ANTIFOULING BIOCIDES

A key contributor to sustainable shipping

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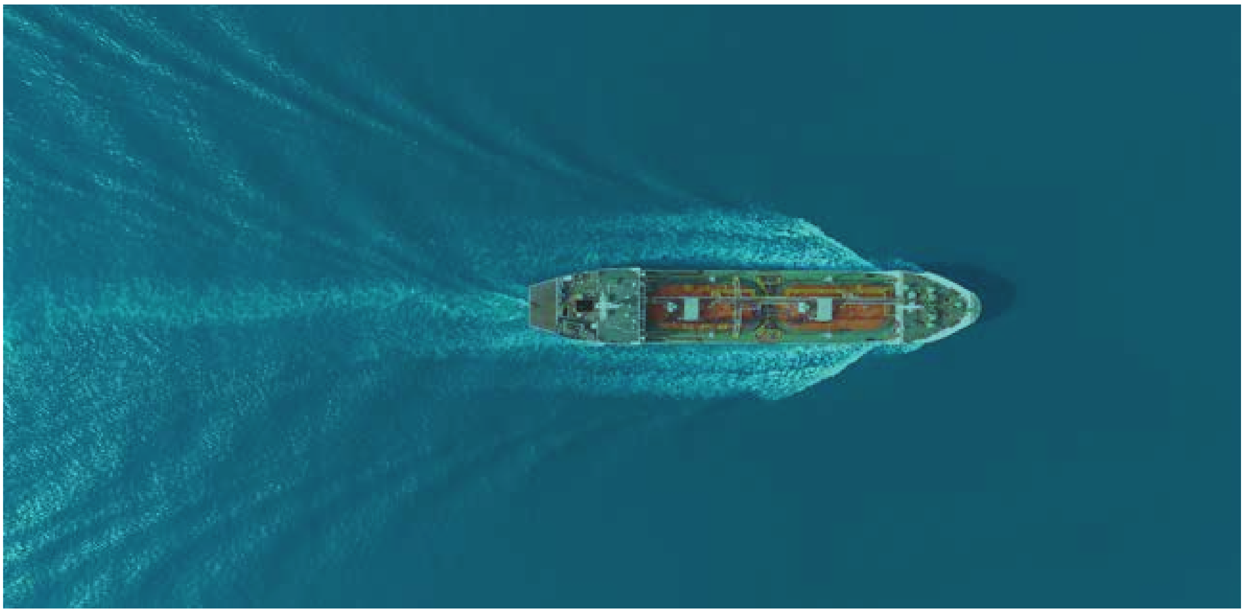
INTRODUCTION



The prevention of biofouling accumulation on the underwater surfaces of commercial and recreational marine vessels is essential for reducing greenhouse gas (GHG) emissions, safeguarding vessel maneuverability and minimizing the transportation of invasive aquatic species between geographical regions.

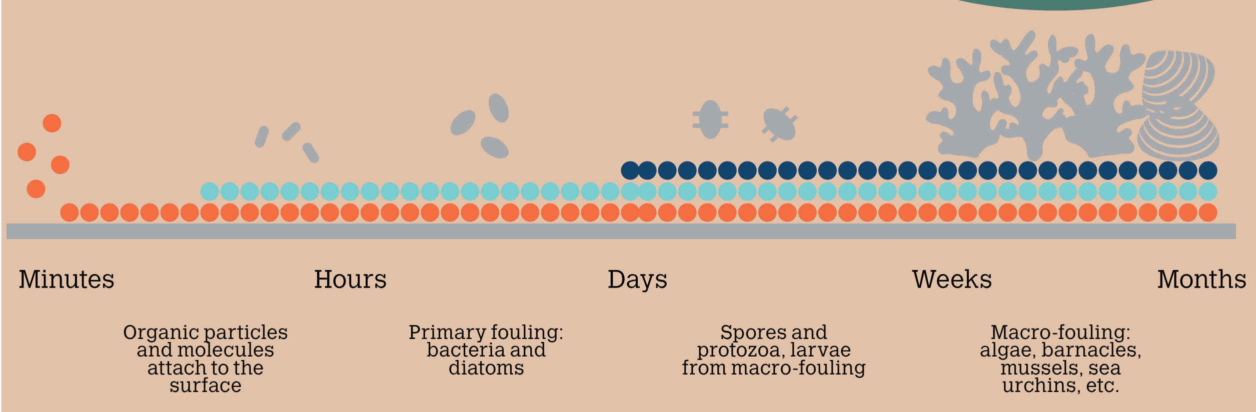
Antifouling coatings available for use today are the result of hundreds of years of development work to ensure that they meet user requirements specific to the operation of marine vessels, that they can be used at scale by the global fleet of marine vessels, and they can be applied to, and continuously function on, the underwater surfaces of vessels.

Both biocidal antifouling coatings and marine biocides approved for use by regulatory bodies have been subject to rigorous and robust evaluation for environmental and human exposure risk to ensure they are safe for use in the marine environment. However, despite meeting extensive regulatory requirements that safeguard human health and impact on the marine environment, marine biocides are often perceived to be a negative entity and their beneficial role in enabling a sustainable shipping industry is often not fully recognized.

What is

MARINE BIOFOULING?

Marine biofouling is a biological process which immediately affects every surface submerged in sea water. Over time, a thick layer of fouling can form on the ship hull which significantly increases friction against the water.



Biofouling describes the accumulation of marine organisms on the surface of submerged natural and artificial structures. The term marine biofouling describes both micro (biofilm, microbial slime, and algae) and macro fouling organisms (weeds and hard-shelled organisms), comprising over 4,000 different species.

Biofouling has presented a challenge to the maritime industry since humankind started to explore the oceans. On a global oceanic perspective, the presence and volume of biofouling organisms present is dependent on water salinity, nutrition levels and temperatures.

Marine biofouling follows a layered succession. It begins with microorganisms forming a biofilm on the hull's surface shortly after immersion in water. This microfouling creates conditions for macrofouling organisms like algae, seaweeds, and hard-shelled species to attach. Within a week, spores, protozoa, and larvae of macrofouling species settle on the hull. Over several weeks, these species grow and anchor themselves to the surface.

The successional model of biofouling outlines a progression from biofilm to slime, weed, and hard fouling. However, external factors such as salinity, light levels, water temperature, and nutrient availability can alter this sequence. These variables make marine biofouling unpredictable and managing it highly complex.

Antifouling coatings are the best line of defense against marine biofouling. However, no one size fits all when considering biofouling management on a vessel-by-vessel basis. It is for this reason that multiple antifouling coating products exist on the market today, with varying combinations of marine biocides.

Without biocidal antifouling coatings, biofouling could cause the fuel consumption of a vessel to rise by around

+40%.

That would translate into a global increase of 338 million tonnes of CO_2 per year.

What are the consequenses of

MARINE BIOFOULING?

1 **Increased greenhouse gas emissions from ships.**
Biofouling accumulation on the hulls of commercial and recreational marine vessels generates increased surface roughness which increases the hydrodynamic drag of a vessel. This increase in hydrodynamic drag increases the amount of fuel that a vessel must burn to maintain a set speed through water, increasing emissions to air.

- Clarksons[1] estimate that emissions from the shipping industry amounted to 845 million metric tonnes of CO_2 in 2022 (Clarkson's 'Fueling Transition, April 2023).
  In the absence of biocidal antifouling coatings, biofouling on the hull and in niche areas could cause the fuel consumption of a vessel to rise by approximately 40%. This, based on the 2022 emissions output estimated by Clarksons would translate into an increase of 338 million tonnes CO_2 per year[2]. This is comparable to the yearly emissions from around 70 million standard passenger cars[3].

- Shipping markets continue to perform strongly, unpinned by trade volume recovery (since the COVID-19 pandemic), widespread congestion and modest fleet supply growth. Therefore, regulations that aim to limit the emissions from shipping will not decrease in ambition, putting antifouling coatings in a prime position to unlock efficiency and emissions savings from below the waterline. For an industry that has a similar annual CO_2 emissions output as Germany, sustainability and rapid decarbonization is key to meeting mandatory reduction targets.

2 **Higher costs and lower vessel efficiency.**
Biofouling accumulation generates higher costs as the increased hydrodynamic drag decreases vessel efficiency and increases the amount of fuel that a vessel must burn to maintain a set speed through water, it can also have a negative impact on vessel maneuverability which can represent a safety risk.

- As the maritime industry moves towards using cleaner, greener, less carbon intensive fuel options, the cost of fuel per metric ton will only increase. Therefore, increased fuel consumption resulting from biofouling accumulation will incur a more expensive cost penalty than today in a not-so-distant future.

- The cost of goods transportation could increase as a result of higher fuel consumption and operational inefficiencies caused by biofouling. This could lead to increased shipping costs being passed on to consumers, impacting global trade and economic activities.

3 **Transfer of species between marine eco-systems.**
Biofouling also acts as a vehicle for the transport of alien/invasive species between eco-systems. As such, vessels with high volumes of biofouling on the hull and in niche areas can represent a marine biosafety risk.

- Many vessels have been turned away from ports in New Zealand and Australia due to posing a marine biosafety risk, leading to disruptions in travel itineraries and potential financial losses for operators.

- The zebra mussel in the USA and Japanese oyster in northern Europe are two examples of invasive species causing problems for both man and the environment.

What is

A BIOCIDE?

BIOCIDES ARE USED TO PROTECT PEOPLE AND ANIMALS, PRESERVE GOODS AND MATERIALS, STOP PESTS AND CONTROL VIRUSES, BACTERIA, AND FUNGI.

More than 95% of the antifouling coatings currently used by marine cargo- and passenger vessels, and leisure craft contain biocides.

All substances which control organisms in a non-physical manner are considered to be biocides. Biocides are used to protect people and animals, preserve goods and materials, stop pests and control viruses, bacteria, and fungi. Examples of biocides include disinfectants, preservatives, antiseptics, pesticides, herbicides, fungicides, and insecticides.

According to the Biocidal Products Regulation (BPR) Regulation (EU) 528/2012, biocidal products are those that are intended to destroy, control, or prevent the effects of harmful organisms, or in any other way control harmful organisms, other than by means of physical or mechanical devices.

In marine industries, biocides are a key component of 'antifouling' coatings and play a pivotal role in preventing biofouling on submerged structures. More than 95% of the antifouling coatings currently used by marine cargo- and passenger vessels and leisure craft contain biocides.

Biocides in MARINE COATINGS

Biocides are used to prevent biofouling on the ship hull, minimize greenhouse gas emissions, prevent transfer of species between ecosystems and ensure operational efficiency.

WHY ARE BIOCIDES USED IN MARINE COATINGS?

For centuries, materials or compounds that have an antifouling effect have been used for biofouling prevention on submerged surfaces.

Biocides enable the maritime industry to meet environmental impact reduction targets set by the International Maritime Organization (IMO) that encourage sustainability in shipping.

Biocidal ingredients have been proven to be the most efficient solution to meet the environmental and performance requirements for marine vessels operating in a highly competitive commercial environment where vessels sail in waters with varying biofouling risk.

Throughout centuries of experience from the use of biocidal compounds, no other solutions have been proven as viable alternatives. Over many years, they have been adapted to meet increasingly tough requirements from the industry on i) application procedures, ii) long-term in-service life (up to 60 months) and iii) coating renewal processes.

In the Age of Sail, sailing vessels suffered severely from the growth of barnacles and weeds on the hull. Starting in the mid-1700s thin sheets of copper were used to protect vessel hulls from biofouling and approximately 100 years later, Muntz metal (approx. 60% copper, 40% zinc and a trace of iron), was nailed onto the hull to prevent marine growth.

The first regularly used antifouling paints (first-generation paints) contained copper oxide and zinc oxide as biocides. However, they quickly lost popularity because of their low durability and consequent rapid decrease in effectiveness. At the beginning of the 1960s, the naval industry developed and started using organotin compound (OT)-based antifouling paints (second-generation paints), e.g., those containing tributyltin (TBT) or triphenyltin (TPhT) as biocides. These paints were widely used in the 1980s, accounting for 90% of ship hulls in operation around the world.

However, in September 2008, the IMO banned the use of TBT-based antifouling paints on vessels less than 25m in length through the Antifouling System Convention. This ban is still in place today.

In response to the increasingly strict regulations on the use of organotin compound (OT)-based paints, third-generation antifouling paints were introduced in 1987. These paints typically comprise inorganic biocides such as cuprous oxide in combination with one or more organic or organometallic co-biocides, sometimes referred to as "booster" biocides.

What are

BIOCIDAL ANTIFOULING COATINGS?

Biocidal antifouling coatings comprise a soluble, or partially soluble, resin system that contains a mixture of biocide(s) effective against a broad range of fouling organisms. They are the most widely used technology for fouling control and account for approximately 90% of the fouling control technology market.

Today, there are several biocides that are approved for use in marine coatings. To be effective across the entire range of fouling organisms, a combination of biocides is generally used. Careful selection of the binder and associated biocide package enables the system to be tailored to the trading requirements of the ship.
Typical biocide packages usually comprise of a blend of an inorganic biocide (usually cuprous oxide) and one or more 'booster biocides' (organic and/or organometallic) to be effective across a spectrum of target organisms.

However, the biological complexity and the high industrial requirements for hull coatings present an increasingly complex challenge for this collection of certified biocides. Biocidal antifouling coatings are expected to perform in any condition (except in ice breaking). The antifouling coating on a vessel is usually renewed every 3-5 years. In between dry dockings, periodic cleaning of the hull surface may be deployed to remove light fouling.

Where would we be

WITHOUT MARINE BIOCIDES?

Biocides exist all around us with the purpose of protecting people and assets among other things yet presenting an acceptable risk profile. They are widely used in cosmetics, cleaning products, some toothpastes, laundry detergents, paints and disinfectants and are used as food preservatives. Their use is widespread, and their effects are well known. This is also true for marine biocidal antifouling coatings who have the additional benefit of providing incomparable fuel emissions to the industry.

But what would happen if we removed biocides from marine antifouling coatings all together?

- **There would be a colossal jump in the volume of biofouling that accumulates on the global shipping fleet of over 50,000+ merchant vessels.**
- **The emissions profile of that industry would sharply increase.**
- **Ships would pose a greater risk to biodiversity.**

Aside from those points, other disruptions may occur.

Imagine this scenario. You have booked a cruise, that cruise ship sails towards a port and gets the news that it cannot dock due to being a marine biosafety hazard. The cruise is over. Or beautiful cruise destinations get wiped off itinerary lists worldwide because the ships cannot dock due to biofouling rules, or prices that the consumer pays are increased because ships must hire in frequent hull cleaning services.

Or imagine the cost of goods increasing further, not in line with global inflation, but because ship operators must pay for their emissions under the EU Emissions Trading Scheme (ETS), or other regional ETS and their emissions have increased significantly due to biocides not being available for use and biofouling on the hull of their vessel has dragged their fuel efficiency down meaning the price of shipping is passed onto the consumer.

Imagine if shipping contributed a lot more that 2.6% of annual global CO_2?
Imagine if the shipping industry did not meet IMO targets to reduce greenhouse gas emissions by 2050?

Optimization of current antifouling coating systems are expected to save 100 million tonnes of CO_2 emissions compared to 2008. Therefore, they represent an important part of the shipping industry's decarbonization efforts. Without biocides, reaching these mandatory IMO targets, in alignment with UN climate change initiatives and Sustainable Development Goals, would not be possible.

Without biocides, the maritime industry would face increased biofouling, higher fuel consumption, elevated greenhouse gas emissions, and potential risks to biodiversity and operational efficiency.

The need

FOR MARINE BIOCIDES

BIOCIDES ARE APPROVED BY THE MOST STRINGENT REGULATORY SCHEMES IN THE CHEMICAL INDUSTRY. BIOCIDES IN USE TODAY HAVE BEEN TESTED, EVALUATED, AND USED FOR MORE THAN TWENTY YEARS.

Biocides are approved by the most stringent regulatory schemes in the chemical industry. The regulatory landscape for new biocidal substances is complex and this is certainly the case for biocidal substances intended for use in marine antifouling coatings. Biocides in use today have been tested, evaluated, and used for more than twenty years.

Approved biocides are under constant evaluation to keep updated with regulatory requirements. Through centuries of trial and error the use of biocides has been the basis for the current regulatory requirements limiting the number of approved biocides to less than 10 compared to more than 40, fifteen years ago.

The BPR was put in place to regulate the use of biocides and avoid the situation of any substances which could pose a risk for humans, or the environment being placed on the market. However, at the same time, these stringent requirements could be blocking new biocides from reaching the market. Also, the cost to develop a dossier for an EU approval application containing all the required information is in the range of 5-10 million euros in investment. However, without EU approval, a new biocide is likely to never reach the market at all. The EU and US are among the most thorough evaluation schemes in the world, and they encompass the entire product (the paint) in which the new substances are used.

The amount of information needed during the application for regulatory approval of a new active substance is understandable. Their purpose is to uphold antifouling efficacy and safety.

The submission of a significant number of studies are requested by regulatory bodies to provide an independent assessment of the biocide´s human and environmental risk profiles. The data resolution is consequently far greater than for many other chemicals. This regulatory criterion has tightened the window into a needle-eye wide opportunity to pass. Millions of dollars in investments and multiple years of regulatory efforts are now required to sustain biocides as a viable candidate for marine coatings.

To be approved, the risk assessment for an antifouling biocide must conclude that it is safe to use and that it is efficacious against biofouling. An approved biocide has to file >100 qualified regulatory studies. Credible information generated by independent research organizations is required to determine an active substance's identity and impurity profile, the physical- and chemical properties, suitable analytical methods in different matrices, toxicological- and ecotoxicological profile and its environmental fate.

AT PRESENT, ALTERNATIVE BIOFOULING CONTROL METHODS ARE NOT SCALABLE

Liquid coatings provide the first line of antifouling defense against biofouling for most marine vessels. There are essentially two main types of liquid antifouling coatings: biocidal antifouling coatings and foul release coatings. Less than 5% of vessels are suitable for biocide free foul release coating use (the most effective foul release coatings also contain biocides).

Alternative antifouling technologies include ultrasound, UV light, biomimetic coatings, and hard non-biocidal coatings, accompanied by periodic proactive hull grooming.

However, current alternative antifouling technologies have limited applicability. There is not one single alternative solution that will work for the majority, akin to what liquid biocidal coatings offer. Although millions of dollars of public and private funds have been spent in the quest to find alternative, sustainable marine antifouling technologies, not one solution is coming to success, yet. Those developed simply do not have a broad enough spectrum to be scalable to the global shipping fleet.

There are no alternative antifouling technologies that are available now and scalable to the same level as biocidal antifouling coatings, without compromising significantly on user and application specifications. That innovation in biocidal antifouling coatings is being stifled by regulatory requirements for the certification of new biocides does not help.

Therefore, greater focus should be placed on prospering innovation in the field of antifouling biocides, in the short to medium term. If you remove biocides from the antifouling technology sector, there will be no innovation that is scalable in time for the urgent needs of the maritime industry to rapidly decarbonize.

Taking the biocide-free route is one option. But we are not there yet. Biocide-free coatings are not practical or economically feasible for most vessels.

References

[1] Clarksons 'Fuelling Transition: Tracking Progress'
[2] The shipping industry looks for green fuels (acs.org)
[3] Combustion of Fuels - Carbon Dioxide Emission (engineeringtoolbox.com) and Greenhouse Gas Emissions from a Typical Passenger Vehicle | US EPA
[4] Clarksons 'Fuelling Transition: Tracking Progress'

[5] For the period 2007–2012, International shipping accounted 2.6% of global CO_2 emissions.
[Third IMO GHG Study 2014].
[6] IMO Initial GHG Strategy that requires a reduction in carbon intensity of international shipping (to reduce CO_2 emissions per transport work), as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008.

CONCLUSION

AS THE FIRST LINE OF DEFENCE AGAINST BIOFOULING FOR HUNDREDS OF YEARS, BIOCIDAL ANTIFOULING COATINGS PLAY AN INTEGRAL ROLE IN SHIPPING'S DECARBONISATION CHALLENGE BOTH NOW AND IN THE SHORT, MID AND LONG-TERM FUTURE.

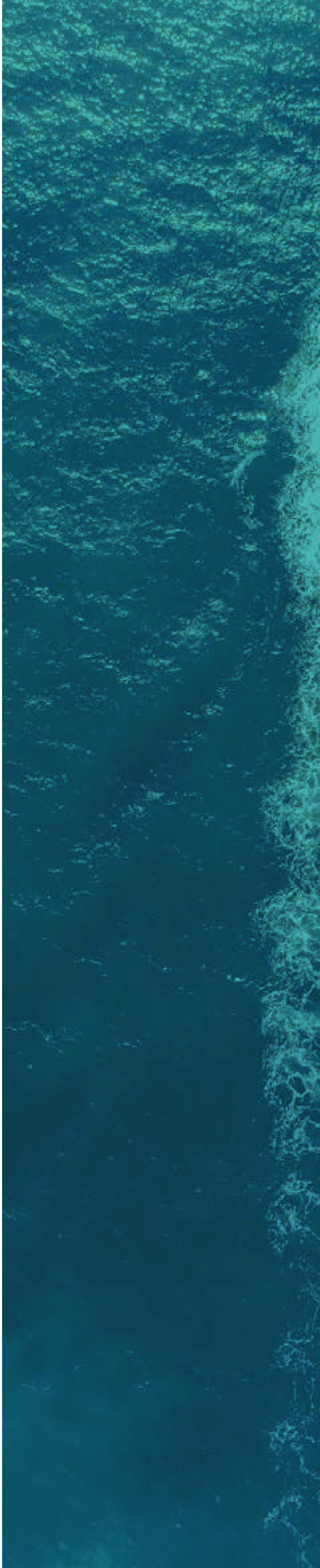
Cutting GHG emissions is an unavoidable necessity for the maritime industry. When it comes to biofouling management, ship operators must ensure that the vessel hull remains to be in good condition to perform optimally with no increased emissions and lowest possible risk of acting as vector for transporting alien/invasive species.

As the first line of defence against biofouling for hundreds of years, biocidal antifouling coatings play an integral role in this challenge both now and in the short, mid and long-term future. They have undergone many decades of development iterations to arrive where they are today.

Being among the most well understood products from a risk (human exposure and environmental toxicology) and end-user perspective, available marine biocides will play an essential role in responding to tomorrow's requirements on hull performance. They are key contributors to the maritime industry meeting sustainability and decarbonization targets.

Alternative antifouling technologies are nowhere near as regulated as antifouling biocides, if at all. Therefore, the consequences of their use are unknown compared to the established, fully vetted/safely proven biocides that can be used today.

The removal of biocides from antifouling coatings would have significant consequences, including increased biofouling, environmental and biodiversity risks, operational disruptions, economic implications, and non-compliance with environmental targets.



CALL TO ACTION

Recognize the importance of effective biocides for a sustainable maritime industry.

Recognize that support for innovation in biocidal antifouling coatings is needed.

THIS WHITE PAPER WAS DEVELOPED BY THE FOLLOWING ORGANISATIONS:

- I-Tech AB
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- ECKART GmbH

THIS DOCUMENT WAS DEVELOPED AND SUPPORTED BY THE FOLLOWING ENTITIES

January 2024

Company: I-Tech AB
Representative: Philip Chaabane
Signature:

Company: American Chemet Corporation
Representative: Neal Blossom
Signature:

Company: Janssen PMP
Representative: Tony Kempen
Signature:

Company: Arxada AG
Representative: Carsten Baehr
Signature:

Company: Cosaco GmbH
Representative: André Simon
Signature:

Company: Bardyke Chemicals Ltd
Representative: DUNCAN CW NORMAN
Signature:

Company: Nordox AS
Representative: Lars Tomasgaard
Signature:

Company: Lanxess
Representative: Antonio Hurtado
Signature:

Company: ECKART GmbH
Representative: Christine Trumm
Signature: