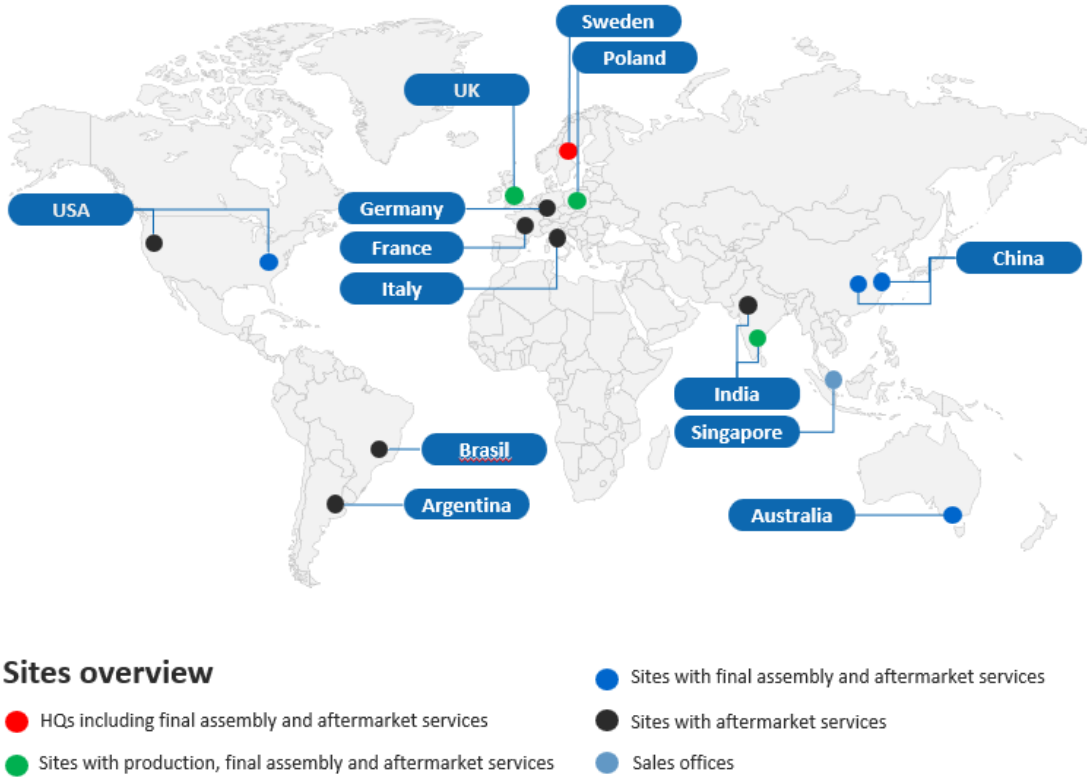

Figure 1. Illustration of Dellner´s Organisation (Credit: Dellner, used with permission)

2.3.2 Environmental management at Dellner Vika

The environmental and health impacts of the operations at Dellner Vika are controlled and regulated in multiple ways. Dellner works with risk assessments of their chemicals and continuously works with substitution of hazardous chemical products. Dellner has furthermore set targets according to the SBTi to reduce absolute scope 1 and 2 GHG emissions by 75.3% from year 2019 to 2030. They have also committed to reducing scope 3 GHG emissions by 27.5% within the same time frame. Dellner's environmental management system is certified according to ISO 14001 and their occupational health and safety management system is certified according to ISO 45001. In addition to these internal initiatives, Dellner Vika is regulated by national and municipal legal requirements. For example, this entails conducting risk assessments and having appropriate risk management measures of chemical risks (Swedish Work Environment Authority, n.d).

The chemical management at Dellner is primarily handled by employees working with environmental and eco-product related questions and issues (J. Lexen, H. Garbergs, personal communication, 10 March 2026). Work at Dellner Vika does not only affect the local production,

as some of their substitutional efforts have global effect, reaching Dellner operations, sites and service locations around the world. Current chemical management practices are based on a few different sources of information, namely hazard, volume and restriction lists. Prioritisation of chemicals is largely based on hazard information, which is available in the chemical management software in use at Dellner. In this, chemical products are ranked according to classifications derived from Hazard-phrases (H-phrases). However, their chemical management software does not combine information about hazard with other data, such as quantities used or legal requirements, although using filters for predetermined lists of restricted chemicals is possible and can provide some guidance. This means that the process of selecting and prioritising chemicals still requires manual interpretation and additional information. When scanning the chemical portfolio and selecting chemicals for further attention or substitution, Dellner therefore complements the information found in the software with data regarding consumption volumes, and legal requirements. Additionally, Dellner makes direct comparisons of SDSs and the constituent chemical substances of their products and works with internal restriction criteria reflecting not only regulatory requirements but also customer requirements (J. Lexen, H. Garbergs, personal communication, 10 March 2026).

3 Method

First, this section provides an overview of the ProScale method and defines its scope, system boundaries and limitations. After describing the methodology and case study, the necessary calculations are explained, followed by a presentation of the interview process.

3.1 ProScale Overview

ProScale was developed with the goal of being a relatively simple method for assessing the toxicity impact of a product or service along the whole life cycle (Lexén et al., 2017). It seeks to utilize available data published to align with REACH, to minimize the need for additional substance-specific data gathering. Compared to USEtox, which is the approach recommended for modelling toxicity impact potentials in LCA by the Life Cycle Initiative, as well as the recommended characterisation model for organisational and product environmental footprint by the EC (European Commission, 2021), ProScale aspires to offer a more user-friendly and practical alternative for industry actors (Halling, 2023). Additionally, ProScale sets out to assess the toxicity impact from direct exposure from chemicals to humans and the environment, whereas USEtox has historically only addressed impacts from the release of chemicals to the environment and its indirect effect on humans.

The first version of ProScale was designed to assess the toxic impact from an occupational safety perspective. Since the original launch in 2017, the method has been developed further to include several additional modules (Kärnman et al., 2026). The scope of the assessment has gradually expanded from focusing on direct human toxicity for workers, to including exposure related to energy production and transport, as well as indirect exposure via the environment (Lexén et al., 2017). The current modified and extended version of ProScale includes four modules: workers (ProScale-W), environment (ProScale-E), service life (ProScale-SL) and indirect exposure (ProScale-IE) (Kärnman et al., 2026). These quantify toxicity via different exposure routes (Table 2).

Table 2. Description of the four ProScale modules.

Module	**Focus**	**Impact category**	**Exposure route**	**Description**
ProScale-W	Workers	Human toxicity	Direct	Assesses direct worker exposure during production, manufacturing and industrial processes and end-of-life.
ProScale-E	Environment	Human toxicity	Direct	Assesses direct environmental exposure and ecotoxicity.
ProScale-SL	Service Life	Ecotoxicity	Direct	Assesses direct use-phase exposure to consumers throughout the service life of the product.
ProScale-IE	Indirect exposure	Human toxicity	Indirect	Assesses indirect human exposure via the environment, such as via food, drinking, air etc.

3.1.1 ProScale Workers

ProScale-W was developed to assess the toxicity impact for workers from direct exposure along the product life cycle. The ProScale Score (PSS) is calculated by combining information about hazard, modelled exposure potential, exposure duration and the quantity of substance handled. A higher score indicates higher toxicity impact for workers. For worker exposure, the PSS is

calculated by multiplying four factors: hazard factor (HF), exposure concentration factor (ECF), person-hour factor (PHF) and mass flow (MF), using Eq.1.

$$PSS_W = HF \times ECF \times PHF \times MF \qquad \text{Equation 1}$$

Table 3 further describes each factor, including their definition, units and system level dependency. A more detailed description and explanation of how they were calculated within the scope of this study is provided in Section 3.3.

Table 3. Description of the ProScale-W equation as adapted by the authors to be used for organisational chemical footprinting. Based on Lexén et al. (2017).

	PSS_{prod}	=	HF	x	ECF	x	PHF	x	MF
Unit	mg/org		-		mg/person×day		person×days/kg_{prod}		kg_{prod}/org
Parameter	ProScale score		Hazard factor		Exposure concentration factor		Person-hours factor		Mass flow
Description	Measure of relative toxicity		Substance hazard, based on hazard frases and acceptable concentrations levels (e.g. OEL or DNEL)		Modelled exposure, based on standard process conditions (ECETOC TRA) and transformed to a dose.		Number of person-days of exposure per mass unit of produced product or service.		The amount of chemical product used per functional unit
System level dependency			Substance dependent		Substance and process dependent		Process dependent		Product system dependent

The calculation of ProScale scores, calculated using Eq.1, is done at chemical product level. These product specific scores (PSS_{prod}) can subsequently be aggregated to represent the system at a desired level. The scores can be interpreted as a measure of the relative toxicity of the chemical product or product portfolio, expressed in mg/organisation. The mass in mg is not an actual quantity, but a hazard- and exposure adjusted expression of the amount of a substance or product used.

3.2 Scope of the assessment

The scope of this study was defined to ensure feasibility while maintaining a comprehensive coverage of Dellner Vika's chemical portfolio. The assessment of the chemical use at Dellner therefore applies a gate-to-gate perspective, focusing on the chemical portfolio handled within Dellner Vika's operational control, i.e. the chemicals used in their final assembly, on-site service and field service activities. Even though chemicals are used throughout the life cycle of the train coupler and during the production of the chemical products themselves, chemical use beyond the organisational gate of Dellner Vika is excluded. The reporting organisation and system boundaries that further define this scope are presented in Sections 3.2.1 and 3.2.2, and Section 3.2.3 outlines the limitations arising from these methodological choices. The overall system boundary and which activities are included are illustrated in Figure 2.

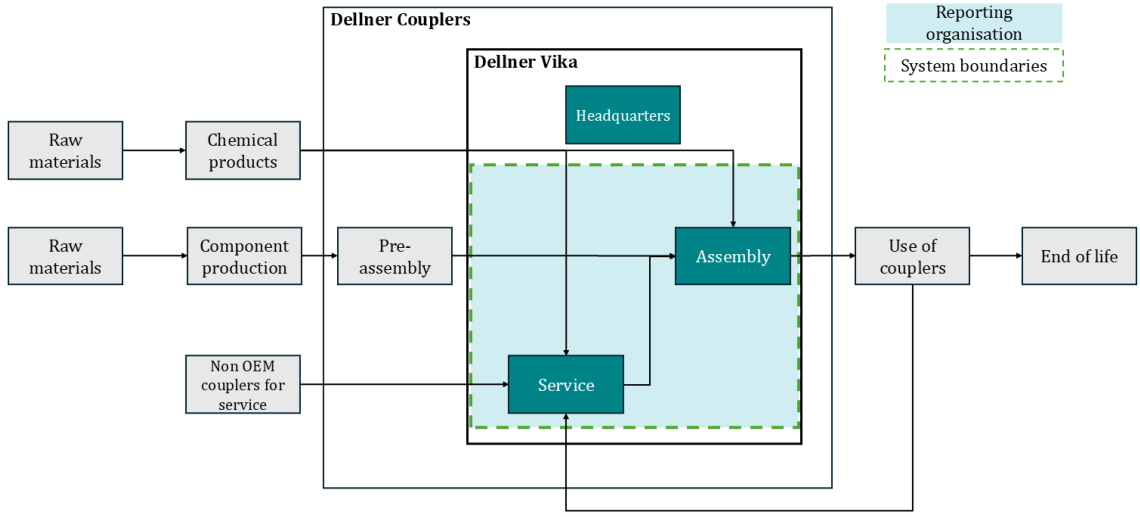

Figure 2. System in which the studied organisation operates, showing the applied gate-to-gate system boundaries that cover the chemicals directly used by the internal employees within the assembly and service activities at Dellner Vika.

3.2.1 Reporting unit

As in LCA, the ProScale methodology requires the definition of a functional unit, to which all flows can be linked. However, in an assessment of an organisation another approach for relating outputs to the functional unit is needed. In this study, it was decided that the definition of the functional unit should be based on existing life-cycle based methodologies for assessing organisations. Since OEF has been developed with very strict requirements to ensure comparability across studies, the methodology allows for little flexibility (Rimano et al., 2019). In contrast, O-LCA explicitly forbids comparison between organisation, which makes it more flexible and more easily adaptable to fulfil the goals of this thesis. This makes O-LCA more suitable as a basis for the discussion of functional unit and system boundaries in the present study. Furthermore, the ProScale methodology was developed to be applicable with the LCA methodology, and it can thus be argued that it is reasonable to apply O-LCA to ProScale. Therefore, the definition of functional unit and system boundaries in this study is based on O-LCA methodology.

The equivalent to functional unit in O-LCA is called “reporting unit”, which consists of the reporting organisation and a reporting flow. The former is a definition of the organisation under study, and the latter is a quantification of the outputs of the reporting organisation over the reference period (Martínez-Blanco & Finkbeiner, 2018). The reporting organisation in this study is the production site (service and assembly) of Dellner in Vika, Falun over the year, and the reporting flow is the annual production of couplers (units). A reference flow of amount of purchased chemical products (kg) is also introduced.

3.2.2 System boundaries

Borrowing the concept of “scope” from the Greenhouse Gas Protocol (Ranganathan et al., 2004), the system boundaries of this study include Scope 1, focusing on the chemical products used within Dellner’s operation and omitting up- and downstream chemical use and emissions. According to UNEP-SETAC (2015), system boundaries in O-LCA should be defined to include both direct and indirect impacts. It should also include supporting activities such as purchasing, heating offices, research and development, et cetera. However, this study only applies a gate-to-gate boundary, focusing on the direct impacts caused by using chemicals in the service and assembly activities at Dellner, Vika by internal employees. This is not ideal from a life-cycle perspective, as it risks missing important impacts in the life cycle, but serves as a starting point

for testing the ProScale tool in an organisational setting. Furthermore, as the assessment targets worker exposure, the impact scope is limited to human toxicity only, excluding any other impact categories such as ecotoxicity. This analysis is operationalised using the ProScale-W module and is conducted using data from 2021-2025.

Figure 2 provides an overview of the reporting organisation and the applied system boundaries in the broader train-coupler life cycle, also showing parts of the up- and down-stream. It illustrates how the applied gate-to-gate boundaries limits the assessment of chemicals to only include those directly used by the internal employees within the assembly and service activities at Dellner Vika. Upstream stages, such as raw material extraction, pre-assembly of train coupler components or production of chemical products, and downstream stages, such as use and end-of-life, fall outside these boundaries.

Figure 3 complements this overview and provides a closer description of the activities included within the applied gate-to-gate system boundaries, highlighting main activities and process steps, as well as the associated chemical inputs of each activity.

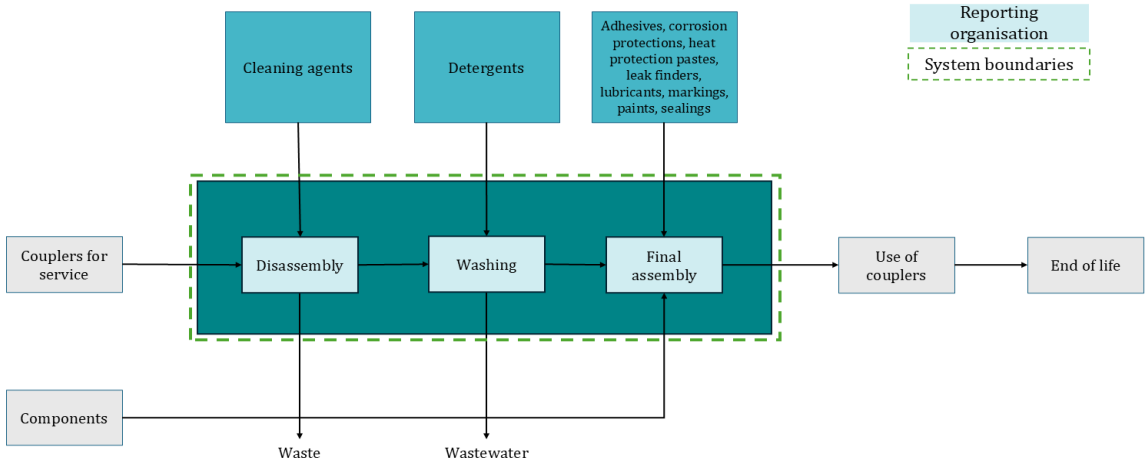

Figure 3. Closer illustration of the activities within the system boundaries of the study.

Within the reporting organisation, the train coupler production and service-related activities can be represented by three main process steps: disassembly, cleaning and final assembly. The final assembly step covers new train couplers as well as couplers brought to the facility for servicing, whereas the disassembly and cleaning activities only concerns serviced couplers.

Chemical products enter the system and these processes as inputs. Cleaning and detergents are only used within the disassembly and washing step, while the majority of chemical products, such as surface protection agents, lubricants, markers and paints are used as inputs in the final assembly. In this study, these chemical products inputs and their constituent chemical substances define the basis for the ProScale calculation within the defined gate-to-gate scope.

3.2.3 Limitations

To balance scientific completeness with practical feasibility, methodological choices were necessary, which inevitably introduced limitations to the study. Choices regarding system boundaries, exclusion of ProScale modules and data coverage all affect how the results should and can be interpreted. In combination with practical constraints related to time and data availability, key limitations include the gate-to-gate system boundary, use of a single ProScale module, and definition of what chemicals and flows to include.

As described in Section 3.1.1, this study applies a gate-to-gate system boundary. This limitation enabled feasible implementation of the ProScale method within the time frame of the study. While this supports the aim of testing ProScale as a tool for developing an organisational chemical footprint, it should be emphasized that this reduces the alignment with life cycle thinking that underpins ProScale as well as the O-LCA and OEF frameworks. This narrow focus increase risk of burden shifting (Pelletier et al., 2014).

Out of the four ProScale modules, only the workers module was included within the scope of this study. Each of these modules address different combinations of life-cycle stages and exposure pathways. For a comprehensive organisational chemical footprint including all ProScale modules would be preferred. Due to time constraints and to ensure feasibility, the analysis was restricted to only include the ProScale-W module. Furthermore, discussion with Dellner highlighted the relevance of this specific module to their operational context, which also supported this prioritisation of ProScale modules. The service-life module was disregarded as there is very little interaction between train couplers and workers nor consumer during the use phase, and the environment module was disregarded as emissions to the environment from the operation site of the study are limited as Dellner described the site as a "closed system". Consequently, the results should be interpreted as an indicator of potential toxicity impact to workers from direct exposure rather than as a complete chemical footprint.

The assessment includes the chemical products deliberately used in Dellner Vika's final assembly and service activities. For these chemical products, Dellner could provide data on the annual purchase volumes, which was assumed to represent the annual consumption volumes, all the information reported in their respective SDS, as well as their risk management efforts and safety routines. The analysis and the use of the ProScale tool is based on the constituent substances declared in the chemical product specific SDSs. Consequently, and in accordance with the ProScale methodology (Lexén et al., 2017), only substances that are required to be reported in the SDS documentation are captured in the analysis. This introduces a limitation to the study as only substances present above the reporting threshold are included in the SDS. Thus, any non-disclosed substances or impurities are not considered. In addition, potential exposure from contaminated grease, debris, metal particles and other unknown chemical residues associated with incoming serviced parts, are disregarded. The exposure of these substances may be relevant in practice but were to be excluded due to lack of data regarding their compositions and quantities. Finally, the assumption that purchased volume or mass of a certain chemical product equals quantities used in the corresponding years may lead to over- or underestimations as these assumptions neglects product storage on site. This limitation is particularly relevant for paint as Dellner Vika keeps comparatively large storages for this category of chemical products.

3.3 ProScale calculations

The ProScale-W framework is designed to quantify the toxicity based on different exposure routes: inhalation and dermal. This separation is necessary as the hazard factors are route-specific, reflecting how their health hazard can vary depending on their way of entry into the body and because the exposure concentration factor is based on exposure modelling from ECETOC TRA tier 1, which is tailored to the different routes. The ProScale methodology currently lacks a standardized translation formula for aggregation of PSSs calculated based on different exposure routes into one single score (Lexén et al., 2017). Consequently, the final output of the ProScale-W calculation is route-specific PSSs: one for inhalation (PSSi) and one for dermal exposure (PSSd).

The calculations using the ProScale formula, Eq.1, generates a PSS for each chemical product used within the reporting organisation (hereafter referred to as $PSSi_{prod}$ and $PSSd_{prod}$). The ProScale framework considers both the chemical product and its constituent substances as the

basis for the assessment. Thereby, the equation requires hazard-, exposure-, duration- and mass-related data on both product and constituent substance level. Table 4 gives an overview of what data is acquired on what level. Further descriptions of each factor and how the data was collected is explained in later sections of this chapter (3.3.1-3.3.4).

Table 4. Input data required for ProScale-W by data collection level (product vs constituent substance).

ProScale factor	Data collection level	
	Chemical product	**Constituent substance**
HF	-	H-phrases Harmonised H-phrases OEL /DNEL
ECF	Process category Use setting Risk management measures	Physical state Vapour pressure /fugacity
PHF	Annual working hours for an activity Quantities of chemical products used within an activity	-
MF	Annual quantities used	Substance mass fraction

Data was compiled for each chemical product and its constituent substances. On constituent substance level, this included data regarding hazard phrases, limit values, physical state, vapour pressure, fugacity and mass fraction. On product level, this included information regarding how the product is used (process category), risk management measures, annual hours worked and quantities used. All data was stored in a datasheet enabling efficient retrieval and reuse of data related to earlier added substances. As a result, commonly occurring chemical substances, such as xylene and toluene, did not need to be repeatedly researched when appearing in multiple products as the data could be reused.

The compiled datasheet served as the basis for the ProScale calculations, which were performed using an existing ProScale Excel template provided by IVL (an example of the full ProScale calculation for one product and one year is found in appendix A.). For each year, $PSSi_{prod}$ and $PSSd_{prod}$ were calculated for each chemical product and exposure route, using the product- and substance-specific data (appendix B, C, D, E, F and G) as input in Eq.1.

To support interpretation, results were aggregated stepwise at different levels. First, product-level scores were summed within each product category, such as lubricants, sealing and detergents. This summation obtained an intermediate aggregation level of product categories ProScale scores, PSS_{cat} (Eq.2). Second, the annual organisational scores ($PSSi_{org}$ & $PSSd_{org}$) were obtained by summing all category-level scores (Eq.3), alternatively by summing all product-level scores (Eq.4), for each exposure route separately, which represent organisation-level scores interpreted as the organisational chemical footprint.

$$PSSi_{cat,1} = \sum PSSi_{cat,1;\,prod,1} + PSSi_{cat,1;\,prod,2} + .. + PSSi_{cat,1;\,prod,n} \quad \text{Equation 2}$$

$$PSSi_{org} = \sum PSSi_{prod,1} + PSSi_{prod,2} + .. + PSSi_{prod,n} \quad \text{Equation 3}$$

$$PSSi_{org} = \sum PSSi_{cat,1} + PSSi_{cat,2} + .. + PSSi_{cat,n} \quad \text{Equation 4}$$

Figure 4 illustrates the relationship between product-, category-, and organisational-level ProScale scores used in the aggregation procedure.

