REPORT

# In-can preservatives in the paint industry

*How to stimulate alternatives to biocides*

Client: Ministry of Infrastructure & Water Management

Reference: BH7424RP001F01

Status: Final/01

Date: 23 November 2021

Royal HaskoningDHV
Enhancing Society Together

**HASKONINGDHV NEDERLAND B.V.**

Laan 1914 no.35
3818 EX Amersfoort
Industry & Buildings
Trade register number: 56515154

+31 88 348 20 00 **T**
+31 33 463 36 52 **F**
info@rhdhv.com **E**
royalhaskoningdhv.com **W**

| | |
|---|---|
| Document title: | In-can preservatives in the paint industry |
| Document short title: | Biocides in Paint |
| Reference: | BH7424RP001F01 |
| Status: | 01/Final |
| Date: | 23 November 2021 |
| Project name: | Biocides in Paint |
| Project number: | BH7424 |
| Author(s): | S. Lemain & B. Mensink |

| | |
|---|---|
| Drafted by: | S. Lemain & B. Mensink |
| Checked by: | B. Mensink |
| Date: | 23 November 2021 |
| Approved by: | S. Lemain |
| Date: | 23 November 2021 |

| Classification |
|---|
| Project related |

Royal HaskoningDHV

# Executive Summary

The Netherlands is strategically committed to contribute to an international transition towards a non-toxic environment and a circular economy. The Dutch Ministry of Infrastructure and Water Management, in cooperation with the Ministry of Economic Affairs and Climate with the support of stakeholders across Europe, have developed a Safe Chemicals Innovation Agenda (SCIA, 2018).
This comprises a coherent agenda for research needs that should accelerate the safe design of chemicals, materials and products ("safe by design"). Efforts are required by the scientific, technical, business and policy making community.

The SCIA agenda comprises 7 themes where research & development is warranted. One of these themes is Theme 3: Preservation. Within this context, one of the areas getting particular attention is the **in-can preservation of (waterborne) paints**. Paint generally comes in a can (or bucket). 'In-can preservation' refers to preserving the paint throughout its lifetime in the can, from production to first opening and possibly beyond.

Over the past decades, paint manufacturers have switched from solvent based paints to waterborne paints for a significant share of their portfolio. The main reason was the reduction of volatile organic compounds (VOC), aiming to perform better on health and environmental aspects. This switch however made paint vulnerable to spoilage. Biocides were and are added to avoid spoilage. Biocides are also used in the raw materials (e.g. binders) that paints are made of. Paint manufacturers are aware of the risks that biocides bare. Most paint manufacturers, however, see a role for biocides in an effective, sustainable in-can preservation strategy.

Preservatives in paint can bare the hazard of sensitisation and allergic reactions. 'Sensitisation' is a health effect that can lead to a lifelong (irreversible) sensitivity to specific (but also to similar) allergens. People who are sensitised must avoid exposure to the allergen for the rest of their life if they wish to avoid the symptoms.

Recent regulatory developments with regards to hazard profiles of biocides trigger the search for alternative preservation methods in this sector. Regulatory restrictions have reduced the current palette of preservatives available to formulators (primarily isothiazolinones and formaldehyde releasers). Labelling requirements based on hazard might overrule the (acceptable) risk to allow substances in certain markets.

This study follows up on previous studies and deviates from previous approaches by primarily taking a different angle, namely: **how to stimulate alternatives to biocides?**

We understand that the research question implicates a certain desire for substitution of biocides. This research is not about the question if biocides should be substituted, but about the question how to substitute if that would be desired. This angle is consciously chosen aiming to add to the existing research landscape.

From the research we find that there is a solution to go biocide-free for a large share of water-borne paints, namely **white (and factory tinted) wall paints, with a high pH**. However, not all (water borne) paint is equal. While there is a possibility for wall paint, **no feasible options were found (yet) for other segments** (e.g. lacquers, technical/industrial coatings). Paint manufacturers indicate that there will not be a silver bullet for all paint, but a combination of both process and formulation technologies will be applied (hurdle technology).

And while paint manufacturers are putting RD&I effort to several alternative preservation methods, new, less hazardous biocides developed by biocide producers are not expected.

Biocide-free paints are on average more costly than those containing biocides. Also, it was found that customer demand for biocide-free paint is lacking in most countries. Hence, there is not much biocide-free paint on most markets. Given these findings it is remarkable that an alternative preservation method has matured within a certain segment, namely **(white) wall paint in the German DIY sector**.
Ecolabels are very powerful on the German DIY market, and have played a crucial role in the maturing of the biocide-free paint market. In other countries such ecolabels do not seem to be that powerful. Steering on the use of biocides via **customer demand** is the preferred route according to manufacturers.

Industries are found not to be simply 'awaiting customer demand'. 'Sustainability' is a theme for all paint manufacturers, largely influencing the RD&I agenda. Yet, 'reduction of biocides' is not an end goal for manufacturers, and it does not clearly or necessarily match manufacturer's other sustainability goals, e.g. energy or $CO_2$ reduction.

It is concluded that there is a **discrepancy between timeframes** of bans on traditional biocides on the one hand and availability of prospected alternatives on the other. In order to continue support of the safe and sustainable production and use of paints while also aiming to reduce substances with certain hazard profiles, alignment of these timeframes is a necessity.

In a final chapter we present ideas on how to move forward to achieve alignment between policy makers' and manufacturer's ambitions. For this, a thought experiment in the form of a scenario analysis was carried out. The authors do not aim to prescribe certain actions. The scenarios are based on an axis representing enforcement versus seduction, and an axis representing high or low governmental and intercompany communication/debate on the way forward (high/low).

## Samenvatting

Nederland zet zich strategisch in om bij te dragen aan een internationale transitie naar een gifvrije omgeving en een circulaire economie. Het Ministerie van Infrastructuur en Waterstaat heeft in samenwerking met het ministerie van Economische Zaken en Klimaat met steun van belanghebbenden in heel Europa een Safe Chemicals Innovation Agenda ontwikkeld (SCIA, 2018).
Dit omvat een coherente agenda voor onderzoeksbehoeften die het veilige ontwerp van chemicaliën, materialen en producten ("safe by design") moet versnellen. Inspanningen zijn vereist door de wetenschappelijke, technische, zakelijke en beleidsmakende gemeenschap.

De SCIA-agenda bestaat uit 7 thema's waar onderzoek & ontwikkeling gerechtvaardigd is. Een van deze thema's is Thema 3: Conservering. Binnen deze context is een van de gebieden die bijzondere aandacht krijgen de **conservering in blik van (watergedragen) verven.** Verf komt over het algemeen op de markt in een blik (of emmer). 'Conservering in blik' of ‘in-can preservation’ verwijst naar het bewaren van de verf gedurende de hele levensduur in het blik, van productie tot eerste opening en mogelijk daarna.

In de afgelopen decennia zijn verffabrikanten voor een aanzienlijk deel van hun portfolio overgestapt van verven op basis van oplosmiddelen naar watergedragen verven. Belangrijkste reden was de reductie van vluchtige organische stoffen (VOS), met als doel beter te presteren op gezondheids- en milieuaspecten. Deze omslag maakte verf echter kwetsbaar voor bederf. Biociden werden en worden toegevoegd om bederf te voorkomen. Biociden worden ook gebruikt in de grondstoffen (bijvoorbeeld bindmiddelen) waarvan verven zijn gemaakt. Verffabrikanten hebben aandacht voor de risico's die biociden met zich meebrengen. De meeste verffabrikanten zien echter een rol voor biociden in een effectieve, duurzame in-can conserveringsstrategie.

Conserveermiddelen in verf kunnen het gevaar van sensibilisatie en allergische reacties voortbrengen. 'Sensibilisatie' is een gezondheidseffect dat kan leiden tot een levenslange (onomkeerbare) gevoeligheid voor specifieke (maar ook voor vergelijkbare) allergenen. Mensen die gesensibiliseerd zijn, moeten blootstelling aan het allergeen de rest van hun leven vermijden als ze de symptomen willen vermijden.

Recente ontwikkelingen in de regelgeving met betrekking tot gevarenprofielen van biociden zetten de zoektocht naar alternatieve conserveringsmethoden in deze sector in gang. Wettelijke beperkingen hebben het huidige palet van conserveermiddelen die beschikbaar zijn voor verffabrikanten (voornamelijk isothiazolinonen en formaldehyde releasers) verminderd. Etiketteringsvoorschriften op basis van gevaar kunnen het (aanvaardbare) risico om stoffen op bepaalde markten toe te staan, overrulen.

Deze studie volgt op eerdere studies en wijkt hiervan af door vooral een andere invalshoek te nemen, namelijk: **hoe stimuleer je alternatieven voor biociden?**

We begrijpen dat deze onderzoeksvraag een zekere wens tot vervanging van biociden impliceert. Dit onderzoek gaat echter niet over de vraag of biociden moeten worden vervangen, maar over de vraag hoe deze te vervangen als dat gewenst zou zijn. Deze invalshoek is bewust gekozen om toe te voegen aan het bestaande onderzoekslandschap.

Uit het onderzoek blijkt dat er een oplossing is om biocidevrije verf te produceren voor een groot deel van de watergedragen verven, namelijk **witte (en in de fabriek gekleurde) muurverf, met een hoge pH.** Niet alle (watergedragen) verf is echter gelijk. Hoewel er een alternatief blijkt te zijn voor muurverf, werden er **(nog) geen haalbare opties gevonden voor andere segmenten** (bijv. lakken, technische/industriële coatings). Verffabrikanten geven aan dat er geen wondermiddel te verwachten is dat voor alle verven van toepassing zal zijn, maar dat een combinatie van proces- en formuleringstechnologieën zal worden

Royal HaskoningDHV

toegepast (‘hurdle technology’). En terwijl verffabrikanten RD&I-inspanningen leveren voor verschillende alternatieve conserveringsmethoden worden geen nieuwe, minder gevaarlijke verwacht van biocideproducenten.

Biocidevrije verven zijn gemiddeld duurder dan die met biociden. Daarnaast blijkt een vraag van klanten naar biocidevrije verf in de meeste landen te ontbreken. Vandaar dat er op de meeste markten niet veel biocidevrije verf is. Gezien deze bevindingen is het opmerkelijk dat binnen een bepaald segment een alternatieve conserveringsmethode tot een volwassen markt is gekomen, namelijk voor **(witte) muurverf in de Duitse doe-het-zelfsector.**
Ecolabels zijn zeer krachtig op de Duitse doe-het-zelfmarkt en hebben een cruciale rol gespeeld bij de ontwikkeling van de biocidevrije verfmarkt. In andere landen lijken dergelijke ecolabels niet zo krachtig. Sturen op het gebruik van biociden via de **vraag van de klant** heeft volgens fabrikanten de voorkeur.

Industrieën blijken niet simpelweg 'te wachten op de vraag van de klant'. 'Duurzaamheid' is een thema voor alle verffabrikanten en heeft een grote invloed op de RD&I-agenda. Toch is 'reductie van biociden' geen einddoel voor fabrikanten en komt het niet duidelijk of noodzakelijk overeen met de andere duurzaamheidsdoelstellingen van de fabrikant, bijvoorbeeld energie- of $CO_2$-reductie.

Geconcludeerd wordt dat er een **discrepantie bestaat tussen de termijnen** voor het verbod op traditionele biociden enerzijds en de beschikbaarheid van alternatieven anderzijds. Om de veilige en duurzame productie en het gebruik van verven te blijven ondersteunen en tegelijkertijd te streven naar het verminderen van stoffen met bepaalde gevarenprofielen, is afstemming van deze termijnen een noodzaak.

In een laatste hoofdstuk presenteren we ideeën over hoe we verder kunnen gaan om afstemming te bereiken tussen de ambities van beleidsmakers en van verffabrikanten. Hiervoor is een gedachte-experiment in de vorm van een scenario-analyse uitgevoerd. De auteurs hebben hierbij niet tot doel bepaalde handelingen voor te schrijven. De scenario's zijn gebaseerd op een as die beperking versus verleiding vertegenwoordigt, en een as die staat voor hoge of lage overheids- en intercompany-communicatie / debat over de weg voorwaarts.

# Table of Contents

# Appendices

# 1 Introduction

**Background**

The Netherlands is strategically committed to contribute to an international transition towards a non-toxic environment and a circular economy. The Dutch Ministry of Infrastructure and Water Management, in cooperation with the Ministry of Economic Affairs and Climate with the support of stakeholders across Europe, have developed a Safe Chemicals Innovation Agenda (SCIA, 2018).

This comprises a coherent agenda for research needs that should accelerate the safe design of chemicals, materials and products ("safe by design"). Efforts are required by the scientific, technical, business and policy making community.

The origin of this strategy lies with the societal and market drive towards lower hazard products and recovery of raw materials. The agenda not only focusses on substances (replace and reduce hazardous for non or less hazardous) but also on achieving equivalent functionality with less hazardous means via technological or even organisational steps.

The starting point for assessments or comparisons for improvements on hazards is always a thorough inventory of substances used and/or formed in operations. This should not solely comprise review of substances, but also the technology applied. The whole process must be considered because of the direct link with exposures and functionality. For this, education, and training of industrial and professional users of chemicals is needed in order to have appropriate skills to assess available information and to ask the right questions.

The SCIA agenda comprises 7 themes where research & development is warranted. One of these themes is Theme 3: Preservation. Within this context, one of the areas getting particular attention is the in-can[1] preservation of (waterborne) paints.

Both regulatory developments and hazard profiles of biocides trigger the search for alternative preservation methods in this sector. Some preservatives bare the hazard of increasing sensitisation[2] and allergic reactions. Labelling requirements based on hazard might overrule the (acceptable) risk to allow substances in certain markets. Regulatory restrictions have reduced the current palette of what is or was generally regarded as safe and effective preservatives available to formulators (primarily isothiazolinones and formaldehyde releasers).

Given this background – the net reduction of biocides for in-can preservation – this study does not conclude on the use of biocides as in-can preservation itself.

**Previous studies**

The Danish EPA has published an extensive study in 2018 on experiments regarding reduction of biocide concentrations for preservation of water-based paints. The study addressed fundamentals to microbial growth in a stepwise approach. Raw materials, substitution of preservatives, reducing water activity and plant hygiene have been assessed. Potential for avoidance of isothiazolinones was indicated, yet the study concludes that none of the tested alternatives had an effect equal to that of the tested biocide solutions and that the continued development and optimization of biocidal solutions is necessary.

In 2020, BAuA interviewed stakeholders in a study on alternatives for in-can preservatives for varnishes,

---

*[1] Paint generally comes in a can (or bucket). 'In-can preservation' refers to preserving the paint throughout its lifetime in the can, from production to first opening and possibly beyond.*

*[2] 'Sensitisation' is a health effect that can lead to a lifelong (irreversible) sensitivity to specific (but also to similar) allergens. People who are sensitised must avoid exposure to the allergen for the rest of their life if they wish to avoid the symptoms.*

paints and adhesives. They concluded innovations are currently limited to a combination of active substances. In addition, they conclude that there were no substantial hints to an especially high occupational risk resulting from in-can preservatives in any step of production and/or end use.

**Objectives**

This study follows up on previous studies and deviates from previous approaches by primarily taking a different angle, namely: **how to stimulate alternatives to biocides?**

It contributes to the understanding of:

1. Opportunities and hurdles to innovation to alternative safe in-can preservation of paints. Biocidal and other options will be addressed. Aspects for consideration are substance/product development drivers and blockers, as well as value chain evolution (e.g. demands from markets/users, new business models and information sharing)
2. The role of legislation and regulation in and outside Europe in research and development of paint preservation (e.g. what are potential buttons for authorities to use/push).
3. The lessons learned and which fruitful opportunities in material and product development can be further enhanced towards application and sizing. Cross-sector input will be taken into account (knowledge from e.g. food industry).

**Method**

*Literature study*

In first instance a literature study is performed to obtain an overview of preservation techniques. Reviews, news articles as well as scientific publications are evaluated and summarized. This provides directions for the initiatives for further exploration. This also generates sources, search terms and parameters for the next step, the web search.

Description of efficacy, costs, toxicity, influence on product and legislative context are addressed where possible.

Generic search terms were used (e.g. preservation, in-can, review, biocidal, biocide, paint, coating, shelf life, deterioration). From this initial search leads for specific techniques were followed up as well.

The search for publications was performed via internet (Google, Google Scholar, paint & coating and food (sector) organisations, companies, universities and their news magazines).

*Web search: who is doing what?*

A webscraper is developed to find initiatives related to in-can preservation online. The scraper has looked at paint manufacturers or related firms only, by scraping the websites of members of national paint associations. The key words that the scraper has looked for were taken from the literature study.

*Interviews*

In-depth, one-on-one interviews were held with relevant stakeholders, from manufacturers to DIY stores and research institutes. The interviews aimed to verify the information found in literature / the web crawl, and to gain additional insight in the playing field.

# 2 Understanding

## 2.1 Paint: food for microbes

### 2.1.1 Types of paint (coatings)

Paint is used to decorate, protect and prolong the life of natural and synthetic materials, and acts as a barrier against environmental conditions. It can also have a signalling function.

Paints may be broadly classified into *Decorative paints*, applied on site to decorate (and protect) buildings and other objects, and *Industrial or performance coatings* which are applied to buildings or in factories to finish manufactured goods. Industrial coatings include other application techniques than decorative paints, e.g. electrostatic powder coating. Powder coating requires heating of the subject and is not suitable for all subjects nor for in-situ application.

**Water based**
Paints can be categorized based on the used resin/binder: e.g. acrylic, alkyd and epoxy. Most water based (or: water borne) paints (i.e. emulsion paints) are acrylic paints. This research does not consider paint based on other solvents than water, such as organic solvents.

### 2.1.2 Ingredients of acrylic (water borne) paint

There are five main basic components of water borne acrylic paint**:**

1. **Water** (solvent)
2. **Binder** (organic resin)
3. **Pigment** (organic or inorganic, e.g. metal oxide),
4. **Extender** / Filler (inert material, e.g. chalk)
5. **Additives**

Binder and pigment are two crucial components that determine the quality of paint.

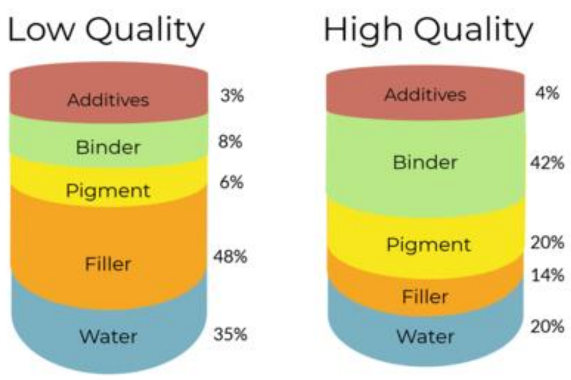



*Figure 2-1: Indicative composition of water borne paint. source https://www.513paintshop.com/blogs/team-513-paint-diary/launch-of-team-513*

**Water** is used for emulsifying the binder, pigments, and additives.

**Binder** is the film-forming component of paint, the vehicle that carries the pigment and then dries or cures, holding it in place. The binder is also responsible for adhesion, durability, flexibility, gloss, and other physical properties.
Binder per se is a chemical, for instances, acrylic polymers and epoxy polymers. It can only become useful when combined with solvent to form 'vehicle', which determines the characteristics of a paint such as slow or fast drying.
The binder in many water borne emulsion paints is based on homopolymers or co-polymers of ethenyl ethanoate (vinyl acetate) and a propenoate (**acrylic**) ester. Ethenyl ethanoate and an acrylic ester (for example, methyl 2-methylpropenoate) are co-polymerized as the applied, wet paint dries, forming a random array in which these groups link into a (cross linked) linear chain.[3]

Emulsion paints dry by a physical process involving the evaporation of water followed by coalescence of the polymer droplets and their subsequent integration into a hard polymer matrix.

Synthetic resins can be alkyds, acrylics, vinyl-acrylics, vinyl acetate/ethylene (VAE), polyurethanes, polyesters, melamine resins, epoxy, silanes or siloxanes. Natural binders are chalk, lime, casein (non-fat milk curds), animal or vegetable glues, and oil. Depending on the source, contamination can vary.
Many of the solid raw materials (incl.pigments and fillers) are produced by open mining, which can result in contamination with organic materials and microorganisms. They often contain biocides to avoid spoilage during storage, or are stored as solid powders. The latter do not require the addition of biocides. Contaminating organics and organisms could function as nutrition for bacteria in the formulated paint.

**Pigments** can be naturally produced by animals, plants or fungi, or can be synthesized. Pigments can be organic and inorganic. Very often pigments are metal compounds such as oxides. Natural inorganic examples are umbers, ochres and siennas; while synthetic inorganic examples are iron oxides for yellow/red/black, and titanium dioxide for white.

The percentage of **filler** in paint largely determines the quality of the paint. It serves to thicken the film and support its structure. Fillers are usually cheap and inert materials like chalk and clay. Hence, higher proportion of fillers in paint reduces cost as it can increase its volume.

**Additives** make up to approximately 3-4% of a can of paint. Yet, additives have huge contributions to the paint. Common additives include, but are not limited to: silicones to improve weather resistance, driers to accelerate drying time, anti-settling agents to prevent pigment settling, and dry-film and in-can preservatives.
Thickener, or rheology modifier, is a common additive. These can be both organic and inorganic. A common organic thickener in water borne paint is HEUR (Hydrophobically modified ethoxylated urethane resins).

**Formulation**
Paints are formulated according to their proposed use - primer, undercoat, special finishes (matt, gloss, heat resistance, anti-corrosion, abrasion resistance). Pigment powder is broken down into individual particles which are coated by and dispersed in the binder (resin). Solvent is then added to give the required consistency. Each batch of ingredients is mixed in large, stirred containers with the required additives. Formulation of paint is a batch process. Amounts ranging up to 40 000 $m^3$ of paint may be made in a single batch.

[3] *https://www.essentialchemicalindustry.org/materials-and-applications/paints.html*

### 2.1.3 What microorganisms need to feed on

(Micro)organisms need the following elements to grow and duplicate:

- Water
- Macro- and micronutrients. Essential for all microorganisms are C, H, N, O, P, S, Se.

Types of microorganisms, from fungi to Gram-negative and Gram-positive bacteria, are diverse. Hence, they feed on very different materials and in varying conditions (e.g. aerobic vs anaerobic). The above-mentioned elements may all be present in water-borne paint.

**Canned Paint vs. Canned Soup: what's the difference?**
Canned soup can be saved for years without going bad. And without the use of biocides. Why is this not the case for paint?
The two products are comparable to a certain extent: both contain a vast amount of water, organic material and some inorganic/inert material.
A main difference is the responsiveness of paint, more precisely the binder, to heat. Where a can of soup is sterilised by heat treatment, this treatment to a can of traditional paint could impact the binder and so the applicability of the paint. Processing of paint – which is designed to stick to surface – in e.g. a heat exchanger rapidly is also very different from for example milk in a pasteurization process.

## 2.2 Supply chain of canned paint

The supply chain of canned paint is displayed in Figure 2-2. In this paragraph each of these steps in the current, mainstream supply chain is briefly described, pointing out its relation to the need for preservation.

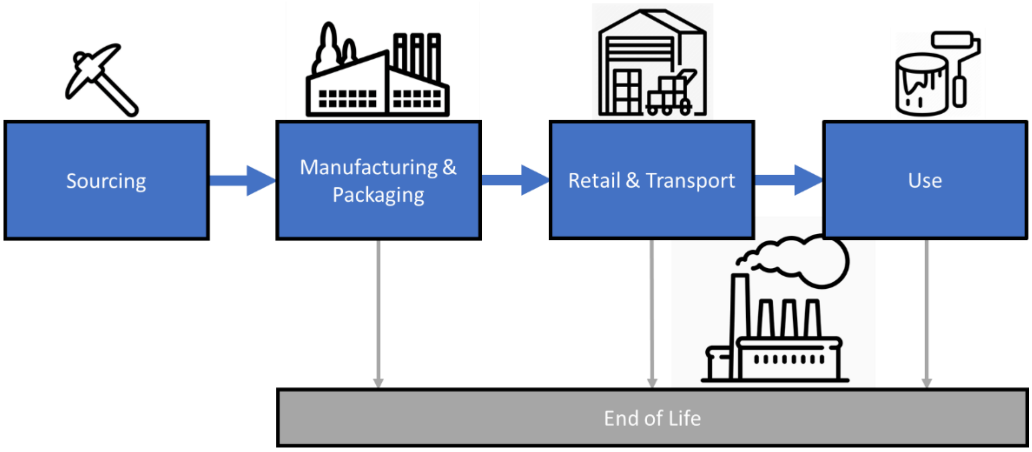



*Figure 2-2: Supply chain of canned paint.*

**Sourcing**
Sourced ingredients for paint production may have a natural or synthetic origin. Synthetic material generally bears less contaminants – potentially microorganisms – than natural material. Water borne ingredients such as binders are traditionally provided with biocides, preventing the ingredient to spoil.

Royal HaskoningDHV

**Manufacturing & Packaging**
Paint is produced in a formulation plant. Formulation plants do not chemically modify the ingredients; it is a matter of mixing. Chemical adjustment of binders, pigments or additives is done by or together with suppliers.
A paint plant does not have the same hygiene requirements as the food or pharma sector, which have high standards to prevent contamination of its products. Paint is produced in batches. Canned paint is estimated to be stored at the plant for up to 6 months before it is shipped to retail.

**Retail & Transport**
Traditionally paint is sold via wholesale to professional users and via DIY stores to consumers. DIY stores may be supplied by wholesale. Shelf-life at wholesale is estimated at up to 6 months, whereas shelf-life in consumer retail may exceed 12 months.

**Use**
Paint is expected to be used within weeks after purchase. Manufacturers adhere to the perceived ‘quality’ of their canned product which does not spoil after opening (on short term). In other sectors (e.g. food and pharma) consumers however are accustomed to the general principle of ‘spoilage after opening’ and ‘best before dates’[4].

**End of life**
Preservation of canned paint concerns the preservation until and including use stage. End of life is very relevant in the sense that there is a direct relation between preservation of canned paint and the amount of paint that deteriorates and is discarded. Paint may enter the end of life stage right after manufacturing, retail & transport or the use stage. Also see paragraph 2.3.1.
In the Netherlands, the minimum treatment of canned paint waste is use as a fuel in a waste to power facility, while recovering metals.[5]

## 2.3 Biocides

### 2.3.1 Why add biocides?

Water-based products are susceptible to microbial contamination. Contamination can be introduced during a variety of stages in the product life cycle, mostly in sourcing, manufacturing, packaging and usage.

Microbial susceptibility can cause product degradation, reduce product performance, induce hygiene and human health issues or potentially cause safety issues when microbial degradation causes bulging containers, pails or drums. This could result in a wide range of possible consequences, including product recall, customer complaints or legal claims, reduced perception of product quality, production stoppage, etc. For these reasons, manufacturers add biocides to their waterborne products.

### 2.3.2 Legal Framework

**Biocides - BPR**
The Biocidal Products Regulation (BPR, Regulation EU 528/2012) concerns the placing on the market and use of biocidal products, which are used to protect humans, animals, materials or articles against harmful organisms like pests or bacteria, by the action of the active substances contained in the biocidal product.

*[4] It should be noted that sectors with ‘spoilage after opening’ or ‘best before dates’, like food and pharma, face a large end of life (waste) challenge.*
*[5] LAP3, Sectorplan 42, ‘Verpakkingen met verf, lijm, kit of hars’*

Royal HaskoningDHV

This regulation aims to improve the functioning of the biocidal products market in the EU, while ensuring a high level of protection for humans and the environment.

In general, all biocidal products require an authorisation before they can be placed on the market, and the active substances contained in that biocidal product must be previously approved for that product type (in this case PT6) and use. The latter also applies to treated articles, such as paints that are imported from outside the EU.

The BPR aims to harmonise the market at Union level; simplify the approval of active substances and authorisation of biocidal products; and introduce timelines for Member State evaluations, opinion-forming and decision-making.

*Preservatives*
In Annex V to the BPR the biocidal products are classified into 22 biocidal product-types, grouped in four main areas. Preservatives form one of four product-type groups under the BPR. The biocides used for (in-can) preservation (of paints and coatings) fall under product-type *PT 6 - Preservatives for products during storage.*
The use of preservatives in food and cosmetics are excluded from the BPR. These are regulated in Food Regulation and Cosmetics Regulation respectively.

*Limited availability for consumers*
Based on risk, the use of personal protective equipment (PPE) may be needed for approval and authorization. Paints requiring PPE will mainly be available for professional users, because of their training and obligation to use PPE/availability of PPE. There are very limited circumstances for consideration of PPE in consumer exposure, because people will not necessarily use PPE even though recommended by the manufacturer. Even when PPE is provided with the product (e.g., gloves with the can), this will not ensure that consumers will use it. If this concerns in-can preservatives (biocides) for paints, it would at least require additional labelling and providing equipment with the can to be sold in the DIY segment.

**Food Regulation**
Regulation EC 1333/2008 sets the rules on food additives: definitions, conditions of use, labelling and procedures. All additives in the EU must be authorised and listed with conditions of use in the EU's positive list (Annex to the Regulation). The list does not categorize for product use; i.e. there is no category ‘preservatives’, although conservatives and food acids are put together in a group with E numbers between E200-E300.

**Cosmetics Regulation**
Regulation EC 1223/2009 on cosmetic products is the main regulatory framework for finished cosmetic products when placed on the EU market. It entails a negative / restriction list for additives (Annex II and III). Annex V is a positive list of preservatives allowed in cosmetics.

**Paints Directive**
Directive 2004/42/EC of the European Parliament and of the Council of 21 April 2004 on the limitation of emissions of volatile organic compounds (VOC) due to the use of organic solvents in decorative paints, varnishes and vehicle refinishing products and amending Directive 1999/13/EC ("the Paints Directive") aims to prevent the negative environmental effects of emissions of VOC from decorative paints and vehicle refinishing products. It does not address the use of biocides as such.

**REACH**
REACH is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals: Regulation (EC) No 1907/2006 of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals. In

principle, REACH applies to all chemical substances; not only those used in industrial processes but also in day-to-day lives, for example in cleaning products, paints as well as in articles such as clothes, furniture and electrical appliances. Biocides regulated under the BPR are regarded as registered under REACH (art 15) and are exempted from authorisation under REACH (art 56).

### CLP

Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures (CLP Regulation) is the EU interpretation and consequently implementation of the Globally Harmonised System (GHS). It determines - based on hazards of substances or products - what information should be provided on labels and packaging, and in addition what this means for transport and storage.

### Criticism of today's legal framework

Regulatory restrictions, consumer, NGO, and retailer pressure have reduced the current palette of safe and effective preservatives available to formulators of paints.

The number of actives that can be used as in-can preservatives in paints under the framework of the biocidal product regulation is around 50 substances[6]. However, most of these substances cannot be used in paints and coatings for technical reasons. Criteria include broad antimicrobial efficacy, stability over a specific pH-range, stability in the respective temperature range, water solubility in the required concentration range, compatibility with the respective raw materials, no negative effect on color and rheology, acceptable (eco)-toxicological properties and cost-efficiency.

The two main families of in-can preservatives used by members of the European Council of the Paint, Printing Ink, and Artist's Colours Industry (CEPE) comprise 18 substances: 13 formaldehyde adducts and 5 isothiazolinones. Taking the technical boundaries into consideration, the number of mainly used biocides comes down to around 13. But not all those substances are applicable for all applications. Each active has a certain efficacy spectrum and is not active against all microbes. This is demonstrated for some important actives in the figure below.

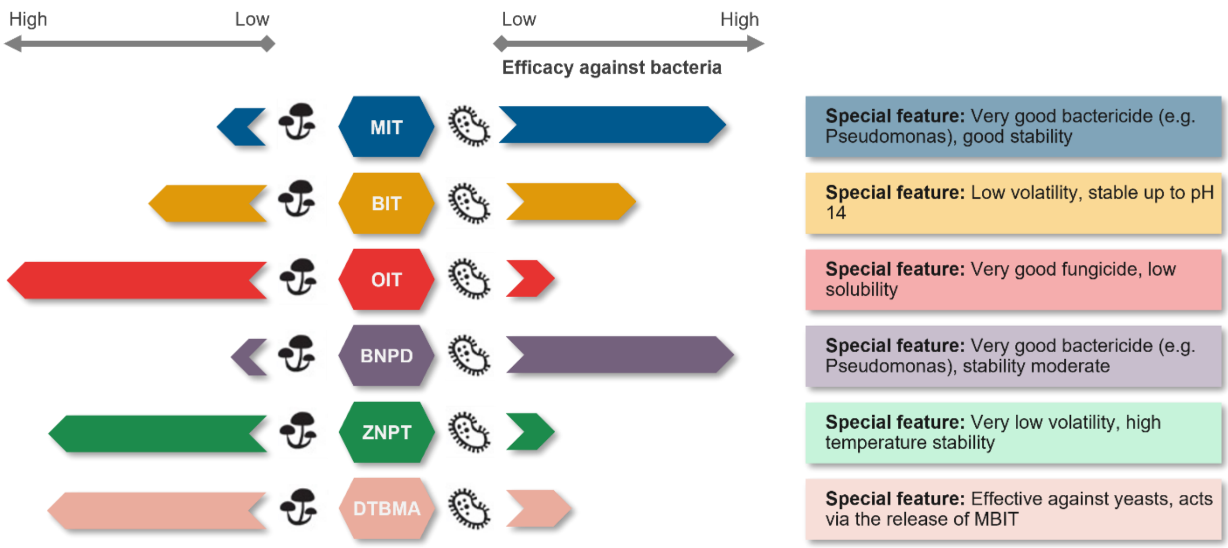



*Figure 2-3: Overview of common biocides. Source: VdL*

[6] *47 in 2018 (CEPE)*

The Biocides Knowledge Network (KNB) of the Netherlands has spoken with companies and trade associations in the preservatives industry[7]. The interviews were prompted by reports of an ever-shrinking availability of preservatives.

The BPR and CLP legislation assess substances one by one, separately from each other. Companies advocate a holistic approach in which policymakers take into account the entirety of preservatives on the market and recognise the specific demands for waterborne paints. An approach in which policymakers first consider the socioeconomic impact and the environmental and health consequences before banning or restricting an active substance.
In 2014 and 2017, memoranda were published to competent authorities advocating this approach by European industry associations, including CEPE and AISE (European trade associations for the paint and detergent industry respectively). However, the European Commission currently has no intention to amend the Biocides Regulation.

The mismatch between the different legislations is also mentioned as a hurdle or unlevel playing field. For example, preservatives in cosmetic products are not subject to the BPR or CLP regulation, but to the Cosmetics Regulation, where restrictions may differ from those in BPR of CLP.

[7] *https://www.kennisnetwerkbiociden.nl/conserveermiddelen-worstelen-met-wetgeving*

# 3 Previous research

This chapter summarizes the main findings from previous research on paint preservation and related research. The main findings are:

1. The use of biocides and alternatives for in-can preservation have been investigated in recent years. Common, well known biocide combinations have been investigated in different ratios. They were considered essential for sufficient preservation.
   Raw material and production hygiene also had an important contribution to avoid or delay spoilage.
   Nanotechnology is scarcely mentioned.
2. Research is extensive in describing the current decrease of available biocides and technology but tends to focus on 'replacing the biocides we have today', i.e. 'like for like' – not focusing on the preservation quest in a broader sense.
   Combinations of promising substances or technologies, e.g. 'hurdle technology', are not yet investigated or reported.
3. Publications by coating organisations or paint manufacturers do not indicate 'out of the box' technologies, e.g. technologies and hygiene standards from the food sector. It is not known if these have been fully explored yet.
4. Applicability of biobased molecules in full formulation appears a good opportunity. A combination of efforts from sourcing to packaging also shows a decrease of the need for conventional biocides.
5. No studies were found targeting the stimulation of biocide-free preservation,
   Studies found in the literature search focus on one or more elements instead of addressing storage stability without biocides as total concept.
6. The main focus on alternatives is directed to biobased molecules with anti-microbial properties (enzymes, or proteins), polymers with anti-microbial structures incorporated and packaging solutions.

## 3.1 Literature study

### 3.1.1 Paints/coatings preservation

The **Danish EPA** study **(2018)** proves by many experimental results that raw materials for paints are a significant source for microorganisms. Substitution of selected components in raw materials can have substantial benefit to the resistance to spoilage, partially because they can also interact with added biocides. Different combinations without isothiazolinones seem possible. Reducing water activity was not considered a viable option because of the required amounts of additions to achieve low water activity on the properties of the paints. Finally, reconstruction of production facilities to higher hygiene standards was proven to be beneficial to reduce product returns due to spoilage.
The study did address fundamentals to microbial growth in a multiphasic approach. However, they did not investigate e.g. potential anti-microbial (biological) additions, physical techniques, biotechnology, use of nanomaterials or final product packaging as source for or option to control microorganisms.

The **BAuA (2020)** report indicates that found literature was considered of minor importance to their research as it was not specifically addressing replacement strategies for existing biocides. Their summary from interviews details two methods for avoidance of in-can preservatives, silicate paints and dry paints. No options for other methods have been suggested as feasible, because of 1. effective concentrations of additions would be too high, 2. potential for hydrolysation under alkaline additions or 3. alcohols which are regulated in VOC emissions.

Other in-can biocidal preservatives are mentioned to be progressively scarce, due to the effort and investments for a dossier to be accepted under the Biocidal Products Regulation (BPR, Regulation (EU) 528/2012) and recent restrictions on available biocides. Innovations are currently limited to a combination of active substances. Optimisation of hygiene in production is implemented or in progress.
The study did not address fundamentals of preservation in detail e.g. factors controlling growth, boosting biocidal effect, water activity adjusters, which have been investigated in the Danish EPA study. By means of interviews interpretations by stakeholders were discussed. The survey did not provide evidence-based results of avoidance of in-can preservatives, but primarily focussed on ways to reduce the amount of isothiazolinones in existing use by replacement /alternative known active substances and hygiene.

**McDaniel et al. (2019)** studied examples of biobased molecules which include enzymes like lysozyme and glucose oxidase, small peptides similar in activity to natural antimicrobial peptides like defensins, but smaller in molecular weight and even whole cells containing such molecules. By retaining the natural biological function (in either direct antimicrobial activity or synergistic activity with a traditional biocide) it is possible to utilize these molecules in liquid and dry film coating systems. Glucose oxidase (GRAS in food – generally recognized as safe) works with traditional biocides synergistically. AMP7 (7 amino acid peptide) works on its own.

**Hodges et al. (2018)** used screening for selection of candidates with anti-microbial activity. Metabolic activity of living cells was the parameter of interest which would correlate to the standard ASTM D2574 used for emulsion coatings in a container. From an initial panel of 30 enzymes, peptides, and small molecule natural products, 23 were selected for evaluation. These were screened against individual members of a microbial contamination panel using the XTT assay. Nine of the 23 bio-based additives were found to reduce cellular metabolism in the XTT assay by ≥ 50%.
Potential to overcome a resistant contaminant was indicated by selection of disruptive properties impacting distinct cellular components to achieve synergistic effects, with a lysozyme, AMP-7, glucose oxidase, and alginate lyase combination as an example. Alginate lyase targets the extracellular polysaccharide layer, AMP-7 disrupts cellular membranes, lysozyme cleaves bacterial cell wall peptidoglycans, and glucose oxidase produces hydrogen peroxide that can induce cellular damage. The research suggests initial metabolic or other rapid-throughput assay has potential to predict likelihood of success of bio-based biocides as in-can preservatives.

**Levin et al. (2019**) indicates there are also a few emerging technologies that could be the next-generation biocides for coatings. The first technology direction is biological-based solutions. Examples include kimchi fermentation peptides or an amino acid-based antimicrobial system. A second future direction is antimicrobial polymers, which incorporate functional ingredients into a polymer structure. The last direction for biocide-free coatings is through packaging.
Their experimental acrylic and styrene acrylic binders and experimental specialty HEUR rheology modifiers showed lower potential for microbial spoilage than traditional products. Dow developed several experimental binders that passed microbial challenge tests and have formulated these binders into simple paints that also passed challenge testing. It was also confirmed that by optimizing the HEUR polymer and formulation, the HEURs passed multiple challenge tests. The results indicate that possibilities exist to create sustainable and robust raw materials with reduced susceptibility to spoilage.

**Bechtold et al. (2020)** evaluates the biocidal effect of silver nanoparticles in the water-soluble polyurethane paint composition. The effect in terms of yellowing and gloss variation was evaluated by a UV-B radiation test. Silver nanoparticles showed no effect on the gloss and yellowing paint film. Also, positive results were obtained for the protection and resistance against bacteria however resistance against fungi was not satisfactory.

### 3.1.2 Food preservation

Techniques used in food preservation have physical, chemical or biological bases.

**Physical techniques**

**Chemat et al. (2017)** reviews techniques like microwave, ultrasound, pulse electric field, instant controlled pressure drop and supercritical fluid processing. These are currently in practise in food preservation. A summary of properties is provided in the below picture:

**Table 6**
Characteristics, main disadvantages and advantages of green extraction techniques.

| Technique | Investment | Sample size | Processing time | Main disadvantages | Main advantages |
|---|---|---|---|---|---|
| Ultrasound | Low | 600 L | Low | Problem for separation | High cell disruption |
| Microwave | Medium | 150 L | Low | Hot spots | Cell disruption |
| DIC | High | 100 L | Low | High energy consumption | High cell disruption |
| SFE | High | 300 L | Medium | Need of know-how | Enhance mass transfer |
| PEF | High | Continuous | Medium | Difficult ease of operation | Electroporation of wall cells |

**Smelt & Brul (2014)** review effects of heat towards food preservation. Traditional canning methods aimed at destruction of all spores (sterilization) or of all spores that can grow in the container below 40◦C. Microorganisms are far more resistant to dry heat than to wet heat. Whereas dry heat resistance is relevant in particular for disinfection of materials such as devices for surgery, in food microbiology most attention has been paid to wet heat resistance. In dry heat treatment, microorganisms are thought to be inactivated by oxidation, whereas protein denaturation and membrane damage seems to play an important role in wet heat inactivation. Bacterial spores are generally the most heat-resistant forms, although the heat resistance of these spores varies considerably.

**EFSA – food additives.** EFSA lists E-numbered substances (food additives) which are used to enhance the colour, flavour, texture or prevent food from spoiling. Indicated groups are antioxidants (to prevent deterioration caused by oxidation), colours, emulsifiers, stabilisers, gelling agents and thickeners, preservatives and sweeteners. Numbers 200 to 299 are indicated as the preservatives, but not exclusively (e.g. Lysosome, E1105). These are added to prolong the shelf-life of foods by protecting them against micro-organisms. Their safety assessment and approval are the responsibility of the European Food Safety Authority.

**Naturally derived preservatives for food**

**Gokoglu, N. (2018)** reviews several naturally derived preservatives. Natural preservatives can be obtained from different sources such as plants, bacteria, fungi, animals and algae. Herbs and spices are considered alternative sources for novel antimicrobial compounds although they are mostly isolated from bacteria and fungi. Plant extracts have antimicrobial activity due to their phytochemical components. Various plant extracts possess antimicrobial activity against a range of bacteria, yeast and molds. Animal based enzymes may exert antibacterial activity by a number of different mechanisms. Lysozymes and other antimicrobial enzymes primarily exert their antibacterial activity by inducing bacteriolysis via catalytic cleavage of cell-surface polymers or cell-wall junctions. Lactoperoxidase, and other peroxidase systems, work antimicrobial. Antimicrobial peptides (AMPs) are oligopeptides containing amino acids in various numbers. AMPs are small biological molecules with a broad-spectrum of activity against bacteria, fungi, protozoa, and some viruses. They are part of the natural defence system of living organisms.
Bacteria produce many compounds that can be used to prevent potential spoilage or growth of pathogenic microorganisms. Food-grade microorganisms can form many different substances that inhibit other microorganisms. Bacteriocins, organic acids, hydrogen peroxide, carbon dioxide and diacetyl produced by Lactic Acid Bacteria (LAB) are their antimicrobial components. Both gram-negative and gram-positive bacteria produce bacteriocins. The LAB bacteriocins have greater antibacterial activity at lower pH values. They have applications in hurdle technology and utilize synergies of combined treatments to enhance

effectiveness in food preservation. Others have found that application of chemical preservatives, thermal or non-thermal physical treatments [pulsed electric field (PEF), High Hydrostatic Pressure (HHP), vacuum, or MAP] positively affects the activity of many bacteriocins by increasing the permeability of cell membranes. Recently research focused on incorporating bacteriocins into food packaging films to control food pathogens. Antimicrobial packaging film prevents the growth of microorganisms on the food surface by contact of packaging material with the surface. Nisin with lactic acid showed synergistic effect in inhibition of Pseudomonas spp.

**Tkaczewska, J. (2020)** addresses protein hydrolysates and biologically active peptides. Protein hydrolysates and biologically active peptides isolated from food proteins, due to their antioxidant and antimicrobial activity, can be used as natural food preservatives. Also, it is possible to include them in packaging materials as preservatives. Full implementation of bioactive peptides and protein hydrolysate suffered from challenges such as their low chemical stability, bitter taste and short-term effectiveness. Encapsulation might assist to overcome these limitations.
Antimicrobial peptides are typically composed of less than 50 amino acids, nearly half of which are hydrophobic. Moreover, these peptides have low molecular weight. Electrostatic interaction of peptides with the cell membrane of microorganisms causes the antimicrobial peptide mechanism of action. Antimicrobial peptides are characterized by membrane permeabilizing action.
The matrix to which bioactive peptides are added, may limit their industrial use. Proteins, proteases, fats and metal ions may interfere in the interaction of antimicrobial peptides with their target pathogen, either by reacting to the antimicrobials directly or by interacting with the cellular target(s) for antimicrobials. The integration of natural derivatives such as protein hydrolysates, bioactive peptides and bacteriocins in edible films, applied to inhibit the growth of microorganisms, has been successfully executed. Casein hydrolysates have pronounced antimicrobial and antioxidant properties. Peptides will be constantly released from the coating to the surface of the product, supporting effective concentrations. Active ingredients of coatings require smaller amounts of these substances compared with direct addition to the entire product.
Active coatings with peptides can be obtained in three ways: direct inclusion of the peptide into the polymer matrix, peptide coating on the polymeric surface and peptide immobilization in the polymer. Microencapsulation can be applied to release the active material slowly over time and at a constant rate, protecting the core material from degradation and reducing the evaporation rate of the core material or to the surrounding environment.

### 3.1.3 Packaging (surface coating)

Rather than applying microbial barriers in the paint itself, one could also think of applying such barriers in the packaging of paint.

**Mahmoud et al. (2017)** describes a technique which interacts with microbes in a physical way. Surface treatment with specifically designed and shaped (paint) coatings is an example. Unlike traditional biocides, this technique does not poison microbes by leaching of a biocide from the surface coating but interacts with microbes in a physical way. It modifies the binder (acrylic polymer) in such a way that the binder itself becomes anti-microbial and forms the physical barrier.
Coatings or paints with this technique are suggested to be used successfully on walls, ceilings and floors in virtually any environment such as bathrooms, kitchens, and public buildings. Whether such binder also can be applied in the composition of inner lining (coating) of a can containing a paint is however not specified.

**Yeung King Lun and co-workers (2020)** have developed a Multilevel Antimicrobial Polymer (MAP-1) coating (dry film) that is effective in killing viruses, bacteria and even hard-to-kill spores. The essence of the new coating technology lies with the creation of surface moieties that actively disrupt the microbial envelope and biomolecules, rendering the microorganisms nonviable upon contact. The coating also prevents microbial adhesion on the surface and thus keeping it clean from microbial contaminants. Using a special blend of antimicrobial polymers, the new coating is claimed to effectively kill up to 99.99 % of bacteria and viruses through contact killing and anti-adhesion technology.

### 3.1.4 Physical form

**Encapsulation**

**Saini et al. (2021)** highlights the urgent need for efficient techniques to preserve food for a long time. This potentially can be done by encapsulation in nanocarriers such as nano-emulsions, nanoliposomes and nano-lipid carriers. These nanocarriers protect functional ingredients such as polyphenols, vitamins, minerals, flavours and antimicrobial agents. Nanocarriers improve stability, functionality, entrapment efficiency and controlled release of functional ingredients.

## 3.2 Alternatives

Technologies to preserve paint can be categorized into two main categories: Formulation and Non-formulation (Treatment). The use of biocides falls under formulation controls. This is illustrated by the figure below.

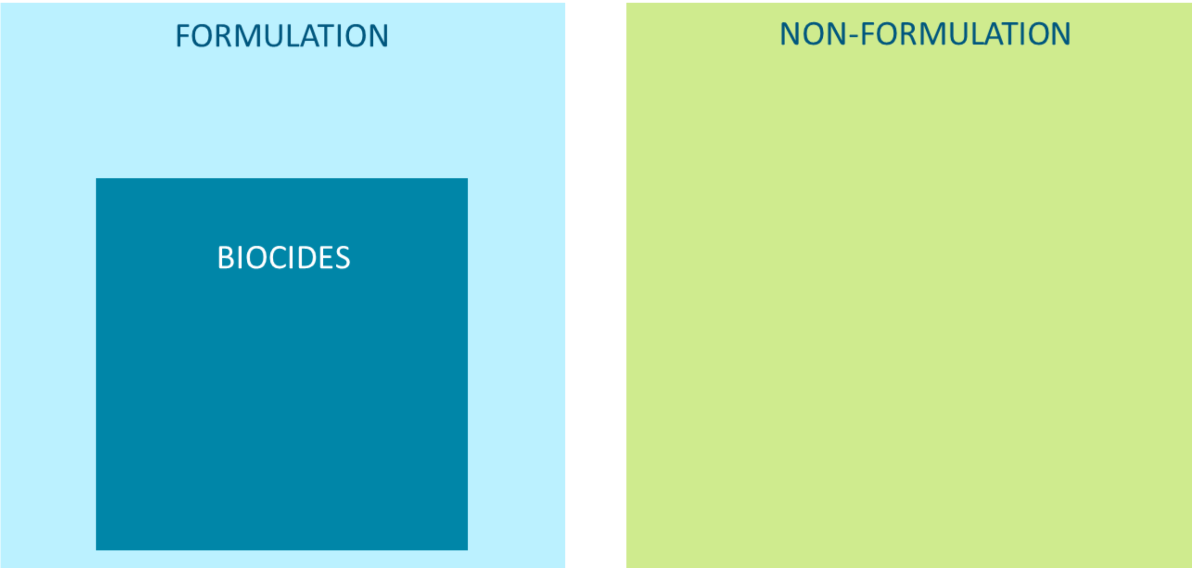



*Figure 3-1: Types of preservation technologies*

**Biocides**
The category of biocides includes all additions aimed to kill micro-organisms. It includes 'like for like' – a new yet similar biocide, but also other types of biocides, including natural biocides and preservatives found in food and cosmetics. Next to 'biocide as an additive', polymers themselves may be designed to have anti-microbial impact. Finally, biocide-killers can be added, making that the biocide itself is degraded in time.

**Formulation**
Alternatives to biocides within the field of 'Formulation' mainly relate to making the in-can paint less susceptible to biodegradation. This can be done mainly in the organic content (binder, additives), water (creating high alkaline (or acid) environment) and the extraction of water (powder paint).

**Non-formulation**
The section 'non-formulation' concerns everything that is not the paint itself. This includes product treatment (e.g. heat), packaging and supply chain optimization. For each of these, examples are found in the coatings industry.

**Food Tech**
The food sector has a long history in preservation technology. Classic technologies are freezing, salting, sweetening, acidifying, drying and heating. Whereas the latter three are covered in other sections, the first three technologies are reckoned unsuitable for the paint industry due to product impact.
Modern product treatment technologies from the food industry include process controls such as Thermo-mechanical treatment (instant controlled pressure drop), Pulsed Electric Field treatment, Super critical fluid, Micro-wave, and Ultra-sound. Given their application (food), these technologies come with high volumes, zero toxicity and, depending on the technology, relatively low costs. Their applicability to the

coatings industry however appears very little studied (reported), possibly because there is no direct fit, i.e. formulations need to change to allow for these technologies to be effective and not negatively impact the product. In addition, the food preservation techniques are not available in the laboratories of paint manufacturers.
Natural or synthetic additives are covered in the section ‘Biocides’.

A detailed overview of alternatives and a review per technology is included in annex A2.

Royal HaskoningDHV

# 4 Web search

This chapter presents the results of the web search and provides details on the method used.

We have searched the web for in-can preservation initiatives using a 'web scraper / crawler'. This is an automated search query.
Main reason for using an automated search query rather than manual search is assurance that a vast share of the industry is actually and fully reviewed.

The used method is listing of relevant websites and scraping of these websites for given key words. The tool plots excerpts with the found key words in an excel file (including website and company info). A manual analysis following this automated exercise determines the actual relevance of fount 'hits'.

The relevant websites were taken from membership information shared by (national) paint industry associations. We have focused on industrialized countries as these are thought to have the most mature organization of paint manufacturers and related stakeholders. A list of reviewed paint industry associations is given in annex A3. A list of company websites derived from this is given in annex A4.
The key words used were termed 'goal key word' and 'tech key word'. The aim was to find relevant combinations of these types of key words. The key words are derived from the literature research. The key words used are given in annex A5.

## 4.1 Results

For the web search, the tool we have built has looked at ca. 850 websites, derived from ca. 30 member associations / listings. The number of websites includes some duplicates as multinationals have different entities in different countries, and so end up multiple times in the list.

An example of output is given in annex A6.

The results of the web scraper are not as expected. It has taken a vast amount of time to firstly attain appropriate links to websites, and secondly to get excerpts that are long enough to make sense and short enough to be practical.
Additionally, the scraping itself takes a lot of time on various computers, despite the scoping we've done inherent to the method. This lead time is not helping in fast adjustments of the tool.

We did not find many hits with the used methodology. In a selected scope of VVVF-members only, we've found 97 hits for 'biocid', and 11 hits for 'biocid' + 'free'.

## 4.2 Analysis

The accuracy of the tool is perceived to be low. Therefore, we are not confident to draw conclusions from the results only.

The results show little relevant hits for alternatives to biocides in in-can preservation. This however does not directly mean that companies are not communicating about this topic, given the accuracy of the tool. For example, some known initiatives do not turn up in the results.

However, as we've found out later during the interviews, it is confirmed that the majority of the companies are not actively communicating about biocide-free in-can preservation on their websites.

# 5 Interviews

This chapter presents the results of the interviews. In-depth, on-on-one interviews were held with relevant stakeholders, from manufacturers to DIY stores and research institutes. The interviews aimed to verify the information found in literature / the web crawl, and to gain additional insight into the playing field.

A list of interviewees is included in annex A7.

## 5.1 Understanding the manufacturer

### 5.1.1 The need to preserve

**From solvent to waterborne**
Over the past decades, paint manufacturers have switched from solvent based paints to waterborne paints. Main reason was the reduction of volatile organic compounds (VOC), aiming to perform better on health and environmental aspects. This switch however made paint vulnerable to spoilage. Biocides were and are added to avoid spoilage. Biocides are also used in the raw materials (e.g. binders) that paints are made of.

Paint manufacturers generally have a large product portfolio: many different recipes for many different applications / markets, based on many different ingredients. One participant indicates to use over 7000 raw materials in Europe alone, in around 350 product lines, each with several product variations. Microorganisms in addition come in many variants. These facts combined indicate the difficult landscape manufacturers operate in when it comes to preservation of their products. Up to today, biocides are considered the only commercially available, all-round preservation technology for waterborne paints.

**Spoiled paint**
There is a lack of standardized methods to check the number or species of microorganisms present in a bucket of paint, and there are only some criteria to conclude sufficient protection against spoilage used for efficacy trials. For example, ASTM D2574 identifies toxic agents which kill all challenge organisms, but fails to selectively identify agents effective against particular strains. DNA sequencing methods allow identification and hence more precision treatment.
In practice, most paint is spoiled when it looks or smells bad. That's when people return the product. Paint properties can be impacted by spoilage, which can influence the performance of the coating and/or stability of the emulsion (i.e. application issues), but this is not necessarily the case.
Products are tested for shelf life by manufacturers. This is done organoleptically (looking and smelling), and/or by microbiological methods assessing the presence of microorganisms. Paint manufacturers may also conduct microbiological testing to determine the lowest concentration of preservative efficacy within paint formulations.

**Shelf life and continued use**
For most applications, quality of paint is guaranteed up to first opening of the can. Yet, manufacturers anticipate customer's expectations on continued use after opening. With biocides, in general paint can be used months after opening.

Shelf life (production to purchase) is up to 5 years. This means the canned paint should stay stable for at least 5 years.
Reasons given for this shelf life is firstly a discrepancy between production and demand. Demand generally comes in peaks (people paint more in spring/summer) while manufacturer's production lines are optimised for stable, all year-round production. In some production lines and for some markets (mostly

larger construction projects), ‘on demand’ production is possible, but this is not considered a viable production method for all purposes.
Secondly, partly due to the indicated time between production and usage, both the manufacturer and retail partners rely on certain flexibility by having canned paint in stock for some years if needed.

### 5.1.2 Organization of innovation

All interviewed manufacturers have an RD&I department. Larger players have their own labs while smaller players cooperate with research institutes and external laboratories. This general approach concerns innovation in the sector in general and in-can preservation in particular. Innovation on in-can preservation requires knowledge of microbial control, effective preservation formulation solutions combined with technology strategies. Major manufacturers include regulatory aspects in the early stage feasibility study of new developments.

Paint manufacturers are generally ‘only’ formulators; there is no chemical processing. Only some larger paint manufacturers can also manufacture key raw materials , e.g. polymers, rheology modifiers, or colorants. Hence, most important innovation partners are raw material suppliers. Product research is done with suppliers of binders, pigments, fillers and other additives.

Availability and procurement of raw materials, including biocides, is considered a sector risk for the paint manufacturing sector. How to handle this risk however is considered part of competition: efforts to adjust formulations are initiated and organised per company, not as an industry sector. Joint activities are mainly on a technical or communicational level, restricted to e.g. standardization and lobbying.

**Innovation takes time**
Innovation takes time, in ideation and development, but also in testing. One can only know if a paint stays stable for two years if two years have passed (though there are possibilities of accelerated storage testing). A preservation technology change is more disruptive than replacing a single ingredient, hence more RD&I time is to be expected. In most firms, RD&I departments distinguish long term and short-term innovation projects.
The only alternative preservation technology in the market today, for white wall paint, took about 15-20 years to mature.
As part of the manufacturer’s ongoing activities, they deal with single ingredient replacements (‘like for like’). These are considered smaller / short term innovations. Yet, even for these types of innovations an average time the market introduction is 3-5 years (of which ~2 years for dossier requirements, after selecting of substitute). The devil is in the details – a participant says - there is so much finetuning, a variation of one parameter / ingredient may cause the solution not to work.
Interviewees indicate that RD&I for in-can preservation is ongoing, and some say that in 5 years’ time there may be a new commercial solution available – not specified what solution.

### 5.1.3 Drivers for innovation

It shows there is no shortage on knowledge and innovation capacity per se. Neither on RD&I budget, sponsoring or funding. What is missing from a paint manufacturer’s side when it comes to innovation on in-can preservation is 1) a clear match with company’s ambitions, and 2) a solid business case.

**Company's ambitions**
All interviewed paint manufacturers show to have ambitions related to sustainability. Important aspects are for example $CO_2$ (energy, transport), packaging (lightweighting, recyclability) and sourcing. These are aspects manufacturers have targets for and can relate to with performance claims (e.g. kg $CO_2$ reduction). 'Health' is considered part of the sustainability equation. But when it comes to numbers, industries see other aspects as more impactful than the use of biocides. An evident link to existing, measurable targets is missing. In other words: the 'claim' companies can make to commercialise their products successfully does not directly fit with other sustainability criteria like reduction on energy, resources and packaging. On the contrary: alternatives may be regarded as less sustainable, due to e.g. increased energy consumption or spoilage of paint. In particular it is noted that 'natural' paints cannot do without biocides for preservation.

*"A responsibly preserved product has the highest score on sustainability"*

Additionally, a claim for a single product as biocide-free bares the risk of perceived negative image of other products in the portfolio: what does it mean that other paints do contain biocides?
RD&I departments throughout all interviewees are found to be working towards (sustainable) alternatives for listed substances. But a clear match between reduction of biocide use and other parameters in a company's sustainability ambition is mostly missing or may even be in conflict. Paint manufacturers do not regard the reduction of biocide use as an end goal – the goal is to preserve responsibly, within a holistic sustainability view. This illustrates the complex background for industry response to listing of substances.

**Solid business case**
Key for each (commercial) innovation is the business case. Regarding in-can preservation, the business case is often not solid. For paint manufacturers seeking alternatives, the investments are not too high per se, but uncertainties in revenues are too large. These uncertainties relate to anticipated (lack of) customer demand and public opinion on substances c.q. changes in the regulatory framework. These aspects are further discussed in chapter 5.2 Market and 5.4 Regulatory framework.

*"Research funds are not a bottleneck for innovation. Time frames are, as well as changes in legislation/requirements during the process."*

### 5.1.4 Conclusions

- By switching to waterborne paints, a need was introduced to preserve paints with biocides.
- 'Sustainability' is a theme for all paint manufacturers, largely influencing the RD&I agenda. Yet, 'reduction of biocides' is not an end goal for manufacturers, and it does not clearly or necessarily match manufacturer's other sustainability goals, e.g. energy or CO2 reduction. This results in a complex issue. And while industry efforts are high on many (sustainability) topics, efforts on reduction of biocidal use do not always surface.
- Paint manufacturer's RD&I is sufficiently organized, connected with partners and funded where needed. What is missing from a paint manufacturer's side when it comes to innovation on in-can preservation is 1) a clear match with company's ambitions, and 2) a solid business case.
- Shelf life is a main factor determining the need for preservation: if shelf life is reduced, paint requires less preservation effort. It would require a system change, including manufacturer, retailer and user, to reduce shelf life.

## 5.2 Understanding the market

*“80% of the volume of all decorative paints today can be preservative free. A basic solution is available; it is a matter of market. For the remaining 20% a solution will come in time. For now, the focus should be on making the existing technology available, not so much to reach the next level for the remaining 20%.”*

The main biocide free paint on the market today is white (and factory tinted), interior wall paint on the DIY market. In Germany, this market is matured with an estimate of 50% being biocide-free.
In most other countries, biocide-free paint – if sold at all - is a niche product, sold as a hypoallergenic, i.e. marketed for allergic/sensitised people. Biocide-free paints are on average more expensive than those containing biocides (up to 30% more costly – though some parties claim identical pricing at the store), making them less popular at the wider public if this is charged on in the pricing.

Manufacturers indicate that the customer is leading when it comes to the use of biocides. Multinationals with biocide-free formulations for the German market do not sell these in the same way in other countries – the local market is leading and demand for biocide-free paint seems to be lacking in most countries.
If any (additional) governmental steering should be done on the substitution of biocides, manufacturers prefer this to go via the market.

Most manufacturers do see a role for biocides in an effective, sustainable in-can preservation strategy. Then again, some manufacturers are fundamentally quite neutral on the topic. As one participant says: “We have no intrinsic preference – with biocides or without. Both are fine for us, as long as we fit with the market.”

*“We have no intrinsic preference – with biocides or without. Both are fine for us, as long as we fit with the market.”*

### 5.2.1 DIY (Do it yourself)

DIY concerns the consumer market. At least for the Dutch market, the buyer decision is mainly based on pricing. Paint manufacturers and retailers indicate that ‘sustainability’ is not a key part of the buyer decision. Based on customer interviews, a slight increase is seen in interest in sustainability. But in all, sustainability is still not a key question for customers. One participant estimates that 95% of buying decision is price, leaving only 5% for quality, sustainability, branding etc.

*“In DIY, 95% of buying decision is price, leaving only 5% for quality, sustainability, branding etc”*

Labelling plays a special role. In the German DIY market, labels are very influential. Because German DIY stores tend to mainly sell labelled/listed products, labels like Blaue Engel and listings like Stiftung Warentest largely dictate shelf position in the stores: with a label you are in, without a label you are out.

Since 2019, Blaue Engel has included 'preservative-free' in its requirements for white (indoor) wall paints (recently expanding to factory and in-store tinted indoor wall paints). This is considered the main driver or momentum for the large scale development of the biocide-free white wall paint market in Germany. NB, such labels could only do this after several companies had their solutions for preservative free wall paint commercially available, not creating a monopoly or no labelled paint at all.
Criteria for ecolabels in Europe differ, even where it concerns the use of biocides for preservation. For example, the Norwegian Nordic Swan addresses formaldehyde, whereas the German Blaue Engel focusses on isothiazolinones.

Notably, direct health claims by manufacturers are not the main drivers in the market. A main reason is uncertainty of the claim: what can be a health advantage for one, can be an issue for another. This can be on substance level or on user level (what is beneficial for a painter is not per se beneficial for the health for a person living or working in the painted area). For example, if a substance facilitates the quick application of paint, this would mean less time required to apply the paint, i.e. less exposures for the painter. But when that substance requires significant evaporation time and ventilation after application, this can impair the health of people (working/living) in the painted area.

### 5.2.2 Professional use

This market concerns people buying paint for professional use, who can use specific technical means (e.g. spraying equipment) and PPE (personal protective equipment). A main buyer decision for the professional market is total cost: not the pricing of the can itself, but the performance of the paint calculated in hours spent painting. For a professional painter, hours are a higher cost than paint. A paint that is quickly applied and has less need for additional runs or corrections, saves time and thus costs. While for professional painters 'sensitisation' could be argued a more important factor than for the consumer market - since professional users have a far higher exposure; it is their daily job to paint – the use of biocides was not raised as a factor in professional user's buying decision. Labels have no significant role in the professional market.

### 5.2.3 White wall paint

White wall paint – generally referring to interior walls - is the main biocide-free paint on the market today and that is because of several reasons. Firstly, wall paint is sold in the largest volumes c.q. applied on the largest surfaces and is therefore most relevant when aiming to impact health issues. Wall paints were also the first and so far only paint to go completely waterborne, whereas for example for lacquers it is accepted to be solvent based.
Secondly, wall paint has fewer performance criteria than other paints such as exterior paints, lacquers or technical coatings. The goal of interior paint is mainly to apply colour (pigment) to a wall. Exterior paint for example, especially on wood, requires a protective film, apart from colouring. The difference is mainly in the binder. This makes that the amount of organic raw materials – food for microorganisms - in exterior paints is higher than in interior paints. Also, very importantly, opposite to other paints the binder in wall paint can sustain a high pH, allowing for the alternative preservation method of applying an elevated pH.
Thirdly, white is the most common colour for walls. In fact, it is the base colour for most paints. Tinting is done by adding pigment to a white base paint. If white paint cannot be biocide free, no paint can.

**Tinting**
Tinting of paint is done during production (factory-tinted) or on-demand in DIY stores using mixing machines. Ecolabel Blaue Engel has recently expanded its requirements of 'biocide-free' to factory and in-store tinted wall paints. In store tinted products face the challenge of the tinting machine, which is

relatively susceptible to contamination. For this reason, pigment pastes used in DIY tinting machines contain biocides, resulting in a biocide containing paint. Innovation on this aspect of tinting machines is possible and expected but will take time as tinting machines are rather expensive and last for several years.

### 5.2.4 Conclusions

- Most manufacturers do see a role for biocides in an effective, sustainable in-can preservation strategy. Then again, some manufacturers are fundamentally quite neutral on the topic and indicate that the customer is leading. They are open to consider ‘best before date’ if that is acceptable to consumers.
- Market demand for biocide free is lacking in most countries
- Main biocide-free paint is white wall paint on the German DIY market. On this market 50% is estimated to be biocide free.
- Biocide-free paints are on average more costly than those containing biocides (up to 30%), though some manufacturers claim identical pricing.
- On the German DIY market, ecolabels are very powerful and have played a crucial role in the maturing of the biocide-free paint market. In the Netherlands NGO’s/ecolabels like Consumentenbond are not that powerful and are not considering sustainability/health of paints in general, nor the use of biocides in particular.
- Steering on the use of biocides via customer demand is the preferred route according to manufacturers

## 5.3 Understanding preservation technologies

### 5.3.1 Biocides

**Isothiazolinones**
Isothiazolinones are the most commonly used biocides for in-can preservation. Isothiazolinones are a broad-spectrum, effective group of biocides that can be used in a wide range of industrial applications. The product formulation helps to inhibit the growth of microbes and has inhibition and biocidal effects on most of the common bacteria, fungi and algae found in water. The product comes in different compositions and depending on this composition may be referred to as BIT, MIT, CIT or other.

**No new biocides expected**
Paint manufacturers are generally not manufacturers of biocides. Biocides are sourced as one of the ingredients. Depending on the lab capacity of a paint manufacturer, the exact combination and quantity of biocides is determined in-house or is outsourced to the biocide manufacturer/supplier. The latter can make an assessment based on product sample and specifications.
Paint manufacturers do not expect much innovation from biocide manufacturers. The application of in-can paint preservation (PT6) is considered too small compared to the effort required to get a new biocide registered under BPR. When sticking to the preservation strategy of biocides, paint manufactures aim at combinations of commercially available and registered biocides.

**Main alternative today: high pH**
The only commercially applied biocide-free alternative preservation technology today (used for white wall paint) is a high pH formulation. Keeping the pH constant is the trick; it tends to change over the shelf life. If it drops too much it loses its anti-microbial effect; if it gets too high (>11.5) the product should be labelled (and is off spec). The high pH is combined with what is considered the basis: high plant hygiene and elimination of biocides contained in ingredients.
Manufacturers anticipate that in the future microbes will become adapted to alkaline environments. In a biocide system dealing with adaptation is less impactful: there is the option of switching to another biocide. Moreover, biocides under the BPR have requirements for use as part of the resistance management in the dossier. When microbes are adapted to an alkalic environment, there is no switching – a full new approach is needed. The technology of high pH is therefore regarded as temporary. Besides, it is not applicable to all paints. All manufacturers therefore confirm to put RD&I effort in finding and developing other alternative strategies.

In the interviews many different alternatives including combinations were discussed. Focus of the interviews was the different directions of alternatives that exist, and what is considered the main or most likely strategy/strategies for manufacturers to follow.

Two main types of control by which alternative preservation can be achieved were confirmed in the interviews: process controls and formulation controls.

### 5.3.2 Process and formulation controls

A technical description of formulation and process controls is given in section 3.2. Specific technologies have been discussed in the interviews, but only on high level as any detailed information on commercially viable technological development is considered intellectual property. This section discusses the main perceived advantages and disadvantages of the two types of control.

Royal HaskoningDHV

**Process controls**
The most evident advantage of process controls is the reduction or potential elimination of biocides. An example is the food industry, where process controls are main means. Apart from any health claim a manufacturer could make, some interviewees indicate that a main advantage of process controls for the paint manufacturer is the reduced or even eliminated risk of any ingredient in the formulation becoming restricted or banned at some point in time.
Opposite of this advantage are several disadvantages to process controls.
Firstly, process controls only protect until opening of the can. It would require a major change in consumer perspective and expectation to have this accepted. Also mind the different markets: while DIY/professional paint is usually bought in quantities to fit a project, hobby / artistic / scholar paint is bought to use for a large period of time, covering a diverse use.
Secondly, process controls generally require a vast amount of energy. This is mostly in conflict with paint manufacturers ambitions, on e.g. energy use or $CO_2$.
Thirdly, a shift of biocidal product use may occur. While the paint is free of biocides, (even more) biocides may be needed for increased plant hygiene (cleaning of piping and installations).
Finally, process controls cannot be applied similarly as in food industry. It still requires some major technological developments for paint not to be affected by heat/cold, radiation, etc. For example, a main issue is the viscosity of the paint. Paint is designed to stick to surface. Passing it through a heat exchanger in short time successfully, like we know from food industry, has so far not been achieved. Unpredictable changes in stability or performance have been reported.
Ingredients may be (thermally) treated before formulated to a paint. E.g., natural fillers have a high biological load – these can be thermally treated. But germs in ingredients are not today's problem – as one participant says - the problem is between mixing and getting it in the bucket. Point is that even with the best hygiene standards, it will never be a germ-free environment (unless it comes to the point of "producing paints like silicon wavers"). As soon as there are germs something is needed to prevent them from growing in the can.

*"Germs in ingredients are not today's problem. The problem is between mixing and getting it in the bucket."*

**Formulation controls**
Regarding formulation controls we identify two main directions.

*Adding biocides*
The use of traditional biocides is a formulation control. It has the advantage of requiring little product to be effective, the product remains stable for years - even after opening, and it has no impact on product quality. Though biocides bare a high <u>hazard</u>, health <u>risks</u> are considered to be low.
There are two main disadvantages to the use of biocides. Firstly, there is the risk of any ingredient in the formulation becoming restricted or banned at some point in time. Any ingredient added to inhibit the growth of microbes should fall under the regime of BPR. This may also be or become true for the high pH alternatives on the market today. 'Multifunctionals' (see next paragraph) may waive this, as for these substances there is another reason to add the substance, but a risk of restriction or ban remains.
Secondly, while little use of highly effective biocides used to do the trick, remaining available biocides may require larger concentrations, impacting product quality.

*Removing the food*

Royal HaskoningDHV

Instead of inhibiting growth by killing life, one could consider removing the food source and so not stimulating growth in the first place. Technologies include non-biodegradable polymers, dry paint (powder; add water before use) and on demand production. The concept is promising: no biocides added, no energy intensive production and safe long-term storage.
Generally, the advantages of removing edible components sound very promising. But it is also the most disruptive technology in terms of production, supply chain, product quality and customer acceptance. In the case of moving to non-biodegradable polymers, i.e. persistent substances, one should be aware of other environmental / health issues when such substances end up in the environment. And in the case of removing water, i.e. powder paints, one should be aware of the increased energy consumption for production (drying), exposure to dust (including $TiO_2$), the fact that the performance of the product is in the stable emulsion – "paint is not a wall paper glue" says one of the participants – and the use of the paint, which may require to last for weeks and hence still require preservatives.
Yet, limiting the nutritional value of the binder / ingredients will help and participants indicate to look at this option.

### 5.3.3 Most anticipated technologies

Alternative preservation of waterborne paints is indicated by the interviewees to be improved by at least industrial hygiene and biocide free raw materials. Additional measures will be necessary, of which multi-functionals are named by all manufacturers. Manufacturers indicate that it will be a combination of technologies that will do the trick – coined 'hurdle technology'. And that it requires an effort from more than the manufacturer alone to get a real step-change.

*"Most options are already considered, and a lot has already been done. If you want to do more, you need to involve the chain: raw materials and retailer."*

**Hurdle technology**
There are several technologies which, on their own, have some benefits in delaying spoilage. Hurdle technology makes use of "hurdles" which the pathogen has to overcome if it has to remain active in the paint, i.e. it is the combination of several technologies. These may be both formulation and process controls. It can be concluded that so far, no silver bullet has been discovered. The best combination will be applied as hurdle technology, confirmed by most interviewees.

**Industrial hygiene**
Process and design are and will be optimised towards high quality cleaning and minimisation of e.g. dead end piping, reducing or eliminating the risk of contamination of the pain in the plant. For many existing formulation plants – the majority of the market - it requires engineering adjustments to ease such hygiene standards. New plants will be designed for easier cleaning. Still, for cleaning of the installations (between batches) biocides may be used, although they belong to a different PT. And also other cleaning measures may be needed: mechanical cleaning (high pressure water), solvents, high pH, low pH, etc.

**Biocide free raw materials**
A must for formulating biocide free paint is to use biocide free ingredients. For example, typical binders are supplied with biocides. There are several ways to handle this, e.g. rapid delivery and processing (on-demand production) of binders without or with very little biocides, or biocides with a short half-life (rapid hydrolysis / degradation). This is where the definition of 'preservative free' becomes very important: how

much biocide (from ingredients) may be present in a product to still make the claim of preservative-free?[8]. Concluding, moving to biocide free paints includes more than only a change at the paint manufacturer's site.
The presence of biocides in ingredients may have been an advantage in the past: biocides are expensive, so everything already included for free is a bonus, and 0.1% active substance does matter for net revenue. But today, paint manufactures need to know their product content more specifically, for labelling/classification in general, or claiming 'preservative free' specifically. And that's where this becomes an issue.

**Multifunctionals**
Mulitfunctionals are chemicals which have multiple properties and are used in formulations for main and minor objectives. Their side effects might be beneficial to avoid or reduce spoilage. As an example, should the substance be an antifoaming agent, it can be added as such. However, the substance might also inhibit microbial growth, but the biocidal effect is not claimed – it is not the main purpose or main reason to add the substance. It is therefore not registered under the BPR. Although some stakeholders consider this to be an option, others generally do not see this being in line with 'responsible care' and consider this to be a major a risk as the substance may fall under the BPR at some point in time (e.g. when one producer does make the claim of biocidal effect).

### 5.3.4 Conclusions

- There is a solution to go biocide-free for a large share of water-borne paints, namely white wall paints with a high pH. The question is how long this will stand as microbes will adapt.
- New biocides for paints in the product type (PT6) are not expected (for the EU).
- Paint manufacturers are putting RD&I effort to several technologies, both process and formulation controls. It is likely that a combination of technologies will be applied.
- Not all (water borne) paint is equal. While there are possibilities for some segments (white wall paint), there are no feasible options (yet) for others (e.g. lacquers, technical/industrial coatings).

[8] *VdL, the German sector organization for the paints industry, has included a definition in its 'VdL-Guideline on Decorative Coatings'*

## 5.4 Understanding the regulatory framework and pressure

### 5.4.1 Biocidal Product Regulation (BPR) and Classification, Labelling and Packaging Regulation (CLP)

The use of biocides as in-can preservative is primarily regulated under BPR but also via the classification resulting from CLP. These regulations have their advantages in terms of creating a level-playing field and clear, targeted dossier needs ensuring thorough evaluation of risks for man and environment. There are also some concerns regarding these regulations. Four main concerns regarding the regulatory framework have been raised by the interviewees: increased risk, the generic approach, the hazard-based approach, and uncertainty during the evaluation process.

*“Final goal should not be to reduce the use of biocide. The goal is to make products more safe and healthy.”*

**Increased risk on short term**

The requirements for a BPR dossier, its evaluation process and the CLP consequences progressively reduce(d) the number of active substances suitable for PT6 (mainly for the consumer market). On the short term, the limited selection of available biocides results in increased use of the same substance(s). This in turn results in increased dependency on suppliers (business risk) and, more importantly regarding the goal of BPR, the increased risk of development of microbial resistance (performance risk) and the increased risk of sensitisation (health risk). It is the line of thought that on the longer term, when paint manufacturers have switched to alternatives, these risks are reduced below the levels we see today.

**Generic approach**

BPR is generic because the obligations apply to all preserved canned paints all over the EU - creating a level playing field within the EU. But not all paints are equal, and producers do not only sell their products in EU alone. For some paint formulations alternative solutions for preservation might apply, for others they do not. When active substances are no longer allowed for those paints that do not have alternative preservation technologies, the formulation will disappear from the market – potentially resulting in former technology formulations (solvent based) being (re-) introduced.

**Hazard basis**

CLP classifies substances based on hazard. For allowing products to enter several markets a hazard-based approach is followed in the EU. Certain hazards are considered unsuitable for any exposure to consumers / general population, and mixtures with such hazard can thus not enter these markets.
The entry 28, 29 and 30 of REACH annex XVII restricts the use of CMR category 1A and 1B substances in products supplied to the general public (i.e, cleaning products, paints) and requires additional labelling for products intended for professional users.
BPR addresses risks of substances in production and use of paints. It is therefore possible that based on risk, products can be allowed, while based on hazard they cannot. Skin sensitising substances can be legally regulated and labelled and, depending on the exposure, their content in consumer products can be reduced or eliminated.
For isothiazolinones (IT’s), biocidal potency differs between members of the group. However, while disregarding these differences and related risk, a generic concentration limit has been set. This drives the use for the most potent IT: companies raise the point that where they use a less potent biocide (IT) today, due to having to meet concentration limits, they might switch to more potent biocides (IT).

Industry favours a risk-based approach: that is how they assess their products and formulations and justify their choices.
A hazard-based approach does also not allow for a holistic view, i.e. a comparable assessment on e.g. sustainability criteria.

**Uncertainty**
Costs for BPR registration and evaluation are high (millions of Euros) and timelines for new biocides to be evaluated take long (years). That itself would not be much of an issue if there was no risk of being restricted or banned a few years later anyway. In the recent past, goalposts have been changed or additional requirements have been introduced during the evaluation process (e.g. endocrine