International Association for Soaps, Detergents and Maintenance Products

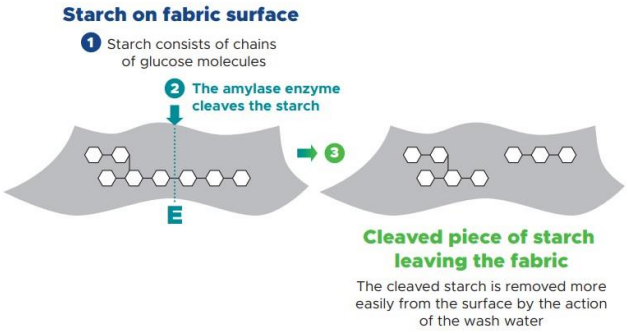
ROLE AND IMPORTANCE OF ENZYMES IN CLEANING AND HYGIENE PRODUCTS

Objective of this paper is to summarize the role and importance of enzymes in Cleaning and Hygiene products following the principle of Essential Use. Enzymes are classified as respiratory sensitizers, however the paper illustrates why generic risk management is not appropriate for this category.

1. Origin and Functioning of Enzymes

Enzymes, which are protein-based catalysts speeding up biological processes, exist abundantly in nature from microorganisms to our own bodies. Enzymes used in detergent products are produced by microorganisms in fermentation processes. The fermentation process uses carbohydrates, protein, mineral salts and vitamins including sugar and other agricultural products as feedstock for organisms[1].

Enzymes are used in detergent products to enhance cleaning performance while decreasing environmental impact. They help the breakdown of larger molecules into smaller fragments, that then can be removed easily by other ingredients in the formulation. In general, each enzyme is good at targeting a certain type of stain removal from surfaces. Enzymes are proteins, thereby they are readily biodegradable. In the detergent industry, commercial enzymes are used to provide a higher degree of stain removal, whiteness, fabric and colour care and overall cleaning performance. These ingredients are selected based on performance and the use that is required[2].



[1] https://www.novozymes.com/-/media/Project/Novozymes/Website/website/document-library/LCAs/CradletogateenvironmentalassessmentofenzymeproductsproducedindustriallyinDenmarkbyNovozymesAS.pdf?la=en

[2] AISE-AMFEP-HCPA-ACI Enzyme Factsheet https://aise.eu/cust/documentrequest.aspx?UID=ecaa311b-701c-4a50-83ea-f66963f04d87

2. Contribution of Enzymes to Cleaning and Hygiene Products

Enzymes contribute to thorough and sustainable cleaning processes in the home and in industrial processes. They enable cleaning at lowered temperatures, milder pH conditions and less water.

Enzyme proteins are needed in very low active ingredient concentrations (<1%, typically <0.1) in cleaning products to improve cleaning performance and be effective. No other chemicals or alternatives can deliver the same benefits at similar low concentrations. This case has been shown across several studies such as for alpha-amylase which is one of the most commonly used enzymes for laundry and cleaning products[3].

3. Safety of Enzymes

Safety is of utmost importance for the enzyme, cleaning, and hygiene industry. Industrial enzymes have an excellent safety profile with little ability to cause adverse responses in humans. Enzymes pose no risk of acute toxicity, repeat dose toxicity, genotoxicity, carcinogenicity or reproductive and developmental toxicity. Reproductive toxicity and carcinogenicity are not endpoints of concern[4].The important exception is the intrinsic potential of enzymes, like other proteins, to act as respiratory sensitizers. Enzymes are classified as Respiratory Sensitizer Category 1 under CLP regulation. Repeated inhalation exposure to a high dosage of the same enzyme may eventually cause a sensitised person to develop allergy symptoms. Sensitization by itself does not cause symptoms, but repeated high dosage exposure to the same enzyme can cause a sensitized person to develop allergy symptoms at a later point[5].

Derived Minimal Effect Levels (DMEL) have been set at 60 ng/m^3 for workers and at 15 ng/m^3 for consumers[6] based on the data generated over decades of years. Published data from the detergent industry[7] and the enzyme manufacturing industry[8]-[9]-[10] shows that controlling airborne exposure using the DMEL as a target leads to a safe working environment with a very limited number of allergies. Incidents of enzyme allergy have only been reported in cases where risk mitigation and the DMEL have not been applied or have failed for technical reasons[11].

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[3] Alpha-amylase RMOA, published on ECHA website https://echa.europa.eu/assessment-regulatory-needs/-/dislist/details/0b0236e180d8ccda, 2018

[4] : Basketter D et al, Enzymes in cleaning products: An overview of toxicological properties and risk assessment/management Regulatory Toxicology and Pharmacology 64 (2012) 117–123. http://dx.doi.org/10.1016/j.yrtph.2012.06.016

[5] Basketter et al, Enzymes and sensitization via skin exposure: A critical analysis, Regulatory Toxicology and Pharmacology 129 (2022) 105112

[6] Basketter et al., 2010. Defining occupational and consumer exposure limits for enzyme protein respiratory allergens under REACH. Toxicology 268: 165-170.

[7] Basketter DA, Kruszewski FH, Mathieu S, et al. Managing the Risk of Occupational Allergy in the Enzyme Detergent Industry. J Occup Environ Hyg. 2015;12(7):431-437. doi:10.1080/15459624.2015.1011741

[8] Johnsen C.R., Sorensen T.B., Larsen A.I., Secher A.B., Andreasen E., Kofoed G.S., Nielsen L.F., Gyntelberg F. (1997) Allergy risk in an enzyme producing plant: a retrospective follow up study. Occupational and Environmental Medicine ;54:671-675

[9] A I Larsen, C R Johnsen, J Frickmann, et al. (2007) Incidence of respiratory sensitisation and allergy to enzymes among employees in an enzyme producing plant and the relation to exposure and host factors. Occup Environ Med;64:763–768. doi: 10.1136/oem.2005.025304.

[10] A. I. Larsen, L. Cederkvist, A M Lykke, P Wagner, C. R. Johnsen, L. K. Poulsen, (2020) Allergy Development in Adulthood: An Occupational Cohort Study of the Manufacturing of Industrial Enzymes. J ALLERGY CLIN IMMUNOL PRACT VOLUME 8, NUMBER 1

[11] Cullinan P., J.M. Harris, A.J. Newman-Taylor et al.: An outbreak of asthma in a modern detergent factory. *Lancet 356*:1899–1900 (2000).

Allergy to enzymes among consumers of enzyme containing laundry and cleaning products has not been reported since the late 1960's. Clinical evidence shows that the prevalence of enzyme specific sensitization in the population is very rare (0.126% in the 1977 –2010 period)[12].This demonstrates that sensitisation due to exposure to enzymes via laundry and cleaning products is not an issue among the general population.

The enzyme and the detergent industry have 50+ years of experience in the safety of enzymes regarding both occupational and consumer conditions and focusing on product design and guidance to obtain exposures below the respective DMELs. Ample material on the safe use of these ingredients have been created, including guidance, webinars and posters for professional workers[13].

4. Sustainability of Enzymes

Enzymes are proteins that catalyze very specific reactions under mild conditions such as low concentrations and moderate pH. Enzymes are widely used in cleaning and detergents and derogated from the restriction of respiratory sensitizers in various EU Label criteria meeting the overall goals of these "sustainability by design" criteria.

- **EU Ecolabel:** laundry detergents; dishwasher detergents; industrial and institutional dishwasher detergents; hand dishwashing detergents; industrial and institutional laundry detergents.
- **Nordic Ecolabel:** laundry detergents and stain removers.

4.1. Sustainability benefits of enzymes:

Enzymes provide several sustainability benefits:

- ✓ **Environmental performance of enzymes:** Enzymes are readily biodegradable as proven in several studies[14,15].
- ✓ **Responsible use of resources:** With use of enzymes, cleaning can be performed under milder conditions. Therefore, enzymes can reduce the chemical load to environments and at the same time equipment can last longer. Enzymes are an important enabler for compaction of detergents.
- ✓ **Lowered emissions and energy use:** With use of enzymes, cleaning temperatures can be reduced to achieve the same result.
- ✓ **Improvement of water quality:** Enzymes contribute to quality of water.

Quantification of these benefits and related case studies can be found in the upcoming sections.

[12] Sarlo, K., Kirchner, D.B., Troyano, E., Smith, L.A., Carr, G.J., Rodriguez, C., 2010. Assessing the risk of type 1 allergy to enzymes present in laundry and cleaning products: evidence from the clinical data. Toxicology 271, 87-93.
[13] SAFE HANDLING OF ENZYMES - AISE
ACIConsumerEnzymeProductRiskAssessmentGuide.pdf (cleaninginstitute.org)
[14] Human & Environmental Risk Assessment on ingredients of household cleaning products- Subsitilisins (2007)
[15] Human & Environmental Risk Assessment on ingredients of household cleaning products- α-Amylase, Cellulase (β-(1,4)- Glucanase), Lipase

4.2. Quantification of sustainability benefits

The white paper on Life Cycle Analysis of enzymes used in laundry detergents shows reduction of CO_2 and water (Figure 1).

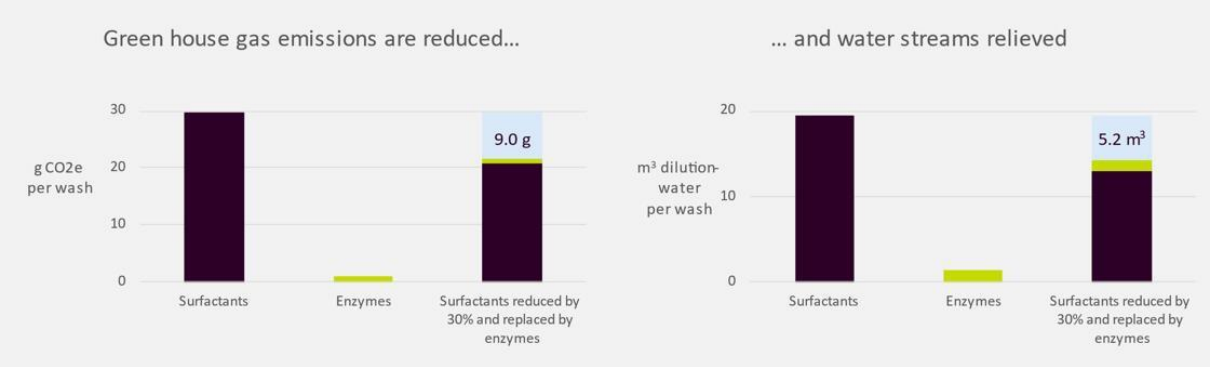

Figure 1. Environmental contribution of enzymes per wash – the left figure: CO2 reduction, the right figure: reduction of water needed to bring detergent ingredients to safe level (NOEC – No Effect Concentration) in the environment (Critical Dilution Volum (CDV))

Enzymes act catalytically, and can repeat their job over and over, resulting in high cleaning activity at very low concentrations. Whereas surfactants act by forming micelles and are used up during the wash processes (Figure 1). Therefore, replacing parts of the conventional detergent ingredients by enzymes will result in a reduction of the total amount of detergent required per wash. Cutting down the amount of surfactant by using enzyme based detergent formulations leads to a significant reduction of CO_2 emissions caused by the manufacturing of detergent ingredients and also in a reduction of the Critical Dilution Volume per wash.

Enzymes are readily biodegradable and their use in detergent formulations significantly contributes to the reduction of energy consumption and CO_2 emissions.

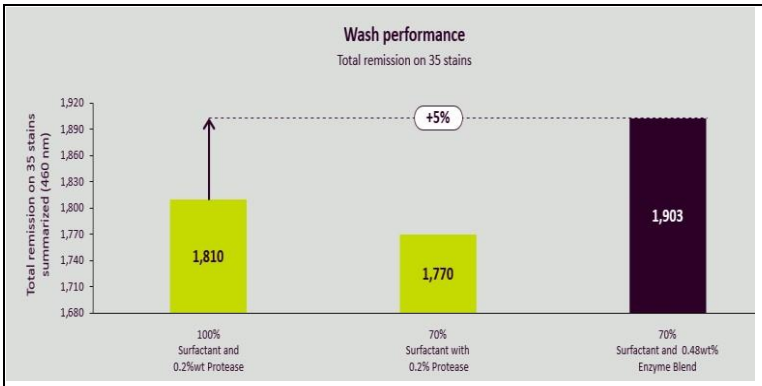

Figure 2 After 30% reduction on surfactants, enzyme products could still deliver 5% performance increase[16]

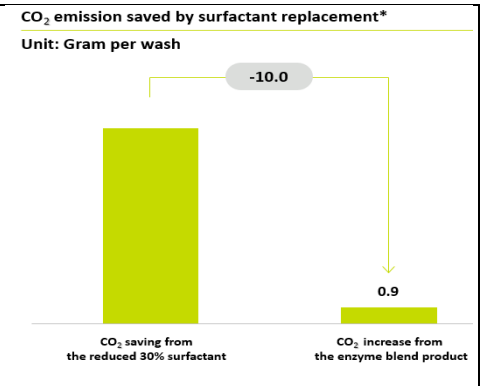

Figure 3 Reduction of CO_2 emissions[17]

[16] Wash conditions: Top loader, standard cotton wash program 37L, 25°C, 15 min. main wash, 2 rinses, water hardness 14°dH, 1.5 kg ballast, emerging market model liquid detergent (74 ml/wash), Surfactants: 5wt% LAS, 8wt% AEOS, 4wt% AEO, 1wt% soap, Enzyme Blend: Protease, Amylase, Lipase, Mannanase, Cellulase (Novozymes 2021)

[17] Surfactants: 5wt% LAS, 8wt% AEOS, 4wt% AEO, 1wt% soap

Additionally, enzymes enable milder cleaning conditions resulting in lower consumption of chemicals. Enzymes are non-corrosive and do not damage surfaces of instrument, members, rubber gaskets etc, so they can last longer. Cleaning index for different cleaning agents clearly prove these points. Sodium hydroxide (1.0 wt.% NaOH) is used as a benchmark and the cleaning performance is determined gravimetrically. The results show significantly less chemical load (0.1% enzyme product compared with 1% NaOH)

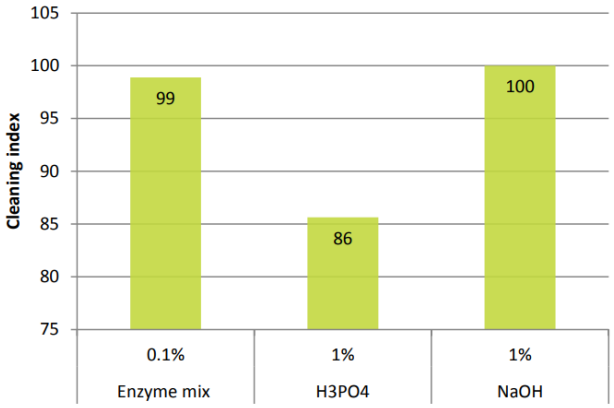

Figure 4 Enzymes help to reduce chemical load (The results are normalized so that the performance of 1.0 wt.% NaOH is set to 100.)

Enzyme Blend: 0.2wt% Progress Uno 100 L; 0.03wt% Amplify Prime 100 L; 0.14wt% Lipex Evity 200 L; 0.05wt% Mannaway 200L; 0.06wt%; Celluclean 5000 L

* CO_2 data in this slide are based on life cycle assessment (link1), (Link2). **Assuming three washes per household per week (Novozymes)

5. Case Studies

5.1. Case Study 1: Enzymes in Cleaning Agents for Food Processing

Cleaning in place (CIP) systems in food processing is one of the areas where enzymes are commonly used. Cleaning in plants that process liquids, such as juice, milk, and beer. Typically, substances used in the cleaning process are warm water, sodium hydroxide, sodium hypochlorite, descaling with nitric, phosphoric, sulphamic, or methanesulphonic acid.

Enzymes are important ingredients in CIP systems. Enzymes break down the residual food debris in facilities for food processing, e.g., fibers and residue from fermentation residue for beer, crops, fruits, and meat, at moderate temperature and neutral pH. They clean the residual substrates that can contaminate and generated a food manufacturing process. When utilising enzyme containing cleaning products, the facilities can be easily cleaned under milder conditions and without vigorous mechanical actions. The equipment can last longer because enzymes are not corrosive. Chemical load to the environment and water consumption are reduced.

The cleaning with enzymes can take place at moderate temperature. 0.1% enzyme product (neutral pH) can replace 1% NaOH (High pH). At the time, an enzyme product can achieve the same washing performance as compared to NaOH, and even better washing performance. Equipment in the food manufacturing facilities can last longer due to the cleaning under the mild conditions as enzymes are not corrosive.
Enzymes reduce the chemical load to the environment energy consumption whilst contributing to thorough cleaning. Therefore, use of enzymes is necessary for health, safety and is critical for the functioning of society

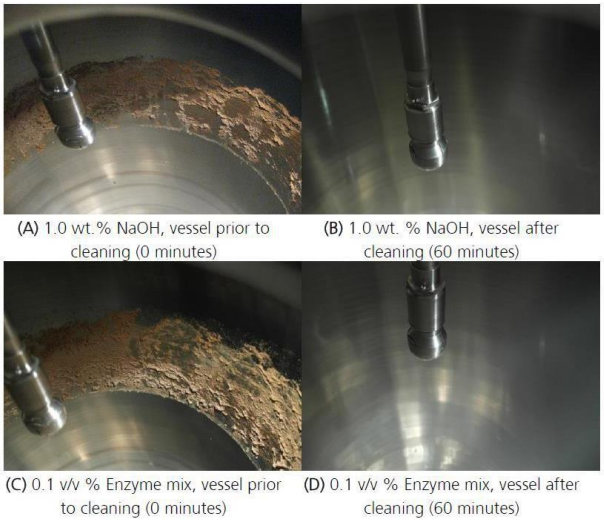

Figure 5. Example on chemicals reduction with utilization of enzymes at CIP facilities (Comparison of cleaning performances of 1% wt% NaOH and 0.1% v/v% enzyme product used for cleaning of a stainless-steel fermentation vessel with yeast soil ring located on the surface)

5.2. Case Study 2: Enzymes in detergents

Use is necessary for health, safety and is critical for the functioning of society

Enzymes have been safely and widely used in consumer laundry products in the EU. For an estimate of the economic impact of potentially reducing the use of these ingredients, we outline below three key product categories where enzymes are used, and the market value for each of these product categories.

Product Category of Enzyme Use (Ref. cleanright.eu)	Market Value of Product Category (Ref. A.I.S.E. 2021)
Consumer Laundry Care	15.3 billion Euro
Consumer Automatic Dishwash	3.2 billion Euro
Professional Laundry	0.5 billion Euro

Figure 6 shows an example of improved stain removal performance at reduced temperatures with the use of enzymes (EU regular liquid detergent without and with 0.006% lipase protein). Washing performance of detergents at low temperature has been improved with increasing enzyme usage since 1985, while the average washing temperature in the EU has decreased from 62°C to 41°C.

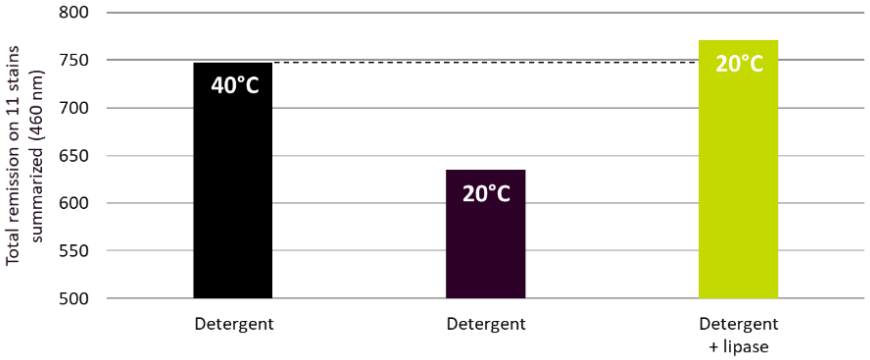

Figure 6. Example on Stain Removal at reduced temperature with Use of Enzymes[18]

One of the main innovations of the industry is the compact detergents products. Compaction means that the product is, amongst others, more concentrated and the chemical load to the environment is reduced. Water use is also reduced and there are savings in fuel as less product is transported. For example, the average dosage had been reduced by half and the aggregated saving of detergent had been estimated as 30 million tonnes in the period of 1997 and 2017[19]. Enzymes contribute significantly to cleaning performance since they have a high performance at low concentrations in the formula. Enzymes minimize the impact on the environment while securing equivalent cleaning performance.

In summary, enzymes in detergents have a unique role and they positively contribute to sustainability, society and economy as a whole.

[18] Wash conditions: EU front loader, standard cotton wash program 20/40°C, 51 min. main wash, water hardness 15°dH, 4 kg ballast,stain set composed of 11 lipase sensitive stains, EU regular liquid detergent (75 ml/wash)

[19] A.I.S.E. Fact sheet 2019 20190410111600-aise_factsheet-2019_compaction_def.pdf