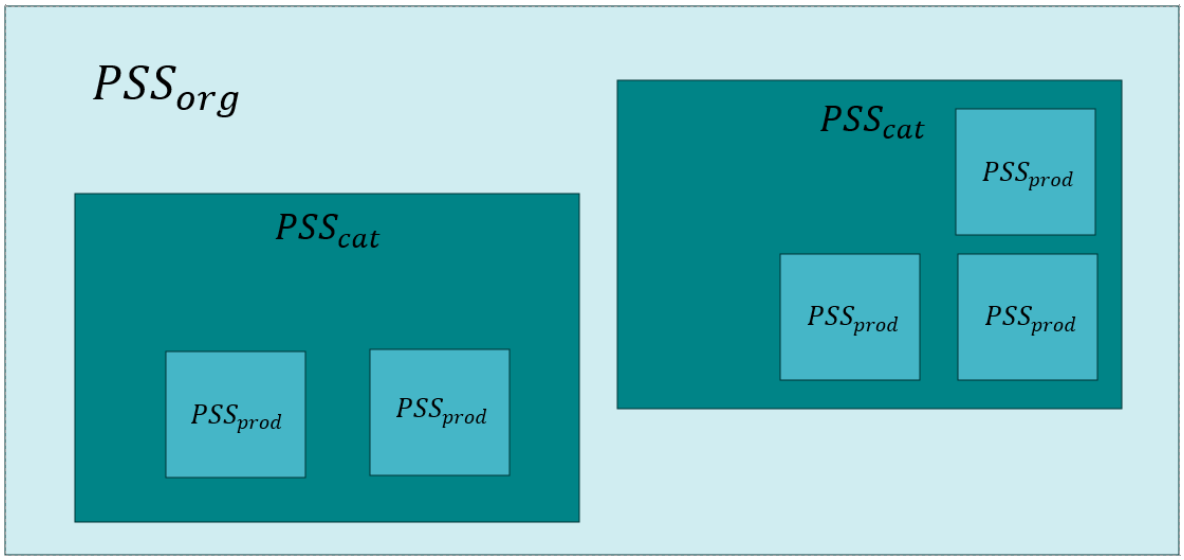

Figure 4. Schematic representation of ProScale score aggregation across reporting levels (product, category, organisation).

3.3.1 Calculating Hazard factors (HF)

The first factor in Eq.1, the hazard factor, is based on the substance's H-phrases and the OEL (or DNEL if OEL is not available). The ProScale frameworks categorises H-phrases into five classes (A-E) based on their hazard bandings, where each class has a score in a numeric range of a factor 10, see Table 5. The hazard factor is then derived based on the OEL. If the OEL is lower than 0.1 mg/m3, the highest hazard score of the band is used. If the OEL is higher than 250 mg/m^3 the lowest score is used. For OELs between these values, Eq.5 is applied to derive a hazard score within the hazard band.

$$HF = HP_{max} \times \left(\frac{OEL}{0{,}1}\right)^{m} \qquad \text{Equation 5}$$

The exponent, m, is given by Eq.6. Since the ratio between the hazard phrases in each hazard band (HP_{min} and HP_{max}) will always be 0.1, the exponent will have the same value regardless of the hazard band.

$$m = \frac{log\left(\frac{HP_{min}}{HP_{max}}\right)}{log\left(\frac{250}{0{,}1}\right)} = \frac{log\,(0{,}1)}{log\left(\frac{250}{0{,}1}\right)} \approx -0{,}2943 \qquad \text{Equation 6}$$

When a substance has multiple H-phrases for the same exposure route, ProScale only accounts for the highest hazard band.

Table 5. Description of hazard banding in ProScale. If the OEL is lower than 0.1 mg/m³, the highest hazard score is used. IF the OEL is higher than 250 mg/m³the lowest score is used. For OELs between these values, eq.5 is applied to derive a hazard score within the hazard class.

ProScale hazard band	H-phrases	Calculation of HF if 0.1<OEL<250
E – "CMR"* 10 000-100 000	All routes: H340*, H350*, H360*, EUH380, EUH440, EUH441	$HF = 10^5 \left(\frac{OEL}{0,1}\right)^m$
D – "Fatal" 1 000 – 10 000	Dermal: H310 Inhalation: H330, H334, EUH032 Oral: H300 All routes: H341, H351, H361, H362, H372, EUH381	$HF = 10^4 \left(\frac{OEL}{0,1}\right)^m$
C – "Toxic" 100 – 1 000	Dermal: H311, H314, H317, H318, EUH070 Inhalation: H331, EUH029, EUH031, EUH071 Oral: H301, H304 All routes: H370, H373	$HF = 10^3 \left(\frac{OEL}{0,1}\right)^m$
B – "Harmful" 10 – 100	Dermal: H312, H315, H319 Inhalation: H332, H335 Oral: H302 All routes: H371	$HF = 10^2 \left(\frac{OEL}{0,1}\right)^m$
A – "Maybe harmful" 1 - 10	Dermal: H313, H316, H320, EUH066 Inhalation: H333, H336 Oral: H303, H305	$HF = 10^1 \left(\frac{OEL}{0,1}\right)^m$

Hazard phrases for each individual substance in the chemical product were derived from the SDS of the chemical product. These were then cross-referenced with the ECHA Chem database. If the substance had a harmonized classification that was not included in the SDS, this classification was added to the list. Industry classifications, referring to hazard classifications submitted to ECHA by manufacturers, were disregarded. These are not necessarily harmonized or legally binding as ECHA does not verify their accuracy (European Chemicals Agency, n.d.b). All H-phrases are noted in the ProScale calculation sheet, although only the highest hazard is used by the model for each exposure route.

Notably, some petroleum-derived substances had harmonized classifications of carcinogenic hazards. According to Note L in the EU CLP Regulation (EC No 1272/2008), the harmonised classification as a carcinogen does not apply to certain petroleum substances if it can be shown that the substance contains less than 3% dimethyl sulphoxide (DMSO) extract, measured by IP 346. This was the case for many of the petroleum-derived substances present in the chemical products according to their SDS. For those cases, carcinogenic H-phrases were thus disregarded.

OELs are substance specific and used as an indicator for potency of a substance in ProScale (Lexén et al., 2017). The OEL values were collected from two main sources. The Institute for Occupational Safety and Health of the German Social Accident Insurance has compiled a database (ILV-GESTIS) of OEL values from multiple countries and provides easy access and an overview of national regulatory benchmarks. This database was used as the primary source of OELs. The database was accessed February 9th to 27th 2026. As a second resource, the SDS of the chemical product was consulted for OEL values.

To determine which nation's OEL value to use, a hierarchical approach was used for selection. The hierarchy used was the following:

1. German AGS OEL
2. European OEL
3. Dutch OEL
4. Swedish OEL
5. OEL as given in the SDS (typically Swedish)
6. Lowest OEL available from ILV-GESTIS

The ProScale guidance document also recommends a hierarchical approach to data selection and prioritization. The ranking used in the present study differs from the hierarchy suggested by Lexén et al. (2017) in two ways. First, using OEL values from the American Conference of Governmental Industrial Hygienists are suggested as the second choice when the German AGS OEL values are unavailable. As these OEL values were not present in the ILV-GESTIS database, these were omitted for convenience and since this is not expected to significantly influence the results. Second, although not included in the original hierarchy presented in the guidance document, Swedish OEL values were considered relevant and included in the hierarchy due to the geographical context of the case study (Sweden). Often, these values could also be found in the SDS of the chemical product. If none of the above OEL values were available, the lowest OEL value reported in the ILV-GESTIS database was used. In these cases, the country of origin of the selected OEL was documented to ensure transparency.

When no OEL was available, neither in ILV-GESTIS nor in the chemical-product-specific SGS, Derived NO-Effect Levels (DNELs) were used as an alternative benchmark. Similar to OELs, these values represent a presumed safe level of exposure. DNEL values were primarily extracted from the SDS and otherwise obtained from REACH dossiers found in the ECHA database. Consistent with the ProScale guidelines (Lexén et al., 2017), DNEL values for long term inhalation of workers were used.

When neither OEL nor DNEL values could be obtained, default values of 0.001 mg/m^3 are applied in accordance with the ProScale methodology, resulting in the most conservative hazard score (Lexén et al., 2017).

The H-phrases and OELs assigned to each chemical substance are found in Appendix B.

3.3.2 Calculating Exposure Concentration Factor (ECF)

The second factor in Eq.1, the exposure concentration factor, is derived from modelled exposure concentrations based on the ECETOC TRA Tier 1 approach. This exposure modelling approach is built-in to the ProScale tool where it utilizes worker exposure scenarios, i.e. process category (PROC), use setting (industrial/professional), risk management measures, and the physical properties of the substances as input parameters (Lexén et al., 2017). The resulting ECFs are conservative estimations of the concentration of a substance that a person can be exposed to during a production or use scenarios of chemicals (ECETOC, 2004). The ECETOC TRA Tier 1 approach was incorporated for ProScale since this is used to evaluate risks in REACH, requires little information and yields moderate overestimations of the predicted exposure.

The ECFs for inhalation and dermal exposure are derived by the approach outlined in Figure 5 and Figure 6. For the ECF of inhalation pathway, EFCi, the choices of PROC, physical state, use setting and fugacity all determine the value for initial exposure prediction assigned (ECETOC, 2023a). The initial exposure values are given in ppm for inhalation exposure of fluid substances and in mg/m^3 for solid substances. The initial dermal exposure value is given in µg/cm^2/day. For dermal ECF (ECFd) only the PROC determines the initial exposure prediction. If applicable, risk reduction measures used are then considered by assigning reduction factors. The reduction factors for local exhaust ventilation (LEV) are different for different PROCs and use settings.

However, the reduction factors for personal protective equipment are the same regardless of the other choices modelled. (ECETOC, 2023a).

The inhalation exposure prediction values are transformed into mg_{sub}/m^3 and dermal exposure predictions are transformed to mg_{sub}/kg_{bw}/day by ECETOC. In this study, these values are then translated into doses in ProScale. The inhalation exposure prediction is multiplied with an inhalation rate of 1.6 m^3/hr, representing an adult population of moderate activity level (Höglund et al., 2012), and in the present study with 8 hours for one working day. Dermal exposure predictions are multiplied with the assumed body weight for workers of 70 kg (ECETOC, 2004). This gives both inhalation exposure concentration facors (ECFi) and dermal exposure concentration factors (ECFd) a unit of mg_{sub}/day. This procedure differs from the ProScale guidance document, which states that ECF is transformed to a dose by introducing the PHF (Lexén et al., 2017).

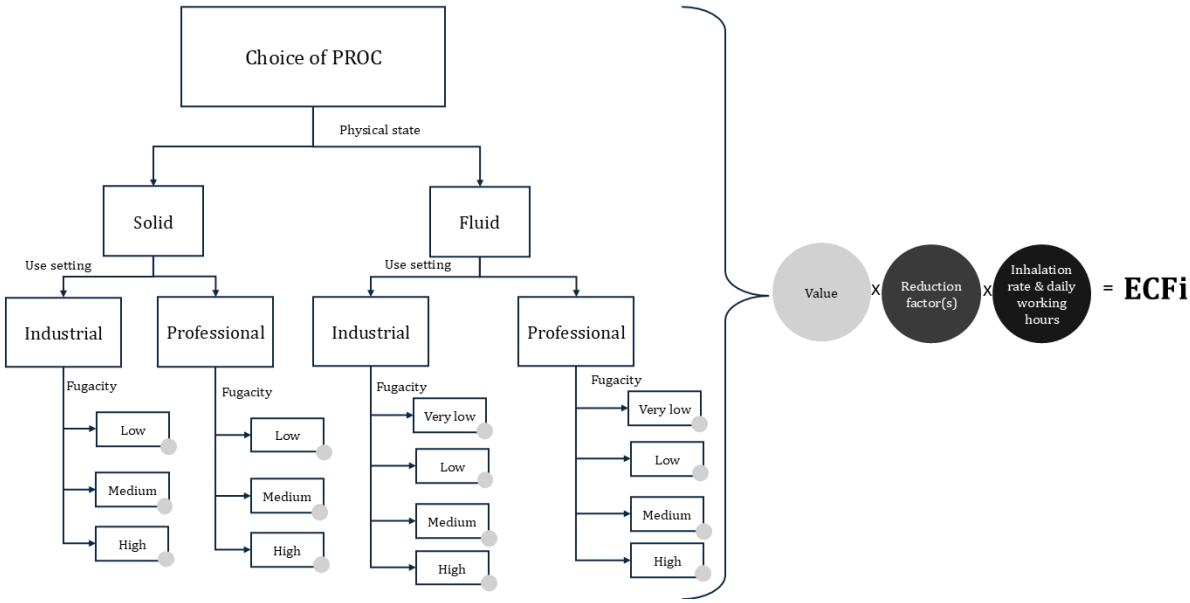

Figure 5. Description of how ECETOC TRA Tier 1 assigns exposure prediction values (gray dots), and how these are multiplied with reduction factors and inhalation rate and working hours in a day to derive ECFi.

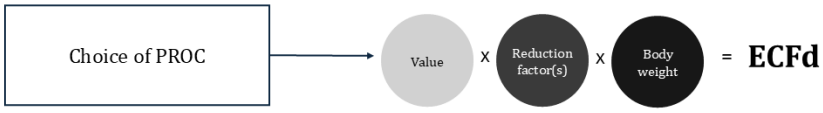

Figure 6. Description of how ECFd is derived. ECETOC TRA Tier 1 assigns an exposure prediction value associated with the PROC, which is then multiplied with reduction factors and body weight.

The worker exposure scenario is based on process categories (PROCs), use setting (industrial/professional) and whether risk management measures are taken. PROCs are standardized process categories used to determine the occupational exposure level for workers. PROCs describe the task, application or process in which the article (in this study, the chemical products) is used, applied or processed from an occupational perspective (Lexén et al., 2017).

The uses of the chemical products were derived from (1) a list of chemical products used by Dellner, in which the use of each product was described with one word (e.g. “paint”, “lubricant”, “grease”), (2) Dellner’s risk assessments for each chemical product and (3) a guidance document provided by the chemical manufacturers on how to use the products.

All this information was considered and formed the basis for the assessment of which PROC was most appropriate for each of the chemical products. The final categorisation into PROCs was performed by the authors in dialogue with Dellner, which can be found in Appendix C. The setting was together with Dellner determined as professional rather than industrial. However, the use of PROC7, i.e. industrial spraying, requires that the use is set to industrial, so an exception was made for this process category. The assigned PROCs for each chemical product can be found in Appendix D.

In the risk assessments performed by the company, there is information about protective measures taken to reduce worker exposure to chemicals. These can be local exhaust ventilation (LEV) or personal protective equipment (PPE). If no risk assessment has been done or was available from the chemical database at the time of data extraction, it is assumed that no protective equipment is used. The protective equipment considered in this study were "LEV with good general ventilation" and "chemically resistant gloves in combination with basic employee training". These levels were determined in dialogue with Dellner. What products required any risk management measures are stated in Appendix D.

To derive ECFi, inputs are needed of the physical state and fugacity at room temperature for each substance. The primary source for physicochemical properties was REACH dossiers from the database of the European Chemical Agency, ECHA. When no information about the physical state of the substance and/or the vapour pressure was available in ECHA, the PubChem database was consulted as a second option (PubChem, n.d.). These databases were accessed February 9th to 27th 2026. If data remained unavailable, SDSs for the individual substance were reviewed. In these instances, multiple SDSs found at Chemical Safety (n.d.) were considered and the vapour pressures compared. If no vapour pressure could be found through these means, the vapour pressure of the chemical product was used as a proxy value. If this did not exist either, an engineering estimation was made based on similar substances. The value for vapour pressure is then translated to category from very low to high according to Table 6, which are used to derive the pre-determined value in ECETOC according to Figure 5.

Table 6. Translation of vapour pressure into ordinal categories for ECFi determination (Lexén et al., 2017).

Vapur pressure (kPa)	**TRA fugacity**
<0.00001	Very low
0.00001 to <0.5	Low
0.5 to 10	Medium
>10	High

For substances classified as solids at room temperature, information regarding vapour pressure was not necessary and instead further information regarding the physical form was collected. Information and description such as "powder", "salt", "flakes", "granules", or "wax" were used to assign a fugacity/dustiness category to the substance. This was done in accordance with the ECETOC TRA model where four different categories based on volatility and dust generation potential are distinguished. For each solid, a low, medium or high value was assigned depending on if the substance could be described as not dusty, slightly dusty, dusty or very dusty, see Table 7. Determining the dustiness levels was based on qualitative descriptions of the material's characteristics in ECHA or SDSs.

The substance specific data (physical state, vapour pressure and fugacity) used for the ProScale calculations are found in Appendix B.

Table 7. Fugacity of solids, based on dustiness of solids (Lexén et al., 2017)

General description	Typical materials	TRA fugacity
Not dusty	Plastic granulates, pellets	Low
Slightly dusty	Dry garden peat, sugar, salt	
Dusty	Talc, graphite	Medium
Very dusty	Cement dust, powders plaster, flour	High

3.3.3 Calculating Person-Hour Factor (PHF)

The PHF is used to relate the ECF to the analysed system by providing an estimate of the duration associated with the production of the functional unit. According to the ProScale guidance, default values for PHF should be used as the primary source of data, if applicable. Otherwise, it can be calculated either as annual amount of work divided by annual production volume for a production process, or as exposure duration divided by amount of product used for use, e.g. painting or installation of product (Lexén et al., 2017).

In this study, the default value considered most similar to the processes conducted at Dellner was painting, with a PHF of 0.2 hrs/kg. This could have been used, being particularly applicable for the processes associated with assembly. However, it was not deemed as applicable for the chemical use associated with disassembly and cleaning steps (hereafter referred to as service). To better represent the conditions at Dellner, site specific PHFs were calculated (Eq.7 and Eq.8). The ProScale guidance document recommends that PHFs are calculated based on numbers from industry sectors rather than a single company (Lexén et al., 2017). This recommendation was disregarded, as the aim of the study is to create an organisation environmental footprint for a single company, with input information that represents the organisation as much as possible.

Since the functional unit is the organisation over one year, the PHF refers to the annual amount worked, divided by some physical flow that represents the organisation over that year. Ideally this would be the number of couplers produced. However, as realistic mass estimation of the couplers could not be derived, the annual numbers of couplers produced and serviced could not be translated into annual mass of couplers produced and serviced. Using numbers of couplers as reporting flow would result in a PHF represented in person×days/coupler, which means there is no cancellation of the mass flow unit (Table 3), resulting in a PSS represented in units of mg×kg/coupler instead of mg. To yield units easier to interpret, the amount of chemicals purchased for service and assembly, respectively, during the reference period are used as reporting flow. Which of the chemical product are used within the different activities are presented in Table 8. The inputs data for and resulting values of the PHF calculations can be found in Appendix E.

$$\mathrm{PHF}_{\mathrm{service}} = \frac{\text{annual hours worked in service } [days]}{\text{annual purchase volume of service chemical products } [kg]} \quad \text{Equation 7}$$

$$\mathrm{PHF}_{\mathrm{assembly}} = \frac{\text{annual hours worked in assembly } [days]}{\text{annual purchase volume of assembly chemical products } [kg]} \quad \text{Equation 8}$$

Table 8. Product categories by activity

Activity	Product categories
Service	Cleaning, detergents
Assembly	Adhesive, corrosion protection, heat protection pastes, leak finder, lubricant, marking, paint, sealing

This separation follows the layout of the site at Dellner to some extent, where service and assembly take place at different locations in the same warehouse with very different exposure conditions. However, it can also be questioned since all workers at the site could reasonably be expected to be exposed to all chemical products used within the facilities.

3.3.4 Calculating Mass Flow (MF)

To derive the fourth factor, the mass flow (MF), two inputs of data were required: the annual quantities used of each chemical product and the mass fraction of each constituent substance within each product. The mass flow reflects the annual quantities used of a specific chemical product. This data was received from Dellner in the format of annual purchased quantities, assuming the purchased amounts correspond to consumed quantities within the same year. Because the consumption data obtained from Dellner was reported in different units, either mass, volume or number of units, all input were converted to mass (kg) based on densities given in SDS. For paint products, for which Dellner confirmed consumption was continuous throughout the study period, purchase records were missing for some of the years. These data gaps were filled by extrapolating data for 2025. This was done by relating the paint volumes to numbers of couplers produced.

The mass fraction in ProScale is derived to understand how much of a substance is needed for a given process. In this study, PSS_{prod} is calculated for one kg of each chemical product used, but as the calculations are based on the constituent substances, their respective mass fraction per kg product was required. These were derived from the mass fractions listed in the SDSs, in accordance with the ProScale guidance for deriving mass flows for purchased products (Lexén et al., 2017). When the mass fraction was given in a range, the upper value within this range was chosen, in accordance with the ProScale guidance (Lexén et al., 2017). In a few cases this approach resulted in the sum of the mass fractions being >100%. This was dealt with by looking at the contribution to the total ProScale score of each substance in the chemical product and using the low value in the mass fraction range for the substance with the lowest contribution to the overall ProScale score. This was done until the sum of the mass fractions did not exceed 100% by more than 5%, which was considered sufficiently close to reality while maintaining relevant information.

See Appendix F for annual mass flow of each chemical product and Appendix G for the constituent substances and their corresponding mass fraction.

3.3.5 Disaggregation by product category, chemical products and chemical substances

Once the annual organisational ProScale scores had been calculated, a stepwise break down of the results was performed. The results were subsequently disaggregated by product category, chemical products and lastly, by constituent chemical substances to identify main drivers of the organisational chemical footprint.

First, annual totals were disaggregated by chemical product categories to determine what categories contributed the most to PSSi and PSSd, respectively. Second, the results were decomposed into individual chemical product contributions to identify product-level hotspots. For both the category- and product-level break down, a threshold of *10% of the annual total scores for at least one year* was applied to define “major contributing” categories and products. This 10% limit was chosen to ensure that the analysis focused on the most important contributors while at the same time maintaining feasibility.

A top list of the most influential chemical products was obtained, and the high scoring products were subsequently analysed to determine whether their annual contribution were primarily driven by their consumption volumes or intrinsic scores (PSS/kg). Finally, these products were further examined on constituent substance-level to assess whether high product scores were driven by one or multiple substances. The analysis was performed for the year during which the contribution of the chemical product to the total PSS was the highest.

3.3.6 Sensitivity analysis

To assess the robustness and reliability of the ProScale methodology when applied within an organisational setting, a sensitivity analysis was performed on a selection of key methodological choices by replacing the one input variable at a time and quantifying the effect of the change.

Two input parameters were assessed. First, the site-specific PHFs were compared to the recommended default value. Second, the choice of PROCs where the interpretation could vary with the practitioner was analysed. The PROC choices considered most sensitive in the study were the use of PROC7 rather than PROC11, as mentioned in 3.3.2, and PROC18 rather than PROC10 for all paste-like lubricants, which are typically applied with a brush (J. Lexen, H. Garbergs, personal communication, 10 March 2026).

3.4 Interview

To complement the quantitative analysis of Dellner's chemical portfolio performed with ProScale, an interview was conducted with employees at Dellner. The purpose of the interview was to assess the practical relevance of ProScale within an organisational setting, the perceived usefulness and practical feasibility of applying ProScale as a basis for calculating an organisational chemical footprint. The interview aimed to give a better understanding of how results such as the ones from this study could be used to support and complement current chemical management practices and how an organisational chemical footprint can be useful within the scope of substitutions, prioritisation, and decision making. Additionally, the interview aimed to evaluate whether the ProScale results and the process of applying ProScale to a full chemical portfolio could be perceived as feasible for continued organisational use, and under what condition it would be relevant to do so.

The interview was designed in a semi-structured manner to ensure main topics were covered but also to allow flexibility and follow-up questions. The interviewee was selected due to their relevant role at the company as *Environmental & Eco Product specialist* and having direct involvement in chemical management and environmental- and safety-related decision-making.

An interview guide was developed based on the study's three research questions and included four main focus areas: (1) Dellner's current practices for chemical management and substitution, (2) the interviewee's reactions to the results from the ProScale analysis, (3) the potential practical use of an organisational chemical footprint in decision-making, prioritisation and substitution efforts, and (4) perceptions of the method in terms of balancing simplicity, credibility, and feasibility. The first focus area primarily aimed to help answer the first RQ by providing contextual understanding of Dellner's current chemical management practices and decision structures, the second and third to help answer the second RQ, while the fourth primarily aimed to answer the third RQ. Throughout the interview, particular attention was given to how the interviewee interpreted the potential of the ProScale method to complement current approaches and practices, how it can support decision making and chemical management and what practical conditions or improvements of the tools would be needed for continued use.

Both the interview guide, as well as the presentation summarising the results from the ProScale analysis was shared with the interviewee beforehand. Sharing this with the participant a few days before the interview intended to support preparation and enable more informed and well thought out discussions and insights from Dellner.

The full interview guide can be found in Appendix H.

4 Results and discussion

This chapter presents and discusses the resulting organisational chemical footprint of Dellner. By analysing the ProScale scores through a stepwise disaggregation, the primary drivers of the footprint are identified. Finally, the interview results and a sensitivity analysis provide the foundation for evaluating the practical usability of the method and the implications of methodological choices.

4.1 Organisational chemical footprint

Figure 7 illustrates the annual total PSS and how these scores vary between 2021 and 2025 for both exposure routes. The figure show that both PSSi and PSSd increased over the study period. This increase cannot be traced to an increase in the number of couplers serviced and assembled, nor to a higher quantity of purchased chemical products. This suggests that there has been a modification of the chemical portfolio of the company across the reference period, which has led to variations in the organisational chemical footprint.

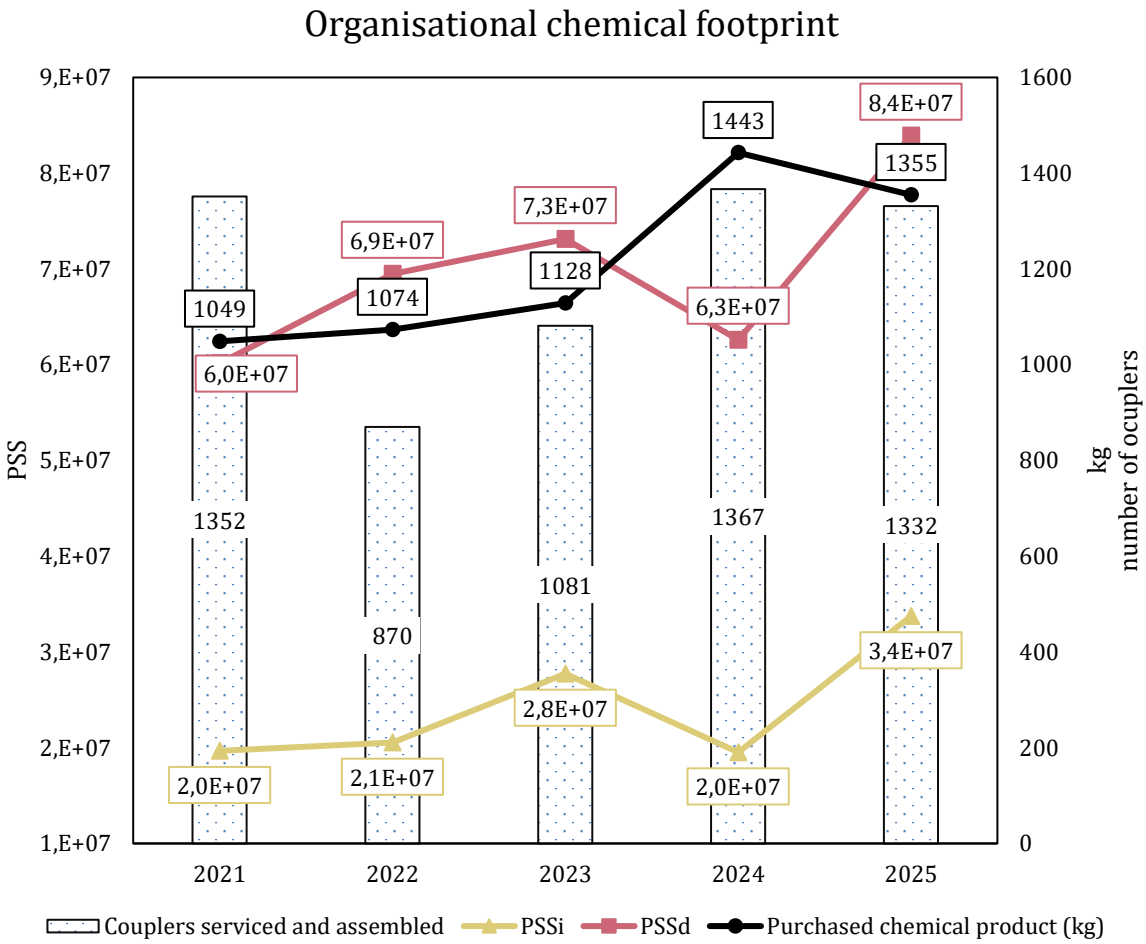

Figure 7. Organisational ProScale Scores 2021-2025. Also pictured are number of couplers serviced and assembled each year (staples) and total amount of purchased chemical products per year.

To support interpretation of the organisational chemical footprint and enable identification of hotspots, the result was further broken down and analysed. Firstly, the results were disaggregated by chemical product category, then by product and lastly into constituent substance level.

4.2 Major contributing product categories

Figure 8 shows the relative contribution of the different product categories to the organisational chemical footprint and total mass of purchased chemicals. This side-by-side comparison of the distribution of contribution to PSSi, PSSd and used quantities highlights the disproportionate impacts of certain product categories. Despite representing small shares of the total mass, some categories still score high and are associated with substantial shares of the organisational chemical footprint. Furthermore, Figure 8 reveals distinct differences in how the same product categories contribute to the inhalation and dermal pathways, respectively.

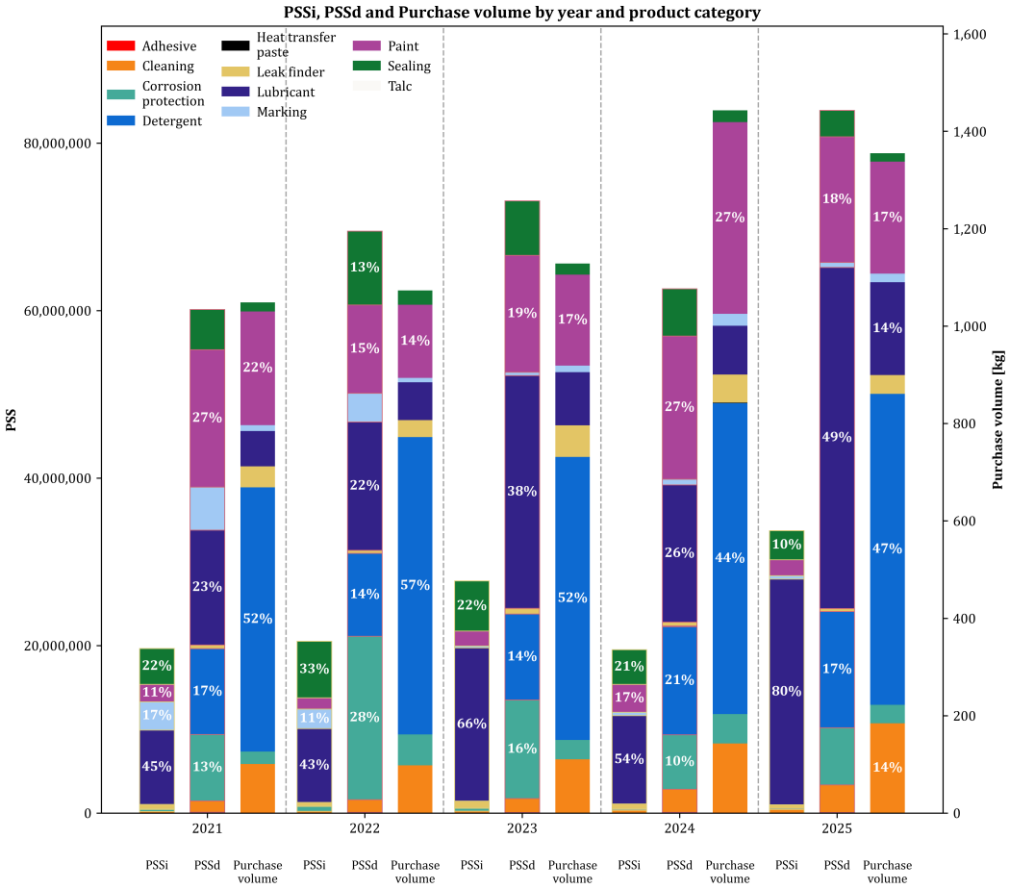

Figure 8. Annual contribution to PSS by product category.

For the inhalation pathway, the lubricant product category dominates the PSSi throughout the study period, ranging 43-80% of the annual total. It is also one of the most important product categories for PSSd, ranging 22-49% of the annual total. The substantial increase of PSS for lubricants in 2025 can partly be explained by rising of consumption volumes, which increased from 73 kg to 191 kg over the study period. Still, even at the highest use, lubricants only represent 14% of the total purchase volume of chemical products (2025). Sealing represents the second largest PSSi contributor, continuously contributing with a substantial share of the annual inhalation score. Additionally, the marking and paint product category contributes substantially to the annual PSSi, representing particularly large shares in some specific years. All other product categories contribute only marginally to the total annual PSSi.

The main drivers for PSSd differ from PSSi. The primary contributing categories is more heterogenous, with up to five categories having a share of 10% or more for some of the years. The dermal exposure route exhibit high impacts from product categories that were nearly

negligible for the inhalation exposure route. Most notable is detergent, which accounts for a large share of dermal toxicity, ranging between 14-18%. Here, the discrepancy between mass and PSS is also clear. Detergents consistently represent the largest fraction of total mass, approximately 50% of the total amount of chemicals used across all years. Despite being used the most, the detergent share of PSSd peaks at "only" 18 % and constitute an almost negligible share of the annual PSSi, indicating that detergents do not constitute a hotspot in the chemical portfolio. This discrepancy can partially be attributed to the calculation of the PHF. The relatively few hours associated with service of couplers divided by the high mass of detergents results in a PHF that is about ten times lower than the PHF of the assembly chemical products. A similar trend can be seen for the cleaning category, which is the only other product category with the service specific PHF. Additional product categories that are prominent in the dermal results but not for inhalation are corrosion protection, which represents up to 28% in 2022 and paint, representing a share of at least 15% and peaking at 37% in 2024.

As the category-level disaggregation of both the inhalation and dermal exposure results illustrate, a limited number of product categories dominate the annual organisational PSS. Lubricants emerge as the primary driver across nearly all the years for both exposure routes and represent the only product category consistently dominating both pathways. The differences in major contributing categories between the two pathways indicate that certain product categories have pathway specific toxicity properties. This discrepancy is likely due to differences in hazardous properties of the constituent substances of the chemical products within each product category. Other reasons that may be affecting the differences in $PSSi_{cat}$ and $PSSd_{cat}$ are how the products are used and applied, where the use of risk management measures affects exposure differently depending on route.

This divergence highlights the benefits of dual pathway assessment. A single focus on either only inhalation or only dermal exposure would generate an incomplete toxicity profile of the chemical portfolio, potentially overlooking products that pose a significant risk through only a single exposure route. Dual assessment could also help identifying hotspots and directing targeted substitution and risk management efforts. Prioritizing products which drive the scores across both routes could yield the highest overall reduction as it simultaneously addresses both inhalation and dermal exposure.

Ultimately, the category-level results suggest that a volume-based chemical management is not sufficient to reduce the organisational chemical footprint, as several product categories that are used in modest volumes represent high shares of the PSS. However, while category-level results indicate where main contribution and toxicity potential arise, they do not reveal what individual chemical products are responsible for observed contributions. Therefore, the subsequent section presents product-level results to enable more specific prioritization of measures within these dominant categories.

4.3 Major contributing chemical products

Figure 9 shows "major contributing" products, i.e. products which contribute with at least 10% of the annual total PSS for at least one year. As for the category-level analysis, this allows a side-by-side comparison of the relative contribution to the annual PSSi, PSSd and total mass consumption by the major contributing chemical products. As Figure 9 shows, the organisational chemical footprint is not only concentrated to a limited number of product categories, but the contribution within these categories is also concentrated to very few chemical products. Out of the approximately 60 different chemical products used each year, only five individual products reach 10% of either PSSi or PSSd for at least one year.

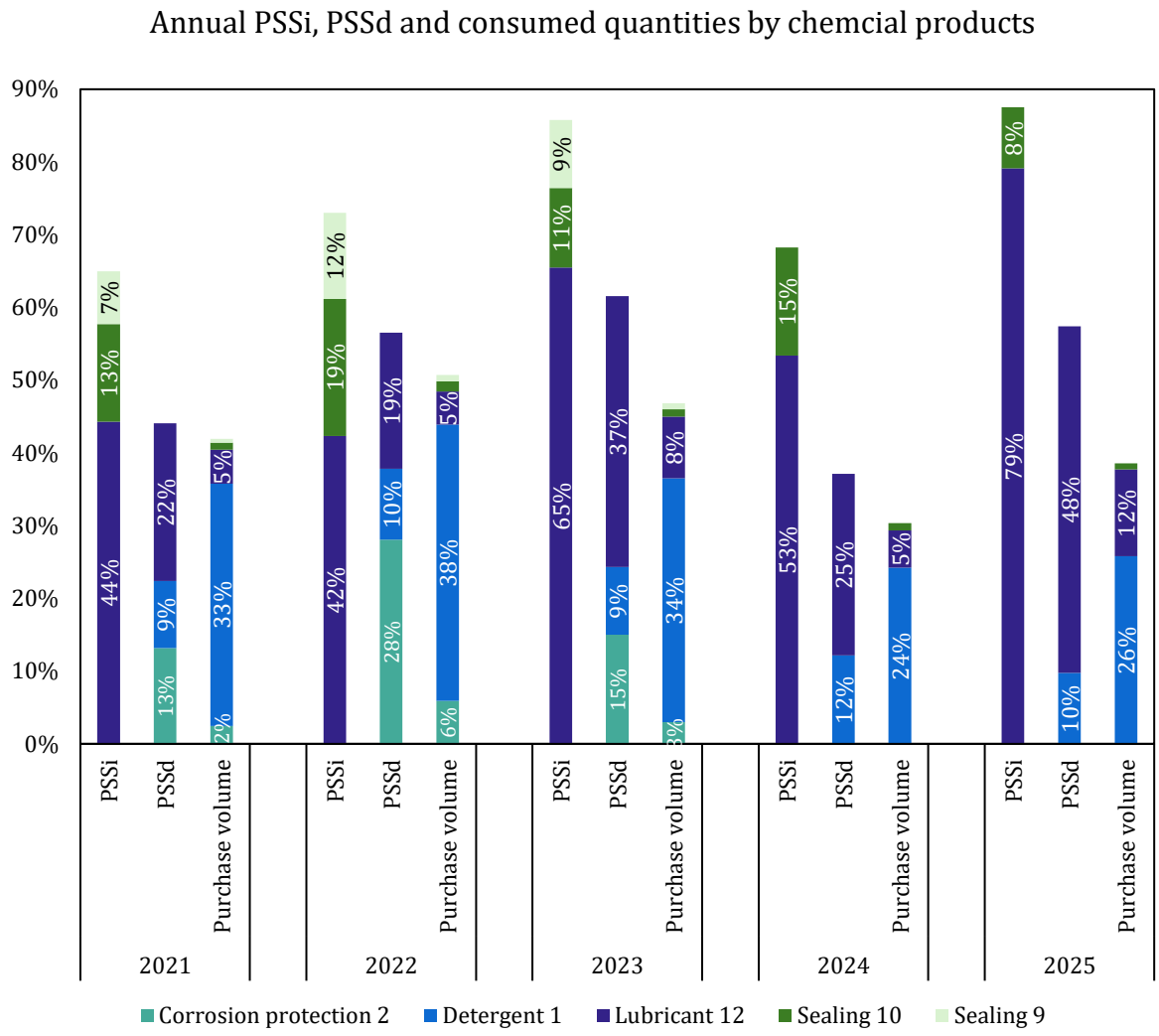

Figure 9. Relative distribution of PSSi, PSSd and consumed quantities by chemical product.

The top contributors for both the PSSi and PSSd exposure pathway are: Lubricant 12, Sealing 9 and Sealing 10 for the inhalation pathway, and Lubricant 12, Detergent 1 and Corrosion protection 2 for dermal exposure. Lubricant 12 is the only product contributing majorly within both pathways. Lubricant 12 consistently represents the largest share throughout the study period, accounting for up to 79% of PSSi and 49% of PSSd in 2025.

This list notably lacks any marking or painting products, even though the painting category consistently contributed significantly to $PSSd_{cat}$ and marking constituted 17% of the total $PSSi_{cat}$ in 2021. The absence of marking and paint product in the product top list could be explained by the distribution of the toxicity among a greater number of products within each category. The painting category is by far the largest, with 35 constituent chemical products. The toxicity impacts for paints are spread across a larger number of individual products. For marking products, a similar trend can be observed. Out of the 9 different products within this category, none is used in a particularly high volume or exhibit high enough potency to emerge as a greater contributor than the other products within the same category.

In contrast, the lubricant category, despite consisting of 11 different products, is almost entirely dominated by Lubricant 12. The dominance of Lubricant 12 in PSS can be explained by its large share in use volume, accounting for 86% of the total use of lubricants in 2025. This demonstrates that product category impact can either be concentrated in a single product or distributed among a wider range of products, such as for marking and paints. This distinction is

important for prioritizing substitution efforts and highlights that chemical management's efforts should not only focus on specific products as this would overlook troublesome categories with collective toxicological impacts. While, for example, individual paints make only small contributions, the category as a whole is problematic. An analysis solely focusing on products would overlook these categories despite accounting for large shares of the total organisational chemical footprint.

A key difference between the exposure pathways is that the largest single contribution to dermal exposure is considerably lower than for inhalation. Across the study period, the contribution from an individual chemical product in the dermal pathway never exceeds 48%, whereas for inhalation, individual contribution often exceeds 50% and reaches up to 79% for Lubricant 12 in 2025. This indicates that, while Lubricant 12 remains a major driver for both pathways, the PSSd profile is characterised by a broader set of chemicals, rather than being dominated by one or two high scoring products, which is the case for inhalation. For dermal exposure, the top scoring products together rarely represents more than 60% of the annual PSSd. Compared to the PSSi profile, this leaves a greater portion to be shared among a wider range of products.

These results shows that the total workers toxicity is concentrated to a limited number of products driving the organisational chemical footprint. This concentration is a key outcome and particularly relevant for the aims of this study. It demonstrates how the development and use of an organisational chemical footprint can be used to identify a small set of products for targeted chemical management and potential substitution efforts.

4.3.1 Hotspot summary

To summarise the hotspot analysis and the disaggregation of the ProScale scores to chemical product-level, Table 9 presents a summary of the set of chemical products representing all the products that exceeds 10% of annual totals in at least one of the years. These findings correspond directly to the major contributors identified in Section 4.3.

This illustrates that a very limited set of chemical products repeatedly emerges as influential for the organisational chemical footprint. This reduces the chemical portfolio into a short and focused list, yielding a manageable number of high-contributing products for subsequent evaluation, substitution, and risk-reduction efforts. However, because the list is driven differently by the two exposure routes, it is important to consider both pathways when prioritising chemical management actions.

Table 9. High scoring (>10% of total PSS) chemical products.

1	Corrosion protection 2
2	Detergent 1
3	Lubricant 12
4	Sealing 9
5	Sealing 10

To further examine the list of top scoring chemical products presented in Table 9, these products were examined in terms of whether their high annual scores can be explained by inherent properties and usage routines, by high use volumes or a combination of both. Such a distinction was made as the organisational scores are consumption-weighted, meaning that high final scores can be influenced by the chemical product simply being used in high quantities. Figure 10 illustrates this by plotting the PSSi and PSSd per kg for each top scoring product. These are presented alongside horizontal lines representing the average per-kg scores for the entire chemical portfolio and study period.

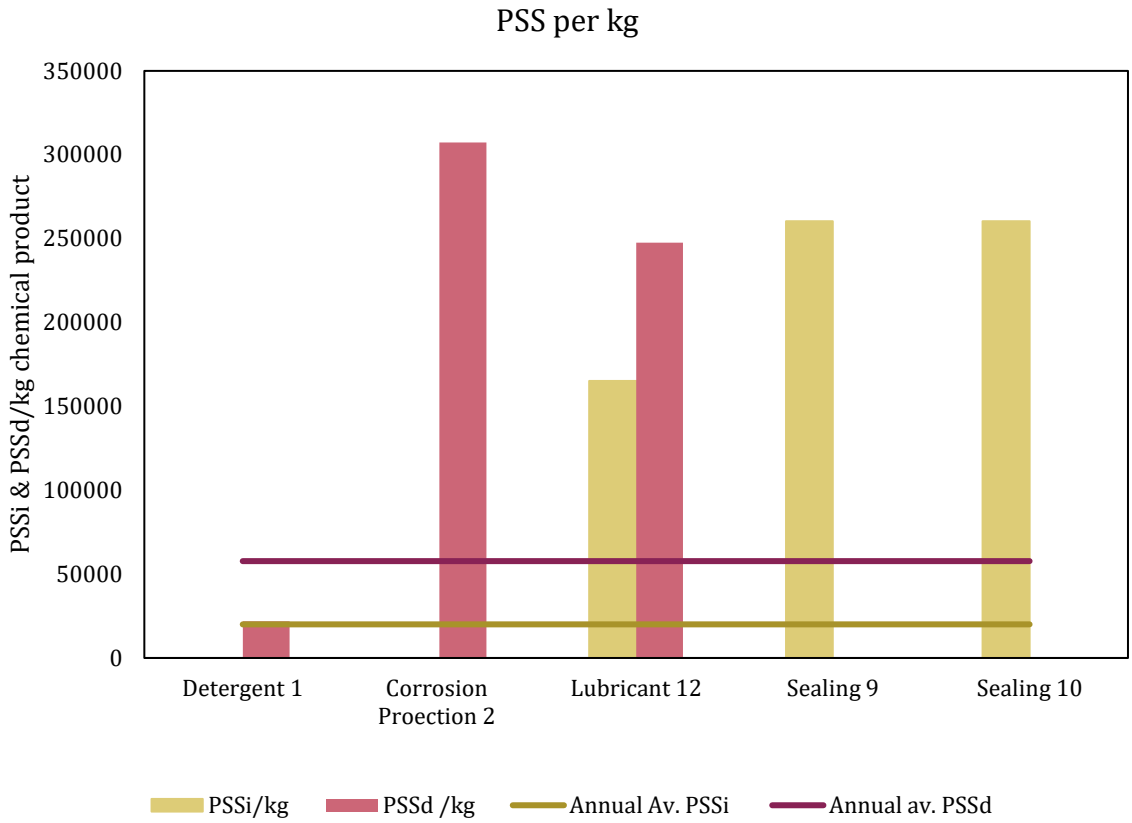

Figure 10. Staples show per-kg PSSi and PSSd for major contributing products. These are compared to averaged portfolio per-kg PSSi & PSSd, which are represented by the horizontal lines.

The per-kg PSS reflects the toxicity impacts built into the product and the way it is used at Dellner, considering the hazard, exposure and duration of use but disregarding how much of the product is consumed. Almost all the top scoring products demonstrates high per-kg scores. For some of the products, such as corrosion protection 2, their high per-kg scores outweigh their otherwise low consumption volumes. For other products, such as Lubricant 12, the high per-kg scores are combined with high annual volumes, resulting in its continuous large contribution to the organisational chemical footprint. In contrast, other products achieve high scores through a combination of relatively low or moderate per-kg scores and high volumes. Detergent 1 illustrates such "volume-driven" profile. Among the five top-scoring products, it is the only one with per-kg PSSd below the portfolio-wide per-kg PSSd. The fact that it is being handled in larger volumes than any other major contributor drives its high total score. These results may help guide management efforts, as products with high scores driven by usage volume and product with high scores driven by per-kg toxicity may require different management approaches.

Based on this screening, the subsequent section 4.4 will further analyse the top scoring chemical products by examining their relative contribution from constituent chemical substances and identifying whether the dominant contribution arise form one or multiple substances.

4.4 Analysis of constituent chemical substances

Within the five top scoring chemical products, only a few substances contributed majorly to the PSS_{prod}. Substances that contribute more than 10% to the total score of their respective chemical products are shown in Table 10. The full list of the constituent substances for these products and their respective contribution to the total PSS_{prod} can be found in Appendix I.

Table 10. Description of constituent substances that contribute majorly to the PSS of their respective products.

Product	Substance	Contribution to $PSSi_{prod}$	Contribution to $PSSd_{prod}$	Contribution to total $PSSi_{org}$ (year)	Contribution to total $PSSd_{org}$ (year)
Corrosion protection 2	Sulfonic acids, petroleum, calcium salts	n.a	98%	n.a	27% (2022)
Detergent 1	Alcohols, C8-10, ethers with polyethylene-polypropylene glycol monobenzyl ether	n.a	35%	n.a	4% (2024)
	Potassium hydroxide	n.a	58%	n.a	7%
Lubricant 12	Benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene	82%	82%	65% (2025)	39% (2025)
	2-(2-heptadec-8-enyl-2-imidazolin1-yl)ethanol	18%	18%	9% (2025)	14% (2025)
Sealing 9	Naphtha (petroleum), hydrodesulfurized heavy	97%	n.a	11% (2022)	n.a
Sealing 10	Naphtha (petroleum), hydrodesulfurized heavy	97%	n.a	18% (2022)	n.a

For Lubricant 12, two substances are major contributors. The substance contributing the most to PSS_{prod} is *benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene.* This substance contributes with 65% of the total PSSi in 2025, indicating that a large impact could be made by substitution or exposure reduction of a single substance within the reporting organisation. Lubricant 12 is used in relatively large quantities but contains only 1% *Benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene.* So, while 12% of the annual chemical mass for 2025 is Lubricant 12, the substance that drives 39% of the dermal and 65% of the inhalation toxicity of the organisation in 2025 constitute only 0.12% of the total chemical portfolio by mass.

As shown in Figure 8, only two chemical product categories consistently contribute majorly to PSSi. In addition to Lubricant 12, Sealing 9 and 10 are important. These products are the same but with different pigments. For these sealants, the impact comes almost entirely (97%) from hydrodesulfurized heavy naphtha. In the year 2022, 29% of the $PSSi_{org}$ is caused by this single substance. A large fraction of the total inhalation toxicity potential within the organisation can thus be concentrated to only three substances. Interestingly, the sealings contain diisocyanates, which are regulated in the EU due to their inhalation toxicity (European Commission, 2020). Yet these are not the substances that drive the PSSi. However, it should be noted that the SDS of Sealing 9 and 10 did not provide a CAS-number for the naphtha, despite there being an associated CAS-number in ECHA that corresponded to the name and EC-number of the substance. The substance has harmonized H-phrases of the highest hazard class that were not listed in the SDS. The assumption that this is the correct substance has not been checked with the supplier and is potentially an overestimation of the risk.

The sulfonic acids of Corrosion protection 2 is a major contributor to PSSd, contributing to 27% of total PSSd in the year 2022. Especially *benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene* in Lubricant 12 is a significant contributor to PSSd as well as PSSi, but somewhat less prominent for the dermal pathway. The substances in Detergent 1 do not contribute majorly to the total $PSSd_{org}$, and contributes at most 4% and 7%, in year 2024. As shown previously, Detergent 1 has a lower per-kg score than the portfolio average but is used in

such large quantities that it still shows up as a major contributor. It is therefore unsurprising that none of the constituent substances are very important for the annual $PSSd_{org}$.

These findings highlight how substances used in very low quantities still can have significant impact on the organisational chemical footprint. Such information could be useful when looking for alternative products for substitutions and offering guidance on what substances to avoid.

4.5 Interview

This section presents the findings from the interview conducted with a Dellner employee working as *Environmental & eco product specialist*. As the interview was semi-structured, not all questions in the interview guide were asked explicitly, although all main focused areas were covered. During the interview, the interviewee described their current practices and chemical management, the ProScale results were presented and their applicability in Dellner's operations discussed, and alternatives for further development of ProScale for organisational use was reflected on. The remainder of this section follows the same overall structure, and the findings are presented according to these main themes.

4.5.1 Current chemical management practices

According to the interview findings, Dellner's current chemical management software is a useful tool for initial identification of chemicals in need for further investigation and possible substitution. However, the interviewee noted that it is not sufficient as a stand-alone prioritisation tool as it only bases its ranking on H-phrases. After the first identification using the chemical management software further assessment is needed and is based on review of SDSs and constituent substances. These subsequent steps are done manually and require expert knowledge and judgement. Dellner compares multiple sources of information and considers several factors in their chemical management and prioritization work. However, the interview revealed that their current practice lacks formalised methods for integrating these into one single basis for prioritisation. It was further noted that there is no routine that "adds together" hazard and quantity used in a simple and structured way and although this way of working is functional it is not always sufficiently clear. The substitution work itself was also emphasized and described as slow and difficult. The main obstacle is finding alternative products that satisfy both occupational safety and environmental standards while also meeting strict technical requirements. Given that safety is critical for their products, substitution cannot be rushed. The interviewee noted that limited resources is a secondary factor that further slows down the substitution process.

The findings from the ProScale analysis in combination with the interview provides additional perspectives and reflections on the current practices. One such reflection concerns the heavy reliance on hazard-based prioritization. While ranking chemicals based on their H-phrases accounts for hazard, it does not consider how the product is used at Dellner and therefore disregards the exposure. The ProScale analysis reveals that focusing solely on hazard classification is insufficient for capturing the toxicological effect and that hazardous chemicals do not always drive the organisational chemical footprint when additional factors such as exposure, duration and mass are considered. For instance, while six products of the chemical portfolio constitute of substances belonging to the most severe hazard category (the E-band), the top-ranking products according to ProScale only highlights two of these as top priority products. The other identified hotspot products instead achieve high PSS through a combination of moderate hazards and high usage/exposure. These findings suggests that the current hazard-centric screening process risks both over-prioritizing products with low toxicity impacts and overlooking other hotspot products that ProScale successfully identifies. Overall, the conducted

analysis indicates that hazards-based reporting alone fails to capture the true scale of toxicity and risks misallocating resources in substitution efforts.

Furthermore, although the interview highlighted that Dellner complements the hazard-based prioritization of products with data on consumption volumes to guide prioritization, an interpretation is that heavily relying on mass-based data could be equally as misleading as heavily relying on hazardous properties of the products and its constituent substances. Naturally, high-volume products draw managerial attention, but the ProScale results illustrate that high annual quantities do not correspond to high annual PSS. As stated in Sections 4.2 and 4.3, detergents account for approximately 50% of the annual consumption volumes while only contributing marginally to the annual organisational chemical footprint. Other products show the opposite pattern and correspond to the highest scores despite almost negligible volumes. This finding leads to the interpretation that volume-focused prioritization strategies risk focusing resources on high-use products while leaving high-potency products unaddressed only because they are used in smaller amounts. Such volume-based approach lacks the ability to distinguish between high-volume products which are handled safely and low-volume products posing toxicological threat to worker wealth.

4.5.2 Feedback on ProScale results

Overall, the reaction to the ProScale results was positive, with the interviewee considering them insightful to Dellner's current chemical management work. The interviewee noted that the ProScale analysis differs from current practices by relying to a larger extent on constituent substances data and that these results could reveal issues not previously identified from the ordinary product-level review in their chemical management software. The interviewee highlighted the breakdown of results into category-, product- and substance-level as informative and helpful for interpreting the organisational chemical footprint, what drives the ProScale score and where in the organisation it occurs. The category-disaggregation was mentioned as especially useful, as it made it easier to locate where in the organisation the largest risks are found. Beyond the breakdown of hotspot categories and products, the interviewee valued the identification of specific toxicity-driving substances. Understanding which of the constituent substances are drivers of the toxicity scores may help guide follow-up efforts. It was expressed that such knowledge could support substitution efforts by identifying what specific substances to avoid or be aware of when looking for alternative products.

According to the interviewee, the ProScale analysis provides a broader basis for prioritisation than the current approach, as it combines several dimensions and not only hazards. At the same time, the interview also revealed some potential limitations of the method. In some cases, for example for the products Sealing 9 and 10, already known problems did not appear clearly in the ProScale results, but another substance in the product still made it show up as a prioritized product for substitution. For other products and product categories, such as paints, were considered "less important" according to ProScale despite being highly prioritised by Dellner today. This made the interviewee raise questions whether the ProScale method can miss important chemicals when data gathering is based on CAS-numbers and substances listed in the SDS. Questions were also raised regarding effects and consequences when required constituent-level data, such as CAS-linked information for polymeric acrylates, are not available. The interviewee therefore regarded ProScale to be both insightful and somewhat data sensitive, as substance-specific data may not always be available.

One reflection arising from the interview feedback concerns the value created from analysing the ProScale results at multiple levels. The interviewee's appreciation of the stepwise disaggregation suggests that the category and product level breakdown complement each other and improves the interpretation, and thereby the usefulness, of the organisational chemical footprint. This indicates that multi-level analysis may help guide attention towards products

with high toxicological impacts. Furthermore, aligning the interviewee's feedback with the findings in Section 4.3, such stepwise disaggregation mitigates the risk that focusing solely on individual products might lead to overlooking categories associated with collective toxicological impacts.

4.5.3 Further development of ProScale for organisational use

From the interview it was found that using ProScale for an organisational chemical footprint is not merely another way of expressing what Dellner already knows about their chemical portfolio. Instead, the method was seen as capable of contributing with new information and perspectives. Even though ProScale was perceived as having potential, the interviewee expressed that it would not replace existing routines but rather complement them. The main reason is that ProScale does not capture any internal or legal requirements, both of which need to be considered as these are central in Dellner's prioritisation and substitution decisions.

Regarding the requirement for implementation of the ProScale method, the interviewee repeatedly emphasised feasibility and simplicity and it was made clear that that use of an additional tool, such as ProScale, would only be justified if time-efficient and straightforward. Automation and integration of ProScale with the chemical management software in use was suggested to make the method more applicable in practice. Concerns were raised both regarding the importance of input data and data management. One such concern was that suppliers perform substitutions which will affect the constituent substances of the chemical products over time, meaning that regular updates of ProScale input data would be necessary as well as the addition of new products and substances. It was also highlighted that the analysis of the ProScale results would need to be automated to maintain a feasible workload.

Reflecting on the finding from the interview, it appears that a chemical management procedure which can merge several different decision factors would be useful. While the ProScale framework does not yet incorporate every factor taken into consideration within today's decision-making process at Dellner, most notably legal and customer requirements, the method still represents a shift towards a more holistic toxicity indicator. By integrating hazard and mass, with exposure and duration into one single metric, ProScale offers a way to quantitively combine variables that currently are weighted only qualitatively by Dellner employees.

4.6 Sensitivity analysis

This section describes the results from the sensitivity analysis conducted regarding the input variables of PHF and PROCs.

4.6.1 Dellner specific vs default PHF

One main challenge of adapting ProScale to an organisational setting was the adaptation of the PHF. According to the guidance document, default PHF values are recommended. However, it was assumed that organisation-specific PHFs would be more appropriate and more accurately represent the actual duration of chemical used within different activities at the site. To evaluate the influence of PHF, a comparison between the standardised ProScale default PHF and the set of values tailored to the operation at Dellner was performed. Figure 11 shows the outcomes of the two approaches.

The strategy for calculating PHF resulted in a difference of about one order of magnitude between service and assembly, with assembly having a higher PHF due to more time spent and lower volume of chemicals used. This influences the results considerably. If the default PHF is used instead, the chemical products used in service contribute with a much larger relative share

of the overall organisational chemical footprint. This is notable when comparing Figure 12 with Figure 8, which visualises the category contribution using default and site specific PHF, respectively.

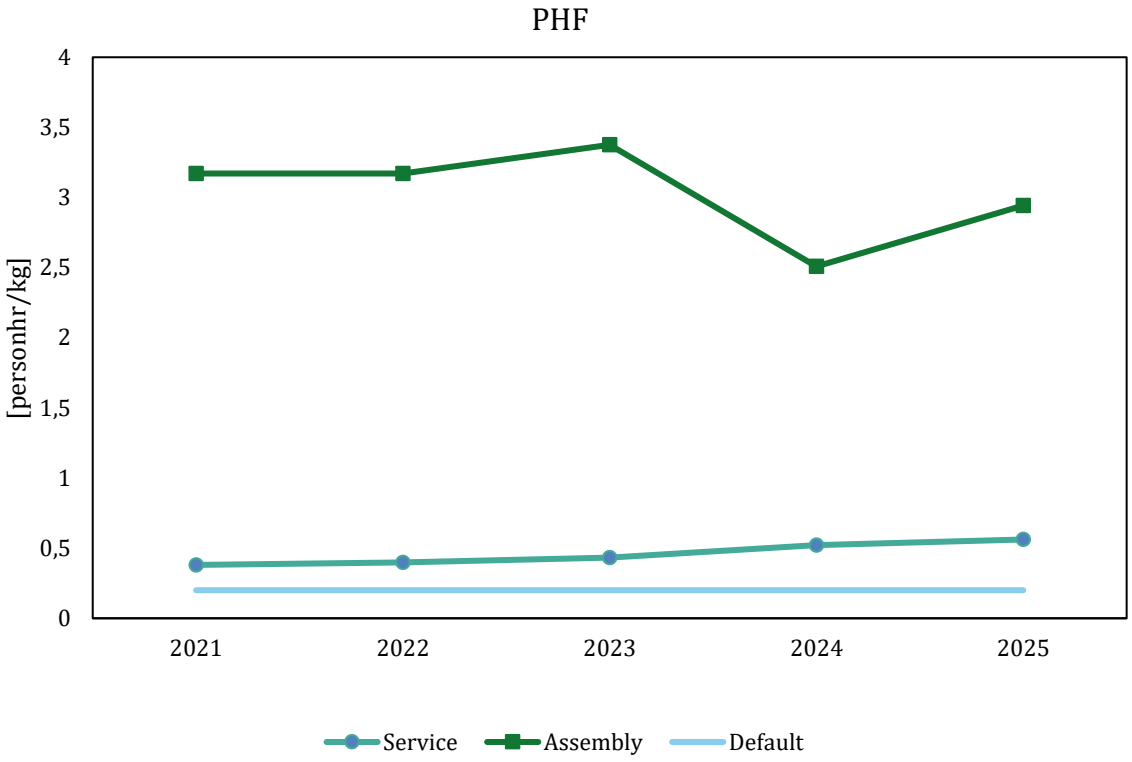

Figure 11. Default and Dellner specific PHF.

How this methodological choice influences the identification of hotspots is presented in Table 11. While the inhalation pathway hotspots are robust and remains unaffected by this change in PHF, the dermal top-list entirely rearrange. Organisational chemical footprint calculated using default PHF values identifies detergents as a major concern for the dermal toxicity. Detergent 1 replaces Lubricant 12 as the top contributor for the entire study period and the top-list is further expanded to also include other high-use products such as Detergent.

Table 11. Top contributing product by pathway. Dellner specific PHF vs default PHF.

		Dellner specific PHF	**Default PHF**
Inhalation	1	Lubricant 12	Lubricant 12
	2	Sealing 10	Sealing 10
	3	Sealing 9	Sealing 9
Dermal	1	Lubricant 12	Detergent 1
	2	Corrosion protection 2	Lubricant 12
	3	Detergent 1	Detergent 2
	4	-	Corrosion protection 2

Both Table 11 and Figure 12 illustrate that a methodological choice of not distinguishing between service and assembly results in substantial shifts in top-ranking products and major contributing categories for dermal exposure. When comparing Figure 12 with Figure 8, service-related products (i.e. detergents and cleaning products) demonstrate the most pronounced change in their share of the total PSSd. The share of the organisational chemical footprint attributed to detergents increases from a maximum of 21% to as much as 59% and previously negligible contribution from cleaning products rises to approximately 10%.

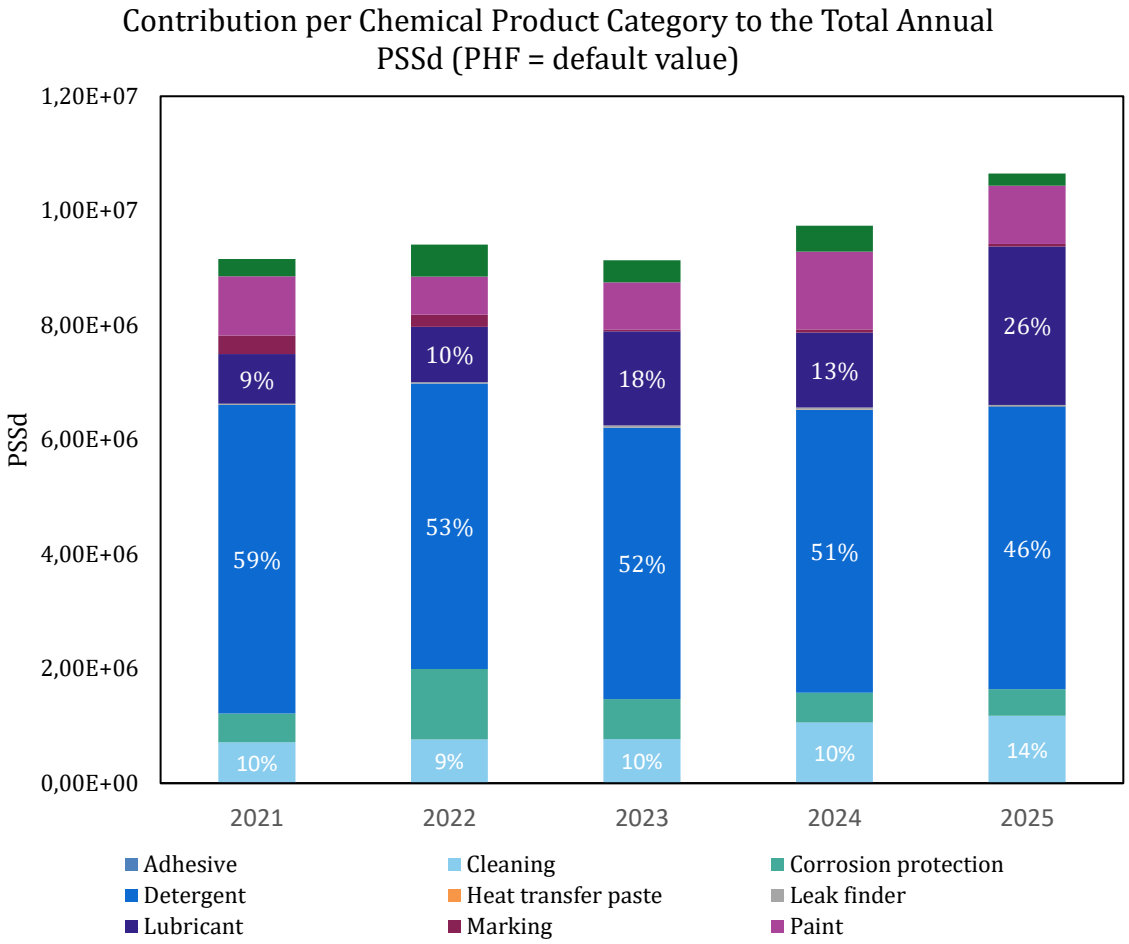

Figure 12. PSSd by product category calculated using default PHF.

4.6.2 Choice of PROC

With the choice of process categories and use setting, linguistic uncertainties arise. The definitions of professional versus industrial setting refer to the level of control on the exposure to workers. According to ECETOC, "the use type 'industrial' should only be used when the worker situation meets characteristics that are typical for industrial use" (ECETOC, 2023b. p10). It is stated that industrial use refers to the design and maintenance of technical equipment, and health and occupational safety management systems. However, this leaves room for much interpretation of the analyst. Based on discussions with the company, the professional use setting was used in this study. However, PROC7 (industrial spraying) was deemed more relevant than PROC11 (non-industrial spraying) based on the actual exposure scenario on the site. Thus, it can be questioned whether the industrial setting should have been used throughout the study, if PROC11 would have been a better choice, or if there can be different type of use within the same production site.

Linguistic uncertainties are also present within other PROCs. For example, Lubricant 12 was assigned PROC18 (greasing at high energy) but could also be described with PROC10 (roller application or brushing). These different interpretations of the definitions of the use types and process categories could potentially affect the results. The PROC sets the baseline exposure predictions, which are then modified with data on physical state, fugacity and risk management measures to derive the ECF. Figure 13 shows how the $PSSd_{prod}$/kg changes with the modifications of PROC18 to PROC10 for Lubricant 12 and PROC7 to PROC11 for Corrosion protection 2.

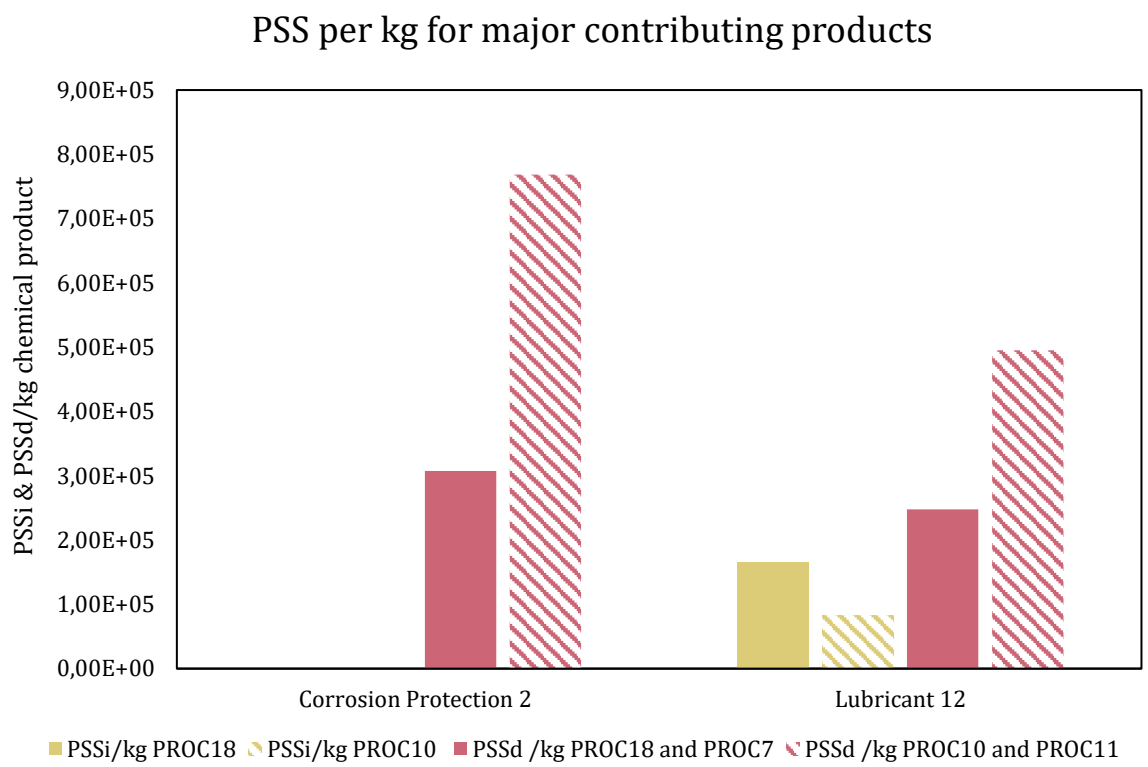

Figure 13. Effects of changing PROCs for Corrosion protection 2 and Lubricant 12.

As can be seen in Figure 13, changing the PROCs resulted in large differences. Particularly interesting is that the PSSi increased while PSSd decreased for Lubricant 12. This could be attributed to the change in ECF that the PROC affects, where the ECF for the inhalation route decreases with the change of PROC18 to PROC10, but the dermal ECF increases (Table 12). These results are expected, since the lubrication at high energy (PROC18) indicates that substances are more volatile whereas roller or brush application of a product (PROC10) is more likely to cause skin exposure.

Table 12. Changes in ECF caused by changing PROC for Lubricant 12.

Physical state (fugacity)	PROC18		PROC10	
	ECFi (mg/day)	ECFd (mg/day)	ECFi (mg/day)	ECFd (mg/day)
Solid (high)	2560	959	1280	1918
Fluid (neg.)	640	959	320	1918
Fluid (low)	640	959	320	1918

It was further analysed how the distribution of PSS_{cat} would be affected by the changed PROCs. Thus, all PROC7 were changed to PROC11 and all PROC18 were changed to PROC10, the results of which can be found in Figure 14, with supporting data in Appendix J. Lubricants showed sligtly less dominance in the total score, contributing at most 65% rather than 80% with newly assigned PROC10. No new categories emerged, but the distribution of the scores became more even for PSSi. The total $PSSi_{org}$ was reduced by an average of 18%.

More dramatic changes were found for $PSSd_{cat}$, where the importance of corrosion protection, which are sprays, contribute more significantly than before. This is expected, since the change from industrial to non-industrial spraying is associated with a higher exposure prediction. Additionally, as mentioned previously, the PSSd of lubricants was increased in this scenario. These changes result in much higher $PSSd_{org}$ scores, which means that the product categories for which the PROCs were not changed contribute a lower fraction to the total. This can for example

be seen for detergents, which at most contribute 14% to $PSSd_{cat}$ after the changed PROCs, compared to 21% previously. Detergent 1 does not emerge as a majorly contributing product after this change, whereas Corrosion protection 1, which previously was not among the top scoring products, would be with this alternative interpretation of PROC.

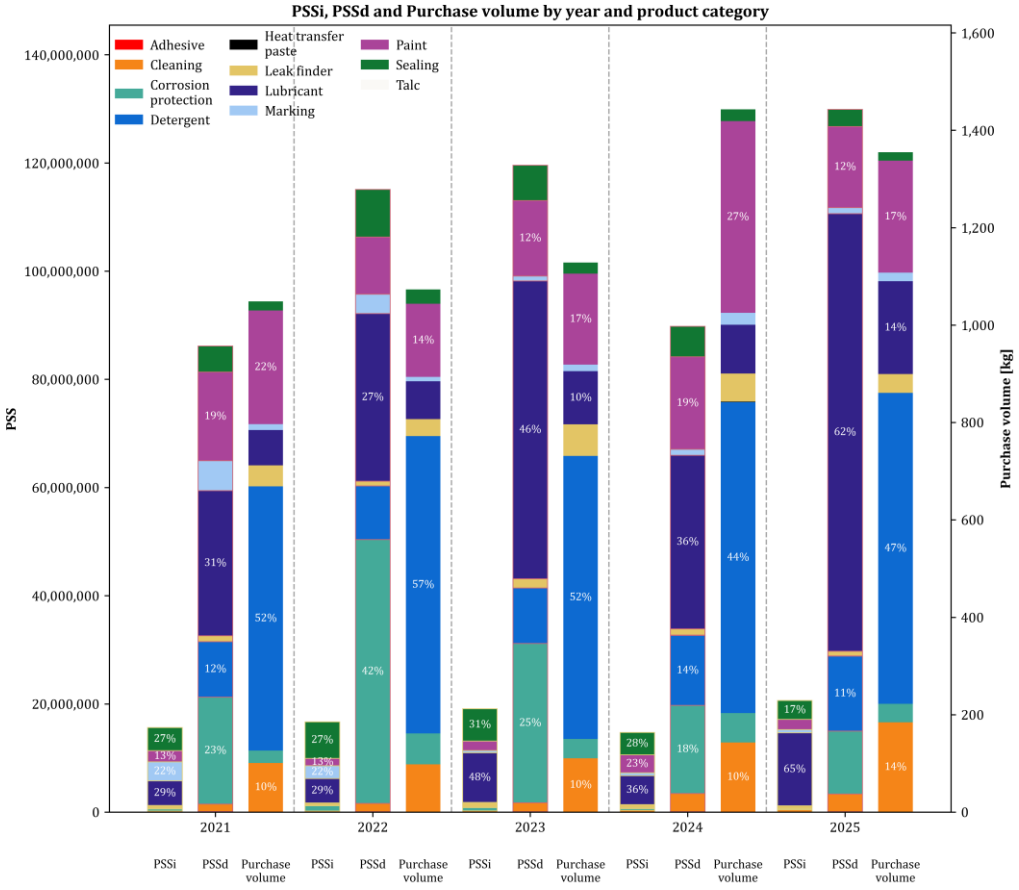

Figure 14. Distribution of PSSi and PSSd over product categories when PROC18 and PROC7 are changed to PROC10 and PROC11, respectively.

Also seen when comparing Figure 14 to the corresponding Figure 8 in Section 4.2 is that $PSSi_{org}$ is reduced and $PSSd_{org}$ increases. In total, an average reduction of 28% for $PSSi_{org}$ could be seen, whereas the average increase for $PSSd_{org}$ was 52%. For internal footprinting this is not crucial, assuming the interpretation of the PROCs are consistent over the year. However, for internal chemical management work and for comparisons across organisations, these findings highlight an important issue in the current state of the ProScale method, where seemingly small linguistic interpretations can impact the results significantly.

4.7 Methodological reflections

This study has shown that the ProScale Workers method can be adapted to develop an organisational chemical footprint, and that such a footprint can provide useful support for prioritisation and substitution work. At the same time, the findings show that this application requires methodological interpretation and remains associated with several practical and conceptual limitations. This section examines the implications of the methodological choices of this study and suggests refinements to improve the applicability of ProScale for future organisational use.

4.7.1 Data collection and management

A primary finding is the challenge regarding data quality and consistency and the need for a harmonized data gathering protocol with instructions for where and how to collect and store data. The current ProScale guidelines include a clear hierarchy for selecting OELs, but similar guidance is lacking for other required input data such as vapour pressure and fugacity. This may lead to inconsistencies and makes the data gathering process vulnerable to biases of the analyst which decreases the reliably of the footprint. This is especially important for ensuring results that reflect the actual toxicity but also for making them comparable across different organisations.

Another data-collection related challenge concerns the level of input data and whether product- or constituent substance-level data best reflects the properties of the product under study. While ProScale relies on substance data, one could debate whether using substance level data accurately reflects the behaviour of this substance when it exists within a product. Additionally, due to regulatory reporting thresholds, SDSs only disclose hazardous chemicals above a certain limit, resulting in the footprint indicator to systematically overlooking potentially high-potent substances due to their low concentration.

Furthermore, the sensitivity analysis highlighted additional challenges related to the PHF and PROCs and the dramatic impacts the choice of these implies. Changing PROCs to other reasonable alternatives showed considerable changes in the total PSSi and PSSd for the organisation. Using default values for PHF entirely rearranged the dermal top-list and shifted the primary concern from lubricants to detergents. For quick and easy application of ProScale there could be arguments for omitting the organisational specific PHF in favour of the default values, especially if all processes look somewhat similar regarding use of chemicals and duration of exposure. However, in case of applying the organisational chemical footprint within corporate decision making, the site-specific PHF is considered to better reflect the real use case.

Lastly, the impacts from data gaps and the subsequent need for assumptions and estimations must be addressed. Because data collection heavily relies on the availability of CAS number of the constituent substances, the absence of these identifiers introduces significant uncertainties. Within this study, missing or incomplete SDS information and the lack of CAS number and/or matches in the ECHA database resulted in missing hazard information and physiochemical properties for several substances. The assumptions required to bridge these gaps could lead to both under- and overestimations and ultimately alter the relative products scores and shifting the list of identified hotspot products. Addressing data uncertainties is essential for ensuring ProScale as a robust organisational tool.

4.7.2 Adapting ProScale from process to organisational level

This study represents an exploration where the ProScale tool is used within a new context, and the focus is shifted from a product system to a whole organisation. Transitioning the framework to represent an entire organisation required significant methodological modifications and the functional unit, ProScale equation units and PHF needed to be adjusted. The standard ProScale equation is designed to calculate a PSS relative to a functional unit of a specific product or production process. However, as this study tests whether the tool can be used at an organisational level, the functional unit to which the score is to be related was defined as “one organisation”. When relating the equation to “one organisation” and without further adjustments, the units of the four ProScale factors would not align mathematically. This was resolved by modifying the PHF and introducing a reference flow (amount of purchased chemicals), which was used in the calculation instead of the reporting flow (number of

couplers). The latter would have been ideal to align ProScale for organisational chemical footprint to O-LCA methodology.

4.7.3 Deviations from O-LCA

In the beginning of this study, a choice whether O-LCA or OEF was to be used as the methodological frameworks was made. Even though it was decided that O-LCA was to guide this assessment, the study still deviated from this framework in several regards. The reality of industrial data availability forced the system boundaries to be restricted to only include activities within a gate-to-gate scope, omitting large parts of the life cycle. In addition, the reporting flow defined according to O-LCA guidelines was not used in the present study, as a mass-based flow was needed for the PHF calculation.

There is a fundamental tension between completeness and practical feasibility, and in this study up- and downstream activities were disregarded from the scope of this assessment. At first this was interpreted as a major deficiency, but interestingly Dellner employees did not view this narrow focus as a drawback. Instead, the gate-to-gate system boundary was thought to be more appropriate for the purpose of internal management and advantages such as simpler data collection was emphasized. Dellner especially pointed out that obtaining data from upstream suppliers is nearly impossible, making a full life cycle assessment either unfeasible or unreliable if upstream data gaps where to be bridged by assumptions and estimates. Consequently, the results from this study should be viewed as an internal management tool for decision making and substitution efforts rather than a static reporting metric used to compare Dellner to the performance of similar organisations, which also aligns with the O-LCA prohibition of comparing organisations to one another. This highlights a shift from the general definition of "footprints" where, for example, the commonly used "carbon footprint" is often used for external reporting and benchmarking.

4.7.4 Omission of molecular weight in the ProScale tool

During the sensitivity analysis investigating the effect of changing PROCs, a flaw in the interim version of the ProScale tool used in this study regarding the exposure predictions for fluid substances was identified. The ECETOC TRA model generates values in ppm which are then transformed into mg/m^3 for the exposure predictions. The transformation is not based on the vapour pressure of the individual substance, but rather a standard equation of 1 ppm being equal to the molecular weight of the substance divided by 24 (ECETOC, 2023b). This transformation is missing in the ProScale tool used for this study. This skews the PSSi results where heavy fluid substances will have lower PSSi than intended, and light substances will have higher PSSi. However, not accounting for molecular weight has no effect on PSSd since the dermal exposure predictions are given in $mg_{sub}/kg_{bw}/day$.

This discovery limits the applicability of the PSSi results of this study, as they can vary with at least one order of magnitude which was found for the substances included in Lubricant 12. It should also be noted that this issue may be difficult to work around for the substances that do not have a CAS number in their SDS, since finding the molecular weight of these may be hard or require additional assumptions, further limiting the usefulness of the tool for comparing both substances and organisations.

5 Conclusions

Through this study, ProScale was tested within a novel application context to derive an organisational chemical footprint. By shifting the focus of the ProScale methodology from product to organisational level, the ProScale-W module was applied to Dellner Couplers AB's whole operations. Whether this application was fully successful is a matter of discussion. While an organisational chemical footprint was indeed derived and perceived to offer new insights and perspectives on chemical management, the overall reliability and applicability is challenged by technical hurdles. Compared to current management practices, ProScale offers a more integrated toxicity indicator. However, the analysis revealed methodological obstacles, including unit misalignment within the ProScale equation, the need for reinterpretation of the PHF and data (in)consistency. Especially the data availability challenges necessitated a gate-to-gate scope, leaving the full life-cycle vision as a target for future development. While this initial application of ProScale at organisational level resolved some of the methodological hurdles, the remaining challenges provide a clear trajectory for continued refinement.

RQ1 – How can the ProScale method be used to derive an organisational chemical footprint?

Deriving an organisational chemical footprint using ProScale requires a shift in the methodological focus from product-specific to organisational level. Within the scope of this thesis and the case study at Dellner, the ProScale-W module served a suitable starting point for such assessment as it focuses on the direct human toxicity impact occurring at the Vika site. To enable this methodological transition, the ProScale equation had to be adapted to represent "one organisation" over a specific reference period instead of "one product system". The results show that ProScale can be successfully implemented to aggregate and combine hazard information, exposure modelling, duration of use and usage data into one single indicator for two exposure routes. However, several adaptations were needed to develop these organisational-level PSS.

A key adaptation related to the PHF. The ProScale guidance recommendation of using industry defaults was abandoned in favour of site- and activity-specific PHFs. These proved more informative and reflected the actual duration of workers exposure more accurately. Furthermore, the reporting flow was based on mass of chemical product input instead of the recommended production output to create a mathematically consisted and interpretable PSS in "mg/organisation". While a gate-to-gate scope contradicts the full life-cycle perspective and intention of ProScale, this was the most practical choice for a first organisational level assessment. These adaptations and limitations enabled a more reliable representation of the specific organisation and its operations.

RQ2 – How can a ProScale-based organisational chemical footprint be used to identify relevant chemicals for chemical management, substitution and decision making?

The presentation and interview of the ProScale results demonstrated a positive attitude towards the usefulness of an organisational chemical footprint. Specifically, the disaggregation of the organisational chemical footprint provides new perspectives and a structured basis for prioritisation. This granular analysis of category-, product- and constituent substance-level results allows management to distinguish between volume-driven and toxicity-driven scores. While the footprint and the breakdown of it effectively identifies candidates for managerial attention and substitutional efforts, feedback from Dellner clarifies that this analysis is currently insufficient to be adopted. Even though it complements current chemical management practices by integrating hazard and volume together with exposure and duration of use, it does not consider legal or internal requirements. Furthermore, in its current form, ProScale and its high dependency on manual data management lacks necessary time-efficiency for continuous corporate use.

Additionally, methodological uncertainties represent another source of variability in the results. Specifically, the assignment of PROCs involves linguistic uncertainties, where interpretation dramatically can alter the ECF and subsequently the PSS. Such choices regarding input data affect the overall reliability of the results, as different analyst might arrive at different footprint scores for the same operations. Without harmonized protocols that clearly structure and guide processes, both the internal and external comparability of organisational chemical footprints is compromised.

RQ3 – To what extent does the ProScale method balance simplicity and relevance to be useful and feasible for companies such as Dellner?

Developing an organisational chemical footprint for Dellner highlighted the need for balancing methodological rigor and actual practical feasibility of performing the assessment. To derive a meaningful indicator, the methodology must be adapted to reflect the reality of the specific site under study, the use of chemicals and the inherent properties of the chemical substances. ProScale is a useful and relatively straightforward screening and prioritisation tool. It serves as a valuable complement to existing chemical management practices, potentially offering new perspectives on priorities and trade-offs that may not be captured through the current chemical management routines at Dellner. It should also be noted that the relevance of ProScale in terms of accurately representing the toxicity of chemical products has not been assessed in this study.

However, ProScale is considered insufficient as a catch-it-all tool for chemical management. The interview clearly emphasized that the tool would only be justifiable if it could generate valuable insight without imposing extra administrative costs. Currently, "simplicity" is hindered by high dependencies on manual data management, such as manual retrieval of CAS numbers and interpretation of SDS documents, and the fact that ProScale does not capture legal and internal requirements as well as the additional work needed for disaggregation and interpretation of the results. To move from an exploratory study context to a part of the chemical management routine, the ProScale tool would have to be developed to include automated data structures. Additionally, integration with existing chemical management software could lower the barrier for implementation.

5.1 Future research

To transform this first application of ProScale standardized framework for organisational setting, several areas of future research, methodological developments and adaptations are required. To lower the adoption barrier for industry and organisations, focus should be placed on integrating ProScale with existing chemical management tools to increase automation and ease of use. Furthermore, if the goal is to ensure that the organisational chemical footprint is comparable across companies requires standardization and harmonization of how the tool is used and how to collect and interpret data. The methodology must establish clear and structured hierarchies for data collection. It should also address the lack of ppm to mg/m^3 transformation in the ECF calculation.

Finally, even though this study generated informative results while applying a constrained gate-to-gate boundary, only including workers toxicity fails to provide a holistic perspective of the chemical footprint. Future research should therefor focus on how system boundaries can be expanded to include the full life cycle in a practical manner. While including up- and downstream activities is a first step, integration of additional ProScale modules is necessary to avoid burden shifting.

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Appendix

Appendix A: Illustration of ProScale calculation for example product

Product X		Constituent Substances of Product X						
		1,2-benzisotiazol-3(2H)-one	Amines, C12-14-alkyldimethyl, N-oxides	4,4-dimethyloxazolidine	Water	2-aminobutan-1-ol	Glycine, N-methyl-N-(1-oxo-9-octadecenyl)-, (Z)-	2-amino-2-methylpropanol
MF	Annual consumption (2021) [kg]	43.2						
	Mass fraction	0.0000249	0.00249	0.000099	0.96	0.000099	0.0249	0.0099
MF		1.08E-03	1.08E-01	4.28E-03	4.15E+01	4.28E-03	1.08E+00	4.28E-01
ECF	PROC	7						
	Type of setting	Industrial						
	State of substance	solid	solid	fluid	fluid	fluid	fluid	fluid
	Vapour pressure [kPa]	-	-	9,00E-01	2,50E+00	5,81E-02	1,00E-04	4,50E-02
	Dustiness of Solid	high	high	-	-	-	-	-
	LEV	No						
	Dermal protection equipment	No						
ECFi [mg/person×day]		1.28E+03	1,28E+03	3,20E+03	3,20E+03	1,28E+03	1,28E+03	1,28E+03
ECFd [mg/person×day]		3,00E+03	3,00E+03	3,00E+03	3,00E+03	3,00E+03	3,00E+03	3,00E+03
PHF	Annual hours worked assembly (2021)	10 318 person×hours (1290 person×days)						
	Annual consumption assembly (2021)	407 kg						
PHF [person×days/kg_{prod}]		3.17						
HF	OEL [mg/m³]	6.81	8.68	0.001	0.001	3.7	0.05	3.7
	H-Phrase	H302 (O) H315 (D) H318 (D) H317 (D) H400 H330 (I) H331 (I)	H302 (O) H315 (D) H318 (D)	H302 (O) H311 (D) H315 (D) H318 (D) H331 (I)	-	H302 (O) H314 (D) H318 (D)	H315 (D) H318 (D) H332 (I)	H319 (D) H315 (D) H412
HFi		2.89E+03	2.69E+00	1.00E+03	0.00E+00	3.46E+00	1.00E+02	3.46E+00
HFd		2.89E+02	2.69E+02	0.00E+00	0.00E+00	3.46E+02	0.00E+00	3.46E+01
	PRODUCT							
PSSi [mg/org]	**5.00E+05**	1,26E+04	1,17E+03	4,34E+04	0,00E+00	6,00E+01	4,36E+05	6,00E+03
PSSd [mg/org]	**4.33E+05**	2,95E+03	2,75E+05	0,00E+00	0,00E+00	1,41E+04	0,00E+00	1,41E+05

Appendix B: Assignment of H-phrases, OELs, and physical properties (substance level data)

Numerical notes 1-5 refer to substance names, where no CAS or EG-number was found for identification. Alphabetical notes refer to sources that were used other than the databases described in Section 3.3.2.

CAS	EG-number	H-phrases in SDS	Harmonized H-phrases	OEL (Source)	DNEL (Source)	Physical state (description)	Vapour pressure/dustiness (Source or rationale)
68154-99-4	-	H312 (D) H318 (D) H315 (D)	-	-	-	liquid	<0.001 (SDS of substance) [A]
29385-43-1	249-596-6	-	-	-	49.3 (ECHA)	solid (granulate)	Medium
556-67-2	209-136-7	H361 (O,D,I)	H361 (O,D,I)	-	73 (ECHA)	liqiud	0.132 (ECHA)
613-48-9	210-345-0	H301 (O) H311 (D) H331 (I) H373 (O,D,I) H315 (D)		-	-	liquid (described in PubChem)	0.013 (Assumption based on vapour pressure of product in which this substance is a part)
7446-26-6	231-203-4	-		-	13.5 (ECHA)	Solid (powder)	High
7620-77-1	231-536-5	-	No H-phrases	5 (SDS)	()	Solid (salt)	Low
8042-47-5	232-455-8	H304 (O)	-	5 (GESTIS, Germany)	()	Liqiud	<0.01 (ECHA)
8002-74-2	647-510-5	-	-	2 (GESTIS, EU-countries)	()	Solid (wax)	Low
-	939-603-7	H317 (D)		-	35.26 (SDS)	Liquid	0.00001 (ECHA)
73398-89-7	277-459-0	H302 (O) H318 (D) H331 (I)	x	-	1.11 (SDS)	solid (powder)	High
58-27-5	200-372-6	H302 (O) H319 (D) H315 (D) H335 (I) H317 (D)		-	-	Solid Powder	High
64-17-5	200-578-6	H319 (D)	-	350 (GESTIS, Germany)	-	liquid	0.005726 (ECHA)
67-56-1	200-659-6	H301 (O) H311 (D) H331 (I) H370 (O,D,I)		130 (GESTIS, Germany)	-	Liquid (Pubchem)	12.9 (PubChem) [B]

67-63-0	200-661-7	H336 (I) H319 (D)	H336 (I) H319 (D)	500 (GESTIS, Germany)	-	liqiud	4.4 (ECHA)
67-64-1	200-662-2	H319 (D) H336 (I)	H319 (D) H336 (I)	1200 (GESTIS, Germany)	-	Liquid	24 (ECHA)
71-23-8	200-746-9	H318 (D) H336 (I)		350 (GESTIS, Sweden)	-	Liquid	2.82 (ECHA)
71-36-3	200-751-6	H302 (O) H315 (D) H318 (D) H335 (I) H336 (I)	H302 (O) H315 (D) H318 (D) H335 (I) H336 (I)	310 (GESTIS, Germany)	-	liqiud	1 (ECHA)
74-98-6	200-827-9	-	-	1800 (GESTIS, Germany)	-	liquid	878 (ECHA)
75-28-5	200-857-2	-	-	2400 (GESTIS, Germany)	-	liquid (assumption)	319 (ECHA)
77-99-6	201-074-9	H361 (O,D,I)	-	-	-	Solid powder	High
78-93-3	201-159-0	H319 (D) H336 (I) EUH066 (D)	-	600 (GESTIS, Germany)	-	Liquid	10.4 (ECHA)
79-10-7	201-177-9	H302 (O) H312 (D) H314 (D) H332 (I) H335 (I)	-	30 (GESTIS, Germany)	-	Liquid	0.529 (ECHA)
79-41-4	201-204-4	H302 (O) H311 (D) H314 (D) H332 (I)	H312(D)	180 (GESTIS, Germany)	-	Liquid	0.09 (ECHA)
80-05-7-	201-245-8	H317 (D) H318 (D) H335 (I) H360 (O,D,I)	-	2 (GESTIS, Germany)	-	Solid (crystals. flakes. pills)	Low
80-15-9	201-254-7	H312 (D) H302 (O) H314 (D) H330 (I) H335 (I) H373 (O,D,I)	H242 H331 (I) H312 (D) H302 (O) H314 (D) H373 (O, D, I)	1 (GESTIS, Latvia)	-	liquid	0.00044 (ECHA)
80-56-8	201-291-9	H302 (O) H315 (D) H317 (D) H304 (O)	-	150 (GESTIS, Sweden)	-	liquid	0.69 (ECHA)
80-62-6	201-297-1	H315 (D) H317 (D) H335 (O,D,I)		210 (GESTIS, Germany)	-	Liquid	3.7 (ECHA)

90-72-2	202-013-9	H302 (O) H312 (D) H314 (D) H318 (D)	H302 (O) H315 (D) H319 (D)	-	0.53 (ECHA)	liquid	0.000075 (ECHA)
95-38-5	202-414-9	H314 (D) H318 (D) H373 (O,D,I) H302 (O)		-	0.46 (ECHA)		0.001 kPa (ECHA)
96-20-8	202-488-2	H302 (O) H314 (D) H318 (D)		3.7 (GESTIS, Germany)	-	Liquid	0.0581 (ECHA)
97-64-3	202-598-0	H318 (D) H335 (I)		25 (GESTIS, Sweden)	-	Liquid	8.1 (ECHA)
97-88-1	202-615-1	H315 (D) H317 (D) H319 (D) H335 (D)	H315(D) H317(D) H319(D) H335(D)	300 (GESTIS, Sweden)	-	Liquid	0.212 (ECHA)
100-41-4	202-849-4	H332 (I) H373 (O,D,I) H304 (O)	H332 (I) H373 (O,D,I) H304 (O)	88 (GESTIS, Germany)	-	liquid	0.952 (ECHA)
100-51-6	202-859-9	H302 (O) H335 (I)	H302 (O) H317 (D) H319 (D)	22 (Gemany)	-	Liquid	0.007 (ECHA)
101-68-8	202-966-0	H332 (I) H315 (D) H319 (D) H334 (I) H317 (D) H351 (O,D,I) H335 (I) H373 (O,D,I)	H332 (I) H315 (D) H319 (D) H334 (I) H317 (D) H351 (O,D,I) H335 (I) H373 (O,D,I)	0.05 (GESTIS, Germany)	-	solid (crystalline), particulate/powd er (ECHA)	High
101-84-8	202-981-2	H319 (D)	H360 (O,D,I) H317 (D) H319 (D)	7.1 (GESTIS, Germany)	-	Solid (crystalline / large crystals or pellets)	High
106-97-8	203-448-7	H220 H280		2400 (GESTIS, Germany)	-		221 (ECHA)
107-98-2	203-539-1	H336 (I)	H336 (I)	370 (GESTIS, Germany)	-	Liquid	0.00156 (ECHA)
108-01-0	203-542-8	H302 (O) H312 (D) H314 (D) H318 (D) H331 (I) H335 (I)		5 (GESTIS, Latvia	-	Liquid (PubChem)	0.612 (PubChem) [C]
108-10-1	203-550-1	EUH066 (D) H319 (D) H332 (I) H335 (I)	H351 (O,D,I) H336 (I)	83 (GESTIS, Germany)	-	Liquid	2.64 (ECHA)
108-31-6	203-571-6	H302 (O) H314 (D) H317 (D) H318 (D) H334 (I) H372 (O,D,I)		0.081 (GESTIS, Germany)	-	solid (crystal flakes)	Low

108-65-6	203-603-9	H336 (I)		270 (GESTIS, Germany)	-	Liquid	0.502 (ECHA)
108-88-3	203-625-9	H315 (D) H361 (O,D,I) H336 (I) H373 (O,D,I) H304 (O)	H315 (D) H361 (O,D,I) H336 (I) H373 (O,D,I) H304 (O)	190 (GESTIS, Germany)	-	liquid	3.089 (ECHA)
109-16-0	203-652-6	H317(D)		-	48.5 (ECHA)	Liquid	0.000006 (ECHA)
109-87-5	203-714-2	H2...	H2...	1600 (GESTIS, Germany)	-	Liquid	40 (ECHA)
110-16-7	203-742-5	H302 (O) H312 (D) H315 (D) H317 (D) H319 (D) H335 (I)		-	0.987 (ECHA)	Solid (crystalline)	Low
110-25-8	203-749-3	H315 (D) H318 (D) H332 (I)	-	0.05 (GESTIS, Germany)	-	Liquid (pubchem)	0.0001 (SDS of substance) [D]
111-76-2	203-905-0	H302 (O) H331 (I) H315 (D) H319 (D)		49 (GESTIS, Germany)	-	Liquid	0.12 (ECHA)
112-30-1	203-956-9	H319 (D)		66 (GESTIS, Germany)	-	Liquid	0.0013 (ECHA)
112-34-5	203-961-6	H319 (D)	H319 (D)	67 (GESTIS, Germany)	-	liquid	0.0029 (ECHA)
114-83-0	204-055-3	H302 (O) H317 (D) H351 (O,D,I)	H302(O)	-	-	Solid (powder)	High
115-10-6	204-065-8	-	-	1900 (GESTIS, Germany)	-	liquid	513 (ECHA)
123-26-2	204-613-6	H317 (D)		-	-	Solid (powder)	High
123-42-2	204-626-7	H319 (D)	H319 (D)	96 (GESTIS, Germany)	-	Liquid	0.129 (ECHA)
123-86-4	204-658-1	H336 (I) EUH066(D)	H336 (I)	300 (GESTIS, Germany)	-	Liquid	1.12 (ECHA)
124-68-5	204-709-8	H315 (D) H319 (D)	H315 (D) H319 (D)	3.7 (GESTIS, Germany)	-	Liquid	0.045 (ECHA)
126-86-3	204-809-1	H317 (D) H318 (D)	H317(D) H318(D).	-	2.86 (SDS)	Solid (wax)	Low
128-37-0	204-881-4	H400 H410		10 (GESTIS, Germany)	-	solid (powder. crystalline)	High

141-43-5	205-483-3	H302 (O) H312 (D) H314 (D) H332 (I) H335 (I)	H302 (O) H312 (D) H314 (D) H332 (I)	0.5 (GESTIS, Germany)	-	liquid	0.05 (ECHA)
141-78-6	205-500-4	H319 (D) H336 (I)	H319 (D) H336 (I)	730 (GESTIS, Germany)	-	Liquid	10.3 (ECHA)
142-90-5	205-570-6	H335(I)		-	97.8 (ECHA)	Liquid	0.00006 (ECHA)
156-60-5	205-860-2	H332 (I) H319 (D) H336 (I)		800 (GESTIS, Germany (DFG))	-	liquid	44.13 (ECHA)
540-97-6	208-762-8	-	-	-	-	Liquid	0.0047 (ECHA)
541-02-6	208-764-9	-	-	-	97.3 (SDS)	Liquid	0.0332 (ECHA)
556-67-2	209-136-7	H361 (O,D,I)		-	73 (SDS)	Liquid	0.132 (ECHA)
609-72-3	210-199-8	H373 (O,D,I) H301 (O) H311 (D) H331 (I)		-	-	liquid	0.013 (SDS of substance)
646-06-0	211-463-5	H318 (D)		150 (GESTIS, Germany)	-	Liquid (Pubchem)	9.3 (SDS of substance) [E]
822-06-0	212-485-8	H302 (O) H315 (D) H317 (D) H319 (D) H330 (I) H334 (I) H335 (I)	H331(I)	0.035 (GESTIS, Germany)	-	Liquid	0.0007 (ECHA)
868-77-9	212-782-2	H315(D) H317(D) H319(D)		11 (GESTIS, Norway)	-	Liquid	0.008 (ECHA)
1185-55-3	214-685-0	H2...		-	25.6 (SDS)	Liquid	3 (ECHA)
1305-62-0	215-137-3	H315 (D) H318 (D) H335 (I)	-	1 (GESTIS, Germany)	-	Solid	High
1310-58-3	215-181-3	H302 (O) H314 (D) H315 (D) H319 (D)	H302 (O) H314 (D)	1 (GESTIS, Sweden)	-	solid (crystalline)	Medium (assumption)
1314-13-2	215-222-5	H4...		2 (GESTIS, EU countries)	-	Solid (white powder)	High
1330-20-7	215-535-7	H312 (D) H332 (I) H315 (D) H319 (D) H335 (I) H304 (O)	H332 (I) H312 (D) H315 (D)	220 (GESTIS, Germany)	-	liqiud	1.167 (ECHA)
1336-21-6	215-647-6	H314 (D) H318 (D) H332 (I) H335 (I)	H314(D)	14 (GESTIS, Finland)	-	Liquid	48 (PubChem) [F]
1477-55-0	216-032-5	H302 (O) H332 (I) H314 (D) H318 (D) H317 (D)		0.1 (GESTIS, Denmark)	-	Liquid	0.00069 (ECHA)
2215-35-2	218-679-9	H315 (D) H318 (D)		-	8.6 (SDS)	Liquid	0.000011 (ECHA)

2549-53-3	219-835-9	H335 (I) H315 (D) H319 (D)		-	-	Liquid	0.00002 (ECHA)
2634-33-5	220-120-9	H302 (O) H315 (D) H317 (D) H318 (D) H330 (I)	H302(O) H315(D) H317(D) H318(D) H330(I)	-	6.81 (SDS)	Solid (white powder)	High
2855-13-2	220-666-8	H302 (O) H314 (D) H318 (D) H317 (D)	H302 (O) H314 (D) H318 (D) H317 (D)	-	0.073 (ECHA)	Liquid	0.00157 (ECHA)
3068-39-1	221-326-1	H302 (O) H318 (D) H330 (D) H317 (D)		-	0.06 (ECHA)	Solid. brown/red powder	High
4083-64-1	223-810-8	H315 (D) H319 (D) H334 (I) H335 (I)		()	3.24 (SDS)	Liquid	0.000025 (ECHA)
7085-85-0	230-391-5	H315 (D) H319 (D) H335 (I)		10 (GESTIS, Sweden)	-	Liquid	0.021 (ECHA)
7320-34-5	230-785-7	H319 (D)	-	-	17.63 (SDS)	solid (granulate)	Low
7440-50-8	231-159-6	-	-	0.2 (GESTIS, Sweden)	-	Solid (powder)	High
7440-66-6	231-175-3	-	-	0.1 (GESTIS, Germany (DFG))	-	solid (dust)	High
7620-77-1	231-536-5	-	No H-phrases	5 (SDS)	-	Solid. salt	Low
7631-86-9	231-545-4	H373 (I)		1 (GESTIS, Germany)	-	solid: particulate/powder	High
7732-18-5	231-791-2	X		-	-	liquid	2.5 [G]
7779-90-0	231-944-3	H4..		-	-	Solid powder	High
7782-42-5	231-955-3	-	-	5 (GESTIS, Sweden)	-	Solid powder	High
7789-75-5	232-188-7	-		0.5 (GESTIS, Latvia)	-	solid (powder or cubic crystals)	High
13040-18-1	235-910-9	H315 (D) H319 (D)	-	-	-	solid (powder)	High
13463-67-7	236-675-5	-	-	0.3 (GESTIS, Germany)	-	solid. crystalline powder	High
14807-96-6	238-877-9	x	x	1 (SDS)	-	Solid. Powder	High
22464-99-9	242-197-8	H361 (O,D,I)		-	2.82 (SDS)	solid (lump. salt)	Low
25307-17-9	246-807-3	H302 (O) H314 (D) H318 (D)		-	2.96 (SDS)	Liquid	0 (ECHA)

26471-62-5	247-722-4	H330 (I) H315 (D) H319 (D) H334 (I) H317 (D) H351 (O,D,I) H335 (I)	H330 (I) H315 (D) H319 (D) H334 (I) H317 (D) H351 (O,D,I) H335 (I)	0.007 (GESTIS, Germany)	-	liquid	0.0015 (ECHA)
27813-02-1	248-666-3	H317 (D) H319 (D)		-	14.7 (ECHA)	Liquid	0.011 (ECHA)
34590-94-8	252-104-2	X		310 (GESTIS, Germany)	-	Liquid	0.0371 (ECHA)
38900-29-7	254-184-4	H302 (O)		-	13.5 (SDS)	solid. (grease?)	Low
51200-87-4	257-048-2	H302 (O) H311 (D) H315 (D) H318 (D) H331 (I)	H302 (O) H311 (D) H315 (D) H318 (D) H331 (I)	-	-	Liquid	0.9 (TGSC) [H]
61789-86-4	263-093-9	H317 (D)	H317	5 (GESTIS, Germany)	-	Solid (salt)	Medium
61791-53-5	263-186-4	H315 (D) H319 (D) H373 (O,D,I)	-	-	-	liqiud	<0.000001 (ECHA)
64742-47-8	265-149-8	H304 (O)		350 (GESTIS, Germany)	-	Liquid	3.7 (ECHA)
64742-52-5	265-155-0	Note L (H350 not necessary)	-	1 (SDS)	-	Liquid	0.01 (ECHA)
64742-54-7	265-157-1	H304 (O) Note L (H350 not necessary)	-	-	2.73 (SDS)	Liquid	0.01 (ECHA)
64742-55-8	265-158-7	H304 (O) Note L (H350 not necessary)	-	-	3.73 (SDS)	Liquid	0.01 (ECHA)
64742-56-9	265-159-2	Note L (H350 not necessary)	-	6 (SDS)	-	liquid	<0.01 (ECHA)
64742-57-0	265-160-8	Note L (H350 not necessary)	-	1 (SDS)	-	liqiud	<0.01 (ECHA)
64742-62-7	265-166-0	Note L (H350 not necessary)	-	5 (SDS)	-	liquid	<0.01 (ECHA)
64742-65-0	265-169-7	Note L (H350 not necessary)	-	5 (SDS)	-	liquid	<0.00 (ECHA)
64742-82-1 (not in SDS)	265-185-4	H336 (I) H372 (O,D,I) H304 (O) EUH066 (D)	H350 (O,D,I) H340 (O,D,I) H304 (O) H372 (O,D,I)	200 (GESTIS, Latvia)	-	liquid	2-150 (ECHA)
68187-67-7	269-119-5	H302 (O) H312 (D) H314 (D) H318 (D)	-	-	-	liquid	0.000069 (ECHA)
68411-46-1	270-128-1	H361 (O,D,I)		-	0.31 (ECHA)	Liquid (assumption)	0.000002 kPa (ECHA)

68424-85-1	270-325-2	H302 (O) H314 (D) H318 (D)	-	-	3.96 (SDS)	liqiud	0.000000000048 (PubChem)
68425-15-0	270-335-7	H317(D)		5 (GESTIS, Germany)	-	Liquid	0 (ECHA)
68512-30-1	270-966-8	H315 (D) H317 (D)		-	1.41 (SDS)	Liquid	0.09 (Chemical book) [I]
68515-49-1	271-091-4	-	-	3 (SDS)	-	liquid	0.000000051 (ECHA)
68584-23-6	271-529-4	H317 (D)		-	11.75 (SDS)	Solid (SALT)	Medium
68608-26-4	271-781-5	H319 (D)		-	0.66 (SDS)	solid	Low
68909-20-6	272-697-1	H373 (O,D,I) EUH066 (D)	H373	-	-	solid (powder)	High
70024-69-0	274-263-7	H317 (D)		-	11.75 (SDS)	Solid (SALT)	Low
85711-55-3	288-315-1	H317 (D) H318 (D) H373 (O,D,I)		-	-	-	-
90640-67-8	292-588-2	H302 (O) H312 (D) H314 (D) H318 (D) H317 (D)	-	-	0.54 (ECHA)	liquid	0.000346 (ECHA)
100545-48-0	309-629-8	H317 (D)		-	0.308 (SDS)	Solid (fine white powder)	High
77703-56-1	416-600-4	-	-	49.37 (SDS)	-	-	-
1282612-27-4	433-080-4	H302 (O) H332 (I)	-	-	-	solid (powder) ECHA	High
28182-81-2	500-060-2	H317 (D) H332 (I) H335 (I)		0.02 (SDS)	-	Liquid	0.0007 (ECHA)
26468-86-0	607-943-2	H319 (D)	H318 (D)	-	-	Liquid	0.0017 (ECHA)
78330-21-9	616-609-5	H318 (D) H319 (D)		-	-	Solid	Medium (assumption)
1213789-63-9	627-034-4	H302 (O) H314 (D) H318 (D) H335 (O,D,I) H373 (O,D,I) H304 (O)		-	0.38 (SDS)	Liquid	0.0000089 (ECHA)
-	905-588-0	H304 (O) H312 (D) H315 (D) H319 (D) H332 (I) H335 (I) H373 (O,D,I)		221 (SDS)	-	Liquid	1.167 (ECHA)
55965-84-9	911-418-6	EUH071 (I) H301 (O) H310 (D) H314 (D) H317 (D) H318 (D) H330 (I)		0.2 (GESTIS, Germany (DFG))	-	Liquid	0.0000003 (ECHA)

1065336-91-5	915-687-0	H317 (D) H361 (O,D,I)	-	-	1.27 (ECHA)	liqiud	0.0000001 (ECHA)
64742-94-5	915-687-0	H317 (D) H361 (O,D,I)	-	-	2.27 (ECHA)	liqiud	<0.0000001 (ECHA)
-	918-167-1	H304 (O) EUH066 (D)		-	-	liqiud	0.07 (SDS of substance) [J]
	918-481-9	H304 (O) EUH066 (D)	H304 (O)	150 (SDS)	-	Liquid	0.05 (ECHA)
128601-23-0	918-668-5	H335 (I) H336 (I) H304 (O) EUH066 (D)	-	-	150 (SDS)	liqiud	0.2 (ECHA)
64742-94-5	918-811-1	H336 (I) H304 (O)	-	100 (SDS)	-	liqiud	0.09 (ECHA)
64742-48-9	919-857-5	H304 (D) H336 (I) EUH066 (D)	H304 (O) H336 (I)	300 (GESTIS, Germany)	-	Liquid	0.3 (ECHA)
-	921-728-3	H304 (O) H315 (D) H336 (I)		-	2.035 (ECHA)	Liquid	2 (ECHA)
-	926-141-6	H304 (O) EUH066 (D)		350 (SDS)	-	Liquid	0.02 (SDS of substance) [K]
-	927-241-2	H304 (O) H336 (I) EUH066 (D)		150 (SDS)	-	liqiud (assumption)	0.01 (Assumption based on "low viscous")
-	927-285-2	H304 (O) EUH066 (D)		-	-	liqiud	0.067 (SDS of substance) [L]
64742-49-0	927-510-4	H304 (O) H315 (D) H336 (I)	-	500 (GESTIS, Poland)	-	liqiud	6 (ECHA)
308062-28-4	931-292-6	H302 (O) H315 (D) H318 (D)	H302 (O) H315 (D) H318 (D)	-	8.68 (ECHA)	Solid (white powder)	High
-	931-384-6	H302 (O) H319 (D) H317 (D)		-	-	liqiud	-
9022-96-2	638-841-6	H319 (D)	-	-	-	liqiud	<0.11 (ECHA)
-	920-901-0	H304 (O) EUH066 (D)		-	-	liqiud	0.04 (SDS of substance) [M]
68002-19-7	-	-	-	-	-	liqiud (assumption)	-
9003-63-8	-	-	-	-	-	powder. Crystalline powder. Chunks [N]	High
107-98-2		H336 (I)	H336 (I)	370 (GESTIS, Germany)	-	Liquid	0.00156 (ECHA)
34590-94-8		X		310 ((GESTIS, Germany))	-	Liquid	0.0371 (ECHA)
96-29-7		H301 (O) H336 (I) H370 (O,D,I) H373 (O,D,I) H315 (D) H317 (D) H318 (D)		1 (GESTIS, Germany)	-	Liquid	1.07 (ECHA)

		H312 (D) H350 (O,D,I)					
101-37-1		H302 (O)		-	2.12 (ECHA)	solid (crystal flakes)	Low
112-24-3	-	-	H312 H314 H317	-	-	liquid (assumption)	-
124-38-9		X		9100 (GESTIS, Germany)	-	liquid	5720 (PubChem) [O]
130-15-4		H301 (O) H314 (D) H317 (D) H318 (D) H330 (I) H335 (I)		0.1 (GESTIS, Latvia)	-	solid (particulate/powder)	High
164462-16-2	-	-		-	40 (SDS)	solid. salt	Low
2082-81-7		H317		-	14.5 (ECHA)	liquid	0.1 (ECHA)
25036-25-3		H315 (D) H317 (D) H319 (D)		-	-	Liquid	-
25068-38-6		H317 (D) H318 (D) H319 (D)		-	-	Liquid	-
51978-15-5		H317 H314 H318		-	-	Liquid	0.013 (Assumption based on vapour pressure of product in which this substance is a part)
613-48-9		H301 (O) H311 (D) H331 (I) H373 (O,D,I) H315 (D)		-	-	liquid	0.013 (Assumption based on vapour pressure of product in which this substance is a part)
160875-66-1	605-233-7	H302 (O) H318 (D)		-	-	Liquid	0.11 (Similar substance, [P])
68082-29-1				-	-	liquid (assumption)	-
SUB144223		H319 (D) H317 (D)		-	-	solid (assumption)	Low
[1]	-	-		-	-	liquid (assumption)	0.03 (Assumption based on vapour pressure of product in which this substance is a part)
[2]	-	-		-	-	liquid (assumption)	0.03 (Assumption based on vapour pressure of product in which this substance is a part)
[3]	-	-	-	-	-	liquid (assumption)	-
[4]	-	-	-	-	-	liquid (assumption)	-
[5]	-	H317(D)		-	-	liquid (assumption)	0.013 (assumption based on vapour pressure of product in which this substance is a part)

Notes for Appendix B.
[1] Reaction mass of (1- methylethylidene)bis(4,1- phenyleneoxy-2,1-ethanediyl) bismethacrylate and 2-{4-[2-(4- {2-2-(methacryloyloxy)etho

[2] Reaction products of 4,4'- isopropylidenediphenol, ethoxylated and methacrylic acid

[3] Hydrocarbons, C6-C7, isoalkanes, cyclics, <5% n-hexane

[4] Aliphatic polyamine adduct

[5] Reaction mass of N,N'-ethane-1,2-diylbis(12-hydroxyoctadecan-1-amide), Octadecanamide, 12-hydroxy-N-[2-[(1-oxooctadecyl)amino]ethyl]-

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Appendix C: Description of PROCs used.

PROC	Processes in the company categorized into the specific PROC	Name in ECETOC TRA	Description from European Chemicals Agency (2015)
PROC1	-	Use in closed process, no likelihood of exposure	Describes the general nature of processes taking place in sectors where the manufacture of substances or production of mixtures takes place or processes with closed process conditions as applied in chemical industry. The closed transfers inherent to the process including closed sampling are included. Open transfers to charge/discharge the system are not included.
PROC2	-	Use in closed, continuous process with occasional controlled exposure	Describes the general nature of processes taking place in sectors where the manufacture of substances or production of mixtures takes place (continuous processes that involve limited manual interventions), or processes with equivalent closed process conditions as applied in chemical industry. The closed transfers inherent to the process including closed sampling are included. Open transfers to charge/discharge the system are not included.
PROC3	-	Use in closed batch process (synthesis or formulation)	Describes the general nature of processes taking place in sectors where the manufacture of substances or production of mixtures takes place (batch processes that involve limited manual interventions) or processes with closed process conditions as applied in chemical industry. The closed transfers inherent to the process including closed sampling are included. Open transfers to charge/discharge are not included.
PROC4	Washing of components in washing machine. Mostly closed system but exposure could happen during switching of batches.	Chemical production where opportunity for exposure arises.	Describes the general nature of processes taking place in sectors where the manufacture of substances or production of mixtures takes place (processes where the nature of the design does not exclude exposure). The closed transfers inherent to the process including closed sampling are included. Open transfers to charge/discharge the system are not included.
PROC5	-	Mixing or blending in batch processes (multistage and/or significant contact)	Covers mixing or blending of solid or liquid materials in the context of manufacturing or formulating sectors, as well as upon end use. Charging/discharging of the blending vessel and sampling are considered separate activities and are not included in this PROC.
PROC6	-	Calendering operations	Processing of large surfaces at elevated temperature e.g. calendering of textile, rubber or paper
PROC7	Spraying of grease, paint, corrosion protection, seals, etc, that takes place in the production with high measures of protection.	Industrial spraying	Air dispersive techniques i.e. dispersion into air (= atomization) by e.g. pressurized air, hydraulic pressure or centrifugation, applicable for liquids and powders. Spraying for surface coating, adhesives, polishes/cleaners, air care products, blasting. The reference to 'industrial' means that workers involved have received specific task training, follow operating procedures and act under supervision. Where engineering controls are in place, they are also operated by trained personnel and regularly maintained according to procedures. It is not meant that the activity can only take place at industrial sites.
PROC8a	-	Transfer of chemicals from/to vessels/ large containers at non dedicated facilities	Covers general transferring operations of large quantities of chemicals from/to vessels, containers, installations or machinery without dedicated engineering controls in place for reducing exposure. Transfer includes loading, filling, dumping, bagging and weighing.
PROC8b	-	Transfer of chemicals from/to	Covers general transferring operations from/to vessels or containers with provision of dedicated engineering controls in place for reducing exposure: it addresses operations where

		vessels/ large containers at dedicated facilities	material transfers are undertaken at locations that are specifically designed and operated for the transfer of larger quantities (tens of kilos and higher) of chemicals and where the exposure is primarily related to the un-coupling/coupling activity rather than the transfer itself. Such situations include tanker loading bays and drum filling. Transfer includes loading, filling, dumping, bagging.
PROC9	-	Transfer of chemicals into small containers (dedicated filling line)	Filling lines specifically designed to both capture vapour and aerosol emissions and minimise spillage. This PROC can also be used to cover sampling operations.
PROC10	All manual applications with brushes and similar equipment. Includes paint, seals, adhesives, grease, cleaning	Roller application or brushing	This includes application of paints, coatings, removers, adhesives or cleaning agents to surfaces with potential exposure arising from splashes. This PROC can also be assigned to tasks such as cleaning of surfaces using long-handle tools.
PROC11	Spraying that is not part of the production.	Non-industrial spraying	Air dispersive techniques i.e. dispersion into air (= atomization) by e.g. pressurized air, hydraulic pressure or centrifugation, applicable for liquids and powders. Includes spraying of substances/mixtures for surface coating, adhesives, polishes/cleaners, air care products, blasting. The reference to 'non-industrial' is to differentiate were conditions mentioned in PROC7 cannot be met. It is not meant that the activity can only take place at non-industrial sites.
PROC12	-	Use of blow agents for foam production	Use of substances to facilitate the process of production of foams by forming gas bubbles in a liquid mixture. It can be either a continuous or a batch process.
PROC13	-	Treatment of articles by dipping and pouring	Treatment of articles by dipping, pouring, immersing, soaking, washing out or washing in substances; Includes handling of treated objects (e.g. from/to treatment basin, after drying, plating). The service life of the article after the treatment needs to be reported separately.
PROC14	-	Production of preparations or articles by tabletting, compression, extrusion, pelletisation	This covers processing of mixtures and/or substances into a defined shape for further use.
PROC15	-	Use of laboratory reagents in small scale laboratories	Use of substances at small scale in laboratories (less than or equal to 1 l or 1 kg present at workplace). Larger operations in laboratories and R+D installations should be treated as industrial processes. This includes the use in quality control processes.
PROC16	-	Using material as fuel sources, limited exposure to unburned product to be expected	Covers the use of (solid and liquid) fuel (including additives), including transfers via the closed system, where limited exposure to the product in its unburned form is expected. Assignment of PROC 8 or PROC 9 not needed in this case. The exposure to exhaust gases is not covered.
PROC17	-	Lubrication at high energy conditions and in partly open process	Covers metal working processes where the lubricants are exposed to high temperature and friction e.g. metal rolling/forming processes, drilling and grinding, etc. Transfers for refilling or discharging from/to reservoirs are not covered.
PROC18	Given by the company for one kind of grease (paste) and assumed to be applicable for similar greases.	General greasing / lubrication at high kinetic energy	Use of lubricant or greasing agents in high kinetic energy conditions, including manual application. It does not refer to any filling operation.

		conditions	
PROC19	-	Hand-mixing with intimate contact (only PPE available)	Addresses tasks, where exposure of hands and forearms can be expected; no dedicated tools or specific exposure controls other than PPE can be put in place. Examples are manual mixing of cement and plasters in construction works or mixing of hair dyes and bleaches.
PROC20	-	Heat and pressure transfer fluids (closed systems) in dispersive use	Includes the filling and emptying of systems containing functional fluids (including transfers via the closed system) e.g. heat and pressure transfer fluids; takes place on routine basis Example: charging and discharging of motor and engine oils, brake fluids, home appliances. Assignment of PROCs 8-9 not needed in this case.
PROC21	-	Low energy manipulation of substances in materials and/or articles	Cover activities such as manual cutting, cold rolling or assembly/disassembly of material/article. It can also be used for handling/transfer of massive (metal) objects.
PROC22	-	Potentially closed operations with minerals at elevated temperature	Describes the general nature of processes taking place at smelters, furnaces, refineries, ovens, excluding casting, tapping and drossing operations. When the temperature has decreased , the handling of the cool material can be covered by PROC21 or PROC26.
PROC23	-	Open processing and transfer of minerals at elevated temperature	Describes certain processes taking place at smelters, furnaces and ovens: casting, tapping and drossing operations. Covers also hot dip galvanising raking of melted solids in paving and water granulation. When the temperature has decreased, the handling of the cold material can be covered by PROC21 or PROC26.
PROC24	-	High (mechanical) energy work-up of substances bound in materials and/or articles	Substantial thermal or kinetic energy applied to substance by e.g. hot rolling/forming, grinding, mechanical cutting, drilling or sanding, stripping.
PROC25	-	Hot work operations with metals	Welding, soldering, gouging, brazing, flame cutting.

PROC26 to PROC28 are not available in the ECETOC TRA Worker's tool and therefore not listed in the appendix.

Appendix D: Assignment of Process category and risk management measures (Product level data)

		Risk management measure	
Chemical Product	**PROC**	**LEV**	**Gloves**
Adhesive 1	10	-	-
Adhesive 2	10	-	-
Adhesive 3	10	-	-
Adhesive 4	10	-	Yes
Adhesive 5	10	-	Yes
Cleaning 1	10	-	-
Cleaning 2	7	-	-
Cleaning 3	11	-	-
Cleaning 4	7	-	-
Cleaning 5	11	-	-
Cleaning 6	10	-	-
Cleaning 7	7	-	-
Corrosion protection 1	7	Yes	-
Corrosion protection 2	7	-	-
Corrosion protection 3	11	Yes	-
Detergent 1	4	-	-
Detergent 2	4	-	-
Detergent 3	4	-	-
Detergent 4	4	-	-
Detergent 5	4	-	-
Heat transfer paste 1	10	-	Yes
Leak finder 1	7	-	-
Lubricant 1	7	-	-
Lubricant 10	10	-	-
Lubricant 11	18	-	-
Lubricant 12	18	-	-
Lubricant 13	7	-	-
Lubricant 2	7	-	-
Lubricant 5	18	-	-
Lubricant 6	10	-	-
Lubricant 7	10	-	-
Lubricant 8	18	-	-
Lubricant 9	7	-	-
Marking 1	10	-	-
Marking 2	10	-	-
Marking 3	10	-	-
Marking 4	10	-	-
Marking 5	7	-	-
Marking 6	10	-	-
Marking 7	10	Yes	Yes
Marking 8	10	-	Yes
Marking 9	10	-	Yes

Paint 1	10	Yes	Yes
Paint 10	10	-	Yes
Paint 11	10	-	Yes
Paint 12	10	Yes	Yes
Paint 13	10	Yes	Yes
Paint 14	10	Yes	Yes
Paint 15	10	Yes	Yes
Paint 16	10	Yes	Yes
Paint 17	10	Yes	Yes
Paint 18	10	Yes	Yes
Paint 19	10	Yes	Yes
Paint 2	10	Yes	Yes
Paint 20	10	Yes	Yes
Paint 21	10	Yes	Yes
Paint 22	10	Yes	Yes
Paint 23	10	Yes	Yes
Paint 24	10	Yes	Yes
Paint 25	10	Yes	Yes
Paint 26	10	Yes	Yes
Paint 27	10	Yes	Yes
Paint 28	10	Yes	Yes
Paint 29	10	Yes	Yes
Paint 3	10	Yes	Yes
Paint 30	10	Yes	Yes
Paint 31	10	Yes	Yes
Paint 32	10	Yes	Yes
Paint 33	10	Yes	Yes
Paint 34	10	Yes	Yes
Paint 35	10	Yes	Yes
Paint 4	10	Yes	Yes
Paint 5	10	Yes	Yes
Paint 6	10	Yes	Yes
Paint 7	10	Yes	Yes
Paint 8	10	Yes	Yes
Paint 9	10	-	Yes
Paint remover 2	10	Yes	Yes
Sealing 1	10	-	Yes
Sealing 10	10	Yes	Yes
Sealing 2	10	-	-
Sealing 3	10	-	-
Sealing 4	10	-	-
Sealing 5	10	-	-
Sealing 6	10	-	-
Sealing 7	10	-	-
Sealing 8	10	-	-
Sealing 9	10	Yes	Yes
Talc 1	10	-	-

Appendix E: Input data for calculation of PHF

	Service			Assembly		
	Annual amount of work [persondays]	Consumption of chemical products [kg]	PHF [persondays/kg]	Annual amount of work [persondays]	Consumption of chemical products [kg]	PHF [persondays/kg]
2021	244	642	0.380	1290	407	3.17
2022	281	708	0.397	1160	366	3.17
2023	299	691	0.432	1477	438	3.38
2024	408	780	0.522	1662	662	2.51
2025	462	822	0.562	1568	533	2.94

Appendix F: Annual mass flow

		Annual consumption in kg OR Liter						Annual consumption in kg				
	Unit	**2021**	**2022**	**2023**	**2024**	**2025**	**Density**	**2021**	**2022**	**2023**	**2024**	**2025**
Adhesive 1	L	0.5	0.4	0.3	0.4	0.3	1.1	0.5	0.4	0.3	0.4	0.3
Adhesive 2	kg	0.3	0.3	0.2	0.4	0.2	1.0	0.4	0.3	0.2	0.4	0.2
Adhesive 3	kg	0.0					1.0	0.0	0.0	0.0	0.0	0.0
Adhesive 4	L		0.1				1.1	0.0	0.1	0.0	0.0	0.0
Adhesive 5	kg	0.0		0.2	0.0		1.0	0.0	0.0	0.2	0.0	0.0
Cleaning 1	L	42.5	36.0	48.0	64.0	77.5	1.0	45.9	36.4	48.5	64.6	78.3
Cleaning 2	L				5.0		1.0	0.0	0.0	0.0	5.1	0.0
Cleaning 3	L		1.0			3.0	0.8	0.0	0.8	0.0	0.0	2.4
Cleaning 4	L	0.4					0.7	0.4	0.0	0.0	0.0	0.0
Cleaning 5	L	73.5	78.0	79.5	93.0	111.0	0.8	79.4	60.1	61.2	71.6	85.5
Cleaning 6	L					20.0	0.8	0.0	0.0	0.0	0.0	15.2
Cleaning 7	L				0.8		0.7	0.0	0.0	0.0	0.6	0.0
Corrosion protection 1	L			9.6	86.4	43.2	0.7	0.0	0.0	6.2	56.2	28.1
Corrosion protection 2	L	28.0	69.0	36.4	4.8		0.9	30.2	63.5	33.5	4.4	0.0
Corrosion protection 3	L					12.0	0.8	0.0	0.0	0.0	0.0	10.1
Detergent 1	L	300.0	350.0	325.0	300.0	300.0	1.2	324.0	407.8	378.6	349.5	349.5
Detergent 2	L	75.0	50.0	50.0	75.0	75.0	1.0	81.0	51.0	51.0	76.5	76.5
Detergent 3	L	50.0	25.0	25.0	25.0	25.0	1.0	54.0	25.4	25.4	25.4	25.4
Detergent 4	L	25.0	25.0	25.0	25.0	25.0	1.0	27.0	25.0	25.0	25.0	25.0
Detergent 5	L	50.0	125.0	125.0	200.0	200.0	0.8	54.0	101.3	101.3	162.0	162.0
Heat transfer paste 1	kg				1.0	0.1	1.0	0.0	0.0	0.0	1.0	0.1
Leak finder 1	kg	43.2	35.0	64.8	57.6	38.4	1.0	46.7	35.0	64.8	57.6	38.4
Lubricant 1	L		21.0		0.5	0.3	0.8	0.0	17.4	0.0	0.4	0.2
Lubricant 10	kg	9.4		1.2	9.4	9.4	1.0	10.2	0.0	1.2	9.4	9.4
Lubricant 11	kg		0.7				1.0	0.0	0.7	0.0	0.0	0.0
Lubricant 12	kg	48.9	48.8	95.8	74.0	161.6	1.0	52.8	48.8	95.8	74.0	161.6
Lubricant 13	L	7.7	5.0	5.9	7.7	10.8	0.8	8.3	4.1	4.8	6.3	8.8
Lubricant 2	L	1.6	0.8		0.8	1.2	0.7	1.7	0.5	0.0	0.5	0.8
Lubricant 5	kg					0.4	1.0	0.0	0.0	0.0	0.0	0.4
Lubricant 6	kg	7.0	7.0	7.0	7.0	6.0	1.0	7.6	7.0	7.0	7.0	6.0
Lubricant 7	kg				2.0	1.0	1.0	0.0	0.0	0.0	2.0	1.0
Lubricant 8	kg					0.1	1.0	0.0	0.0	0.0	0.0	0.1
Lubricant 9	L			0.3	0.5	2.8	0.9	0.0	0.0	0.2	0.4	2.4
Marking 1	L	0.5	0.6				1.0	0.5	0.6	0.0	0.0	0.0
Marking 2	L	0.5					0.9	0.5	0.0	0.0	0.0	0.0
Marking 3	L			0.7	1.6	0.9	0.9	0.0	0.0	0.6	1.5	0.8
Marking 4	L	1.1	1.0		4.5		1.4	1.2	1.4	0.0	6.5	0.0

Marking 5	L	12.0	6.0	15.0	17.0	18.0	0.8	13.0	4.8	12.0	13.6	14.4
Marking 6	kg				0.4		1.0	0.0	0.0	0.0	0.4	0.0
Marking 7	L		1.5	0.2	1.5	1.5	0.9	0.0	1.3	0.1	1.3	1.3
Marking 8	L			0.0		0.9	1.0	0.0	0.0	0.0	0.0	0.9
Marking 9	L		0.7	0.9	1.3	0.1	1.0	0.0	0.7	0.9	1.3	0.1
Paint 1	L	0.0	0.0	0.0	7.0		1.6	0.0	0.0	0.0	11.1	0.0
Paint 10	L	43.6	28.1	34.9	13.0	43.0	1.2	47.1	33.7	41.9	15.6	51.6
Paint 11	L	1.0	0.7	0.8		1.0	1.2	1.1	0.8	1.0	0.0	1.2
Paint 12	L	0.0	0.0	0.0	40.0		0.9	0.0	0.0	0.0	34.4	0.0
Paint 13	L	0.0	0.0	0.0	20.0		0.9	0.0	0.0	0.0	17.8	0.0
Paint 14	L	0.0	0.0	0.0	20.0		0.9	0.0	0.0	0.0	17.2	0.0
Paint 15	L	0.0	0.0	0.0	18.0		1.1	0.0	0.0	0.0	19.6	0.0
Paint 16	L	3.7	2.4	2.9	8.0	3.6	1.0	3.9	2.2	2.8	7.6	3.4
Paint 17	L	5.3	3.4	4.3	2.4	5.3	1.1	5.8	3.6	4.5	2.5	5.6
Paint 18	L	12.2	7.8	9.7	15.0	12.0	1.4	13.2	10.6	13.2	20.3	16.2
Paint 19	L	0.0	0.0	0.0	6.0		0.9	0.0	0.0	0.0	5.2	0.0
Paint 2	L	7.1	4.6	5.7	28.0	7.0	1.6	7.7	7.2	9.0	44.2	11.1
Paint 20	L	0.0	0.0	0.0	22.1		1.4	0.0	0.0	0.0	31.8	0.0
Paint 21	L	4.9	3.1	3.9		4.8	1.5	5.3	4.6	5.7	0.0	7.0
Paint 22	L	4.9	3.1	3.9	32.0	4.8	1.5	5.3	4.6	5.7	46.7	7.0
Paint 23	L	4.9	3.1	3.9		4.8	1.4	5.3	4.4	5.5	0.0	6.7
Paint 24	L	4.5	2.9	3.6		4.4	1.4	4.8	4.0	5.0	0.0	6.2
Paint 25	L	13.8	8.9	11.0	8.5	13.6	1.5	14.9	12.9	16.0	12.3	19.7
Paint 26	L	8.6	5.6	6.9		8.5	1.5	9.3	8.1	10.0	0.0	12.3
Paint 27	L	7.6	4.9	6.1		7.5	1.5	8.2	7.1	8.8	0.0	10.9
Paint 28	L	5.2	3.3	4.1	5.1	5.1	1.4	5.6	4.7	5.8	7.2	7.2
Paint 29	L	0.0	0.0	0.0	0.9		1.1	0.0	0.0	0.0	1.0	0.0
Paint 3	L	21.3	13.7	17.0		21.0	1.6	23.0	21.7	26.9	0.0	33.2
Paint 30	L	1.7	1.1	1.4		1.7	1.1	1.9	1.3	1.6	0.0	1.9
Paint 31	L	0.0	0.0	0.0	0.9		1.1	0.0	0.0	0.0	1.0	0.0
Paint 32	L	0.0	0.0	0.0	1.7		1.1	0.0	0.0	0.0	1.9	0.0
Paint 33	L	0.8	0.5	0.6		0.8	1.1	0.8	0.6	0.7	0.0	0.9
Paint 34	L	0.0	0.0	0.0	14.0		1.4	0.0	0.0	0.0	20.2	0.0
Paint 35	L	1.0	0.7	0.8		1.0	1.1	1.1	0.7	0.9	0.0	1.1
Paint 4	L	7.1	4.6	5.7		7.0	1.6	7.7	7.2	9.0	0.0	11.1
Paint 5	L	0.0	0.0	0.0	7.0		1.6	0.0	0.0	0.0	11.1	0.0
Paint 6	L	3.0	2.0	2.4	3.0	3.0	1.2	3.3	2.4	3.0	3.7	3.7
Paint 7	L	0.0	0.0	0.0	18.0		1.6	0.0	0.0	0.0	28.8	0.0
Paint 8	L	0.0	0.0	0.0	9.0		1.2	0.0	0.0	0.0	10.8	0.0
Paint 9	L	10.2	6.5	8.1	18.0	10.0	1.2	11.0	7.8	9.7	21.6	12.0
Paint remover 2	L					2.5	1.0	0.0	0.0	0.0	0.0	2.4
Sealing 1	kg	1.0	2.0	0.1	3.0	2.0	1.0	1.1	2.0	0.1	3.0	2.0
Sealing 10	L	8.1	11.8	8.7	11.2	9.3	1.3	8.7	14.9	10.9	14.1	11.7
Sealing 2	L	0.9	0.9	1.0	0.6	0.4	1.1	0.9	0.9	1.0	0.6	0.4

Sealing 3	L	0.3	0.5	0.5	0.2	0.5	1.1	0.3	0.5	0.5	0.2	0.5
Sealing 4	L	0.6	0.5	0.2	0.5	0.3	1.2	0.6	0.5	0.2	0.5	0.3
Sealing 5	L	0.2	0.5	0.3	0.4	0.1	1.2	0.2	0.6	0.3	0.5	0.1
Sealing 6	L	0.1	0.5	0.1	0.6	0.4	1.1	0.1	0.5	0.1	0.6	0.4
Sealing 7	L			0.3			1.1	0.0	0.0	0.3	0.0	0.0
Sealing 8	L					0.1	1.1	0.0	0.0	0.0	0.0	0.1
Sealing 9	L	4.3	7.4	7.4	3.7	1.6	1.3	4.7	9.3	9.4	4.7	2.0
Talc 1	kg		0.5				1.0	0.0	0.5	0.0	0.0	0.0

Appendix G: Mass fraction of constituent substances

Numerical notes 1-5 refer to substance names, where no CAS or EG-number was found for identification.

Chemical product		**Constituent substances**								
		1	2	3	4	5	6	7	8	9
Adhesive 1	Cas:	130-15-4	613-48-9	7631-86-9	80-15-9					
	Mass fraction:	0.001	0.01	0.1	0.025					
Adhesive 2	Cas:	7085-85-0								
	Mass fraction:	1								
Adhesive 3	Cas:	7085-85-0	108-31-6							
	Mass fraction:	1	0.0001							
Adhesive 4	Cas:	[1]	[2]	58-27-5						
	Mass fraction:	0.5	0.025	0.0025						
Adhesive 5	Cas:	7085-85-0								
	Mass fraction:	1								
Cleaning 1	Cas:	112-34-5	164462-16-2							
	Mass fraction:	0.05	0.05							
Cleaning 2	Cas:	67-63-0	26468-86-0	101-84-8	160875-66-1					
	Mass fraction:	0.02	0.02	0.00005	0.03					
Cleaning 3	Cas:	67-63-0								
	Mass fraction:	1								
Cleaning 4	Cas:	64742-49-0	156-60-5							
	Mass fraction:	1	0.05							
Cleaning 5	Cas:	124-38-9	67-63-0	67-64-1	919-857-5 (EG)	927-241-2 (EG)				
	Mass fraction:	0.1	0.5	0.5	0.1	0.25				
Cleaning 6	Cas:	927-285-2 (EG)	920-901-0 (EG)	918-167-1 (EG)						
	Mass fraction:	0.5	0.5	0.25						
Cleaning 7	Cas:	[3]	124-38-9	109-87-5	64-17-5	67-63-0				
	Mass fraction:	1	0.1	0.2	0.2	0.05				
Corrosion protection 1	Cas:	919-857-5 (EG)	106-97-8	68608-26-4	74-98-6	75-28-5	78330-21-9			
	Mass fraction:	0.5-1	0-1	0.05	0-1	0-1	0.01			
	Cas:	61789-86-4	918-481-9 (EG)	919-857-5 (EG)	74-98-6	75-28-5	106-97-8			

Corrosion protection 2	Mass fraction:	0-0,1	0-0,1	0-0,5	0-1	0-1	0-1			
Corrosion protection 3	Cas:	61789-86-4	64742-48-9							
	Mass fraction:	0.05	0.55							
Detergent 1	Cas:	68154-99-4	13040-18-1	1310-58-3	7320-34-5					
	Mass fraction:	0.03	0.05	0.1	0.05					
Detergent 2	Cas:	34590-94-8	13040-18-1	141-43-5	29385-43-1	68154-99-4				
	Mass fraction:	0.05	0.05	0.2	0.005	0.05				
Detergent 3	Cas:	141-43-5								
	Mass fraction:	0.3								
Detergent 4	Cas:	68424-85-1								
	Mass fraction:	0.3								
Detergent 5	Cas:	926-141-6 (EG)								
	Mass fraction:	0.6								
Heat transfer paste 1	Cas:	1185-55-3	540-97-6	541-02-6	556-67-2	68909-20-6				
	Mass fraction:	0.035	0.009	0.0018	0.0021	0.17				
Leak finder 1	Cas:	2634-33-5	308062-28-4	51200-87-4	7732-18-5	96-20-8	110-25-8	124-68-5		
	Mass fraction:	0.0000249	0.00249	0.000099	0.96	0.000099	0.0249	0.0099		
Lubricant 1	Cas:	926-141-6 (EG)	68608-26-4	124-38-9	34590-94-8					
	Mass fraction:	0.75	0.05	0.05	0.05					
Lubricant 2	Cas:	106-97-8	123-86-4	64742-48-9	74-98-6	7782-42-5	9022-96-2			
	Mass fraction:	0.6	0.2	0.2	0.2	0.1	0.1			
Lubricant 5	Cas:	1282612-27-4	13463-67-7	64742-57-0	80-56-8					
	Mass fraction:	0.3	0.1	0.7	0.0025					
Lubricant 6	Cas:	61791-53-5	64742-56-9	64742-65-0	7440-50-8	7440-66-6	7782-42-5	7789-75-5		
	Mass fraction:	0.01	0.3	0.3	0.1	0.1	0.2	0.3		
Lubricant 7	Cas:	1314-13-2	64742-62-7	68187-67-7						
	Mass fraction:	0.025	0.5	0.025						
Lubricant 8	Cas:	1305-62-0	8042-47-5	8002-74-2						
	Mass fraction:	0.4	0.3	0.1						
Lubricant 9	Cas:	124-38-9	25307-17-9	64742-54-7	64742-55-8	68425-15-0	68584-23-6	70024-69-0		
	Mass fraction:	0.01	0.001	0.1	0.05	0.05	0.01	0.01		

Lubricant 10	Cas:	38900-29-7	64742-52-5	7620-77-1						
	Mass fraction:	0.1	0.3	0.1						
Lubricant 11	Cas:	38900-29-7	64742-52-5	7620-77-1						
	Mass fraction:	0.1	0.3	0.1						
Lubricant 12	Cas:	128-37-0	68411-46-1	95-38-5						
	Mass fraction:	0.01	0.01	0.025						
Lubricant 13	Cas:	124-38-9	919-857-5 (EG)							
	Mass fraction:	0.03	0.8							
Marking 1	Cas:	73398-89-7	3068-39-1	123-42-2	64742-47-8	96-29-7	22464-99-9			
	Mass fraction:	0.01	0.01	0.05	0.4	0.05	0.002			
Marking 2	Cas:	123-42-2	64742-47-8	96-29-7	22464-99-9					
	Mass fraction:	0.05	0.4	0.05	0.002					
Marking 3	Cas:	108-65-6	123-86-4	905-588-0 (EG)	918-668-5 (EG)					
	Mass fraction:	0.025	0.05	0.1	0.5					
Marking 4	Cas:	123-86-4	1330-20-7	97-88-1	80-62-6					
	Mass fraction:	1	0.01	0.01	0.01					
Marking 5	Cas:	108-65-6	115-10-6	141-78-6	64-17-5	67-64-1				
	Mass fraction:	0.03	0.6	0.01	0.25	0.01				
Marking 6	Cas:	64-17-5	97-64-3	71-23-8	100-51-6					
	Mass fraction:	0.65	0.3	0.15	0.05					
Marking 7	Cas:	108-88-3	9003-63-8	97-88-1	921-728-3 (EG)					
	Mass fraction:	0.25	0.5	0.01	0.4					
Marking 8	Cas:	123-86-4	1330-20-7	67-63-0						
	Mass fraction:	0.5	0.1	0.05						
Marking 9	Cas:	123-86-4	1330-20-7	67-63-0						
	Mass fraction:	0.5	0.1	0.05						
Paint 1	Cas:	100-41-4	108-31-6	123-26-2	1330-20-7	7779-90-0				
	Mass fraction:	0.05	0.001	0.003	0.2	0.1				
Paint 2	Cas:	100-41-4	108-31-6	123-26-2	1330-20-7	7779-90-0				
	Mass fraction:	0.05	0.001	0.003	0.2	0.1				
Paint 3	Cas:	100-41-4	108-31-6	123-26-2	1330-20-7	7779-90-0				

	Mass fraction:	0.05	0.001	0.003	0.2	0.1				
Paint 4	Cas:	100-41-4	108-31-6	123-26-2	1330-20-7	7779-90-0				
	Mass fraction:	0.05	0.001	0.003	0.2	0.1				
Paint 5	Cas:	100-41-4	108-31-6	123-26-2	1330-20-7	7779-90-0				
	Mass fraction:	0.05	0.001	0.003	0.2	0.1				
Paint 6	Cas:	100-41-4	123-86-4	1330-20-7						
	Mass fraction:	0.037	0.5	0.1						
Paint 7	Cas:	[4]	107-98-2	7779-90-0	2855-13-2	1477-55-0	111-76-2	77-99-6		
	Mass fraction:	0.087	0.05	0.016	0.029	0.01	0.01	0.003		
Paint 8	Cas:	7779-90-0	1314-13-2	1336-21-6	126-86-3	2634-33-5	111-76-2			
	Mass fraction:	0.01	0.003	0.01	0.003	0.00036	0.05			
Paint 9	Cas:	111-76-2	126-86-3	1314-13-2	1336-21-6	2634-33-5	7779-90-0			
	Mass fraction:	0.05	0.003	0.003	0.01	0.00036	0.01			
Paint 10	Cas:	7779-90-0	1314-13-2	1336-21-6	126-86-3	2634-33-5	111-76-2			
	Mass fraction:	0.01	0.003	0.01	0.003	0.00036	0.05			
Paint 11	Cas:	1314-13-2	1336-21-6	126-86-3	2634-33-5	111-76-2	7779-90-0			
	Mass fraction:	0.003	0.01	0.003	0.00036	0.05	0.01			
Paint 12	Cas:	108-88-3	1330-20-7	100-41-4	107-98-2	71-36-3				
	Mass fraction:	0.003	0.75	0.1	0.25	0.25				
Paint 13	Cas:	128601-23-0	123-86-4	108-65-6						
	Mass fraction:	0.5	0.5	0.5						
Paint 14	Cas:	108-88-3	1330-20-7	100-41-4	107-98-2	71-36-3				
	Mass fraction:	0.003	0.75	0.1	0.25	0.25				
Paint 15	Cas:	80-05-7-	55965-84-9	67-63-0						
	Mass fraction:	0.001	0.000015	0.05						
Paint 16	Cas:	100-41-4	107-98-2	108-88-3	1330-20-7	71-36-3	90640-67-8	90-72-2		
	Mass fraction:	0.05	0.084	0.003	0.25	0.1	0.01	0.05		
Paint 17	Cas:	100-41-4	108-65-6	123-86-4	1330-20-7	28182-81-2	4083-64-1	822-06-0		
	Mass fraction:	0.037	0.25	0.1	0.21	0.75	0.01	0.001		
Paint 18	Cas:	100-41-4	123-86-4	1330-20-7						
	Mass fraction:	0.037	0.5	0.1						
Paint 19	Cas:	1330-20-7	67-63-0	100-41-4	68082-29-1	107-98-2	112-24-3	108-88-3		
	Mass fraction:	0.49	0.5	0.087	0.1	0.05	0.01	0.003		

Paint 20	Cas:	78-93-3	67-63-0	7779-90-0	108-10-1	85711-55-3		25068-38-6		
	Mass fraction:	0.13	0.069	0.05	0.028	0.001	0.17	0.25		
Paint 21	Cas:	100-41-4	100545-48-0	107-98-2	128601-23-0	1330-20-7	25036-25-3	68002-19-7	7779-90-0	
	Mass fraction:	0.05	0.003	0.063	0.13	0.1	0.25	0.05	0.011	
Paint 22	Cas:	100-41-4	100545-48-0	107-98-2	128601-23-0	1330-20-7	25036-25-3	68002-19-7	7779-90-0	
	Mass fraction:	0.05	0.003	0.063	0.13	0.1	0.25	0.05	0.011	
Paint 23	Cas:	100-41-4	100545-48-0	107-98-2	108-88-3	1330-20-7	25036-25-3	68512-30-1		
	Mass fraction:	0.05	0.01	0.05	0.003	0.2	0.25	0.25		
Paint 24	Cas:	100-41-4	100545-48-0	107-98-2	108-88-3	1330-20-7	25036-25-3	68512-30-1		
	Mass fraction:	0.05	0.01	0.05	0.003	0.2	0.25	0.25		
Paint 25	Cas:	100-41-4	1065336-91-5	123-42-2	123-86-4	1314-13-2	1330-20-7	64742-94-5	7779-90-0	SUB144223
	Mass fraction:	0.05	0.01	0.029	0.1	0.003	0.17	0.095	0.1	0.25
Paint 26	Cas:	100-41-4	1065336-91-5	123-42-2	123-86-4	1314-13-2	1330-20-7	64742-94-5	7779-90-0	SUB144223
	Mass fraction:	0.05	0.01	0.029	0.1	0.003	0.17	0.095	0.1	0.25
Paint 27	Cas:	100-41-4	1065336-91-5	123-42-2	123-86-4	1314-13-2	1330-20-7	64742-94-5	7779-90-0	SUB144223
	Mass fraction:	0.05	0.01	0.029	0.1	0.003	0.17	0.095	0.1	0.25
Paint 28	Cas:	100-41-4	1065336-91-5	128601-23-0	1330-20-7	SUB144223				
	Mass fraction:	0.05	0.0057	0.19	0.25	0.5				
Paint 29	Cas:	64742-94-5	64742-94-5	64742-94-5	108-88-3	128601-23-0	1330-20-7	SUB144223		
	Mass fraction:	0.05	0.05	0.0063	0.003	0.1	0.25	0.5		
Paint 30	Cas:	64742-94-5	64742-94-5	64742-94-5	108-88-3	128601-23-0	1330-20-7	SUB144223		
	Mass fraction:	0.05	0.05	0.0063	0.003	0.1	0.25	0.5		
Paint 31	Cas:	64742-94-5	64742-94-5	64742-94-5	108-88-3	128601-23-0	1330-20-7	SUB144223		
	Mass fraction:	0.05	0.05	0.0063	0.003	0.1	0.25	0.5		
Paint 32	Cas:	64742-94-5	64742-94-5	64742-94-5	108-88-3	128601-23-0	1330-20-7	SUB144223		
	Mass fraction:	0.05	0.05	0.0063	0.003	0.1	0.25	0.5		
Paint 33	Cas:	64742-94-5	64742-94-5	64742-94-5	108-88-3	128601-23-0	1330-20-7	SUB144223		
	Mass fraction:	0.05	0.05	0.0063	0.003	0.1	0.25	0.5		
Paint 34	Cas:	78-93-3	67-63-0	7779-90-0	108-10-1	85711-55-3	905-588-0 (EG)	25068-38-6		

	Mass fraction:	0.13	0.069	0.05	0.028	0.001	0.17	0.25		
Paint 35	Cas:	100-41-4	108-88-3	123-26-2	128601-23-0	1330-20-7	7779-90-0			
	Mass fraction:	0.087	0.003	0.003	0.05	0.49	0.05			
Paint remover 2	Cas:	646-06-0	67-56-1	200-659-6 (EG)	108-01-0					
	Mass fraction:	0.75	0.03	0.05	0.01					
Sealing 1	Cas:	556-67-2	1314-13-2							
	Mass fraction:	0.0002	0.79							
Sealing 10	Cas:	101-68-8	13463-67-7	26471-62-5	68515-49-1	77703-56-1	905-588-0 (EG)	64742-82-1 (not in SDS)		
	Mass fraction:	0.01	0.05	0.00025	0.25	0.05	0.025	0.025		
Sealing 2	Cas:	101-37-1	108-31-6	109-16-0	2082-81-7	51978-15-5	79-41-4			
	Mass fraction:	0.1	0.0001	0.05	0.4	0.01	0.01			
Sealing 3	Cas:	130-15-4	609-72-3	613-48-9	79-41-4	80-15-9				
	Mass fraction:	0.001	0.01	0.01	0.01	0.03				
Sealing 4	Cas:	[5]	110-16-7	112-30-1	114-83-0	130-15-4	3068-39-1	80-15-9		
	Mass fraction:	0.01	0.01	0.1	0.01	0.001	0.001	0.01		
Sealing 5	Cas:	110-16-7	114-83-0	123-26-2	130-15-4	142-90-5	2549-53-3	80-15-9		
	Mass fraction:	0.1	0.1	0.1	0.001	0.1	0.3	0.1		
Sealing 6	Cas:	109-16-0	114-83-0	27813-02-1	79-41-4	80-15-9	868-77-9	1979-10-07		
	Mass fraction:	0.05	0.01	0.5	0.03	0.025	0.01	0.1		
Sealing 7	Cas:	80-15-9	613-48-9	609-72-3	79-41-4	130-15-4				
	Mass fraction:	0.03	0.01	0.01	0.01	0.001				
Sealing 8	Cas:	108-31-6								
	Mass fraction:	0.00001								
Sealing 9	Cas:	77703-56-1	905-588-0 (EG)	64742-82-1 (not in SDS)	101-68-8	26471-62-5	68515-49-1	13463-67-7		
	Mass fraction:	0.05	0.025	0.025	0.01	0.00025	0.25	0.05		
Talc 1	Cas:	14807-96-6								
	Mass fraction:	1								

Notes for Appendix G.
[1] Reaction mass of (1- methylethylidene)bis(4,1- phenyleneoxy-2,1-ethanediyl) bismethacrylate and 2-{4-[2-(4- {2-2-(methacryloyloxy)etho
[2] Reaction products of 4,4'- isopropylidenediphenol, ethoxylated and methacrylic acid
[3] Hydrocarbons, C6-C7, isoalkanes, cyclics, <5% n-hexane

[4] Aliphatic polyamine adduct
[5] Reaction mass of N,N'-ethane-1,2-diylbis(12-hydroxyoctadecan-1-amide), Octadecanamide, 12-hydroxy-N-[2-[(1-oxooctadecyl)amino]ethyl]-

Appendix H: Interview guide

Note: The following interview guide is in Swedish, the original language in which the guide was written and used. Key findings used in the report has been translated into English by the authors.

Intervjuguide for intervju med Dellner 30-03-2026

Syfte: Utvärdera huruvida resultaten från ProScale analysen av Dellners kemikalie-portfölj upplevs användbara och processen genomförbar i praktiken. Från analysen togs ett avgränsat antal kemikalier fram som anses "viktigare" för organisationens kemiska fotavtryck och analyseras djupare. Frågan är om detta kan ge ett hanterbart och kompletterande underlag för vidare utvärdering, substitution och riskreducerande åtgärder. Samtidigt avser intervjun att ge förståelse för genomförbarheten i en sådan analys då användbarheten av metoder och verktyg ofta hänger att analysprocesses bygger på låg arbetsinsats, tillgång till lättillgängliga data m.m (utan att analysen för den delen blir för enkel så att den inte längre speglar verkligheten eller genererar trovärdiga slutsatser).

Det intervjun syftar till att svara på är inte bara *om* ProScale är användbart men *när, för vem, till vad* och *under vilka villkor* verktyget hade kunnat appliceras i Dellners verksamhet.

Studiens forskningsfrågor ses som vägledande genom intervjun och återges nedan:

- RQ1: How can ProScale be used to develop an organisational chemical footprint?

→ Hur ska ett organisatoriskt fotavtryck vara uppbyggt, med systemgräns, databehov, aggregation mm?

- RQ2: How can an organisational chemical footprint be used to identify relevant chemicals for chemical management, substitution and decision making?

→ Hur kan resultaten från ProScale användas i prioriteringsfrågor, substitutionsarbete, riskreduktion mm?

- RQ3: To what extent does the ProScale method balance simplicity and analytical depth to be useful and feasible for companies such as Dellner?

→ Hur ställs ProScale mot dagens arbetssätt i termer om enkelhet, trovärdighet, transparens, datainsats mm?

Upplägg: Intervjun är semistrukturerad och förväntas ta ca 60 min. Intervjun kommer att hållas av två intervjuare där en håller i samtalet och en tar anteckningar och följer upp.

Intervjun kommer att hålla följande struktur:

1. Inledning av intervjun
2. Frågor om nuvarande hantering och struktur för beslutsfattande om användningen av kemiska produkter.
3. Genomgång av studien och beskrivning av ProScale-resultaten.
4. Diskussionen om användbarhet av ProScale i praktiken.
5. Hinder och förutsättningar för att ProScale skulle fortsätta användas inom deras verksamhet.
6. Diskussionen om vad en expansion av användningen av ProScale skulle kunna innebära (fler moduler och/eller större delar av livscykeln).

Frågor:

1. **Inledande frågor**:

- Kan du kort beskriva din roll och hur du arbetar med kemikaliefrågor idag?
- På vilket sätt kommer du i kontakt med beslut om kemikalier, riskbedömning eller substitution?

2. Nuläge: *Få en bild av dagens processer och hur Dellner arbetar med Chemical Management idag.*

Frågor:

- Hur arbetar ni idag med att identifiera kemikalier som kräver extra uppmärksamhet?
- Hur går det till när ni bedömer om en kemisk produkt bör bytas ut?
- Vilka typer av information använder ni idag i sådana beslut?
- Vad fungerar bra i ert nuvarande arbetssätt?
- Anser ni att det finns brister i dagens sätt att hantera kemikalier och potentiella substitutioner och prioriteringar? Vad är svårt eller tidskrävande?
- Finns det situationer där ni saknar ett bra sätt att prioritera mellan flera kemikalier?

3. Resultat från ProScale: *Testa resultatens relevans, trovärdighet och utförbarhet.* Detta segment av intervjun börjar med att intervjuaren går igenom resultaten som sammanställts i en presentation i vilket följande presenteras:

- organisatoriska totalresultat
- produktkategorier som bidrar mest
- shortlist med hotspot-produkter
- nedbrytning av drivande substanser

Frågor:

- Vad är de spontana reaktionerna och tankarna då resultatet har presenterats?
- Hur skiljer sig dessa resultat mot de produkter och produktkategorier som redan är i fokus utifrån ert nuvarande sätt att arbeta?
- Ger resultaten en tydligare bild av var de största problemen är eller vilka kemikalier som bör prioriteras i substitutions eller riskminimeringsarbetet?
- Är det hjälpsamt att resultaten bryts ner från total nivå till kategori, produkt och ibland ämnesnivå?
- Är det värdefullt att kunna se om ett högt resultat drivs av hazard, exponering eller använd mängd?

4. Användning i praktiken: *Koppla till RQ2 huruvida resultaten från ProScale-W är användbart för chemical management, substitution och beslutsfattande.*

Frågor:

- Skulle ett organisatoriskt kemiskt fotavtryck tillföra något som ni inte redan får från dagens riskbedömningar och substitutionsarbete? Skulle detta kunna ersätta dagens sätt, komplettera det eller säger det bara samma sak (dvs dubblerar arbetat)?
- På vilket sätt skulle ett sådant här resultat kunna användas i ert praktiska kemikaliearbete?
- Skulle det hjälpa er att prioritera vilka produkter ni ska titta närmare på först?
- Skulle det kunna användas som stöd i substitutionsarbete?
- I vilka beslutssituationer hade resultaten från ProScale analysen varit mest användbara?

5. Enkelhet, detaljnivå och trovärdighet: *Kopplar till RQ3, verkar ProScale-W vara ett tillräckligt lätt men ändå relevant nog?*

- Upplever ni att den här typen av metod verkar tillräckligt enkel för att kunna användas i företag?
- Upplever ni att resultaten ändå är tillräckligt informativa för att vara meningsfulla?
- Behöver ni ämnesnivå, eller räcker produktnivå i de flesta fall?
- Är två separata exponeringsvägar, inhalation och dermal, användbart eller för komplext?

- Vad skulle behöva vara på plats för att ni skulle vilja använda ett sådant här verktyg vidare?
- Vad är det viktigaste kravet för att det ska bli praktiskt användbart?
- Finns det förbättringar som hade behövt genomföras för att ni skulle använda ProScale-W i ert arbetssätt?

6. Användbarhet av hela ProScale-suiten. *Fokus på hur ProScales andra moduler samt mer heltäckande systemgränser hade påverkat resultaten och användbarheten av dessa för Dellner.*

- I vår studie har vi ju bara kollat på processerna på Dellner, Vika. Hur hade er upplevelse av verktyget och resultaten förändrats om även uppströms- och nedströmsprocesser hade analyserats? Hur tungt väger negativa effekter internt jämfört med i andra delar av värdekedjan?
- Hade era redan implementerade miljöledningssystem (ISO, SBTi.) varit till hjälp i ett sådant kartläggningsarbete?
- Hur hade era upplevelser av resultaten förändrats om de även involverade miljöeffekter och inte bara toxicitetspotentialen mot arbetarna?
    - Hade svaret på frågan om var i värdekedjan som påverkan spelar störst roll förändrats?

Avslutande frågor:

- Finns det något vi inte har frågat om som ni tycker är viktigt för att bedöma nyttan av ProScale hos Dellner?

Appendix I: Contribution of constituent substances to the PSS of the worst five chemicals.

Chemical product	CAS number	Name	Contribution to $PSSi_{prod}$	Contribution to $PSSd_{prod}$
Corrosion protection 2	61789-86-4	Sulfonic acids, petroleum, calcium salts	3%	98%
	-	Hydrocarbons, C10-C13, n-alkanes, isoalkanes, cyclics, < 2% aromatics	5%	0%
	-	Hydrocarbons, C9-C11, n-alkanes, isoalkanes, cyclics, <2% aromatics	26%	2%
	74-98-6	Propane	0%	0%
	75-28-5	Isobutane	0%	0%
	106-97-8	Butane	66%	0%
Detergent 1	68154-99-4	Alcohols, C8-10, ethers with polyethylene-polypropylene glycol monobenzyl ether	0%	35%
	13040-18-1	Potassium decanoate	0%	6%
	1310-58-3	Potassium hydroxide	96%	58%
	7320-34-5	Tetrapotassium pyrophosphate	4%	1%
Lubricant 12	128-37-0	2,6-di-tert-butyl-p-cresol	0%	0%
	68411-46-1	Benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene	82%	82%
	95-38-5	2-(2-heptadec-8-enyl-2-imidazolin-1-yl)ethanol	18%	18%
Sealing 9	101-68-8	4,4'-methylenediphenyl diisocyanate	2%	52%
	13463-67-7	Titanium dioxide	0%	0%
	26471-62-5	m-tolylidene diisocyanate	0%	1%
	68515-49-1	1,2-Benzenedicarboxylic acid, di-C9-11-branched alkyl esters, C10-rich	0%	0%
	77703-56-1	4,4’-methylenebis(1-butyl-3-phenylurea)	0%	0%
	-	reaction mass of ethylbenzene and xylene	1%	1%
	64742-82-1	Naphtha (petroleum), hydrodesulfurized heavy	97%	46%
Sealing 10	101-68-8	4,4'-methylenediphenyl diisocyanate	2%	52%
	13463-67-7	Titanium dioxide	0%	0%
	26471-62-5	m-tolylidene diisocyanate	0%	1%
	68515-49-1	1,2-Benzenedicarboxylic acid, di-C9-11-branched alkyl esters, C10-rich	0%	0%
	77703-56-1	4,4’-methylenebis(1-butyl-3-phenylurea)	0%	0%
	-	reaction mass of ethylbenzene and xylene	1%	1%
	64742-82-1	Naphtha (petroleum), hydrodesulfurized heavy	97%	46%

Appendix J: Results from sensitivity analysis

	Total PSS_{org}					Contribution to PSS_{org}				
Inhalation	2021	2022	2023	2024	2025	2021	2022	2023	2024	2025
Adhesive	2,33E+04	1,92E+04	2,11E+04	1,93E+04	1,40E+04	0%	0%	0%	0%	0%
Cleaning	1,86E+05	2,06E+05	2,27E+05	3,22E+05	4,24E+05	1%	1%	1%	2%	2%
Corrosion protection	3,93E+05	9,69E+05	5,83E+05	3,10E+05	1,54E+05	3%	6%	3%	2%	1%
Detergent	9,85E+04	6,52E+04	7,05E+04	1,08E+05	1,17E+05	1%	0%	0%	1%	1%
Heat transfer paste	0,00E+00	0,00E+00	0,00E+00	5,72E+04	6,04E+03	0%	0%	0%	0%	0%
Leak finder	5,57E+05	4,51E+05	8,89E+05	5,87E+05	4,59E+05	4%	3%	5%	4%	2%
Lubricant	4,52E+06	4,50E+06	9,20E+06	5,34E+06	1,35E+07	29%	27%	48%	36%	65%
Marking	3,51E+06	2,38E+06	4,00E+05	5,41E+05	5,85E+05	22%	14%	2%	4%	3%
Paint	2,08E+06	1,34E+06	1,77E+06	3,33E+06	1,90E+06	13%	8%	9%	23%	9%
Sealing	4,28E+06	6,76E+06	5,96E+06	4,14E+06	3,48E+06	27%	40%	31%	28%	17%
Talc	0,00E+00	5,15E+03	0,00E+00	0,00E+00	0,00E+00	0%	0%	0%	0%	0%
Dermal	2021	2022	2023	2024	2025	2021	2022	2023	2024	2025
Adhesive	1,25E+05	1,08E+05	8,99E+04	1,04E+05	7,83E+04	0,1%	0,1%	0,1%	0,1%	0,1%
Cleaning	1,35E+06	1,51E+06	1,65E+06	3,36E+06	3,29E+06	2%	1%	1%	4%	3%
Corrosion protection	1,98E+07	4,88E+07	2,94E+07	1,63E+07	1,16E+07	23%	42%	25%	18%	9%
Detergent	1,03E+07	9,90E+06	1,02E+07	1,29E+07	1,39E+07	12%	9%	9%	14%	11%
Heat transfer paste	0,00E+00	0,00E+00	0,00E+00	8,33E+04	8,80E+03	0,0%	0,0%	0,0%	0,1%	0,0%
Leak finder	1,08E+06	8,76E+05	1,73E+06	1,14E+06	8,92E+05	1,3%	0,8%	1,4%	1,3%	0,7%
Lubricant	2,68E+07	3,10E+07	5,51E+07	3,21E+07	8,09E+07	31%	27%	46%	36%	62%
Marking	5,53E+06	3,60E+06	8,89E+05	1,10E+06	1,11E+06	6%	3%	0,7%	1%	0,9%
Paint	1,64E+07	1,06E+07	1,40E+07	1,71E+07	1,50E+07	19%	9%	12%	19%	12%
Sealing	4,80E+06	8,80E+06	6,53E+06	5,63E+06	3,15E+06	6%	8%	5%	6%	2%

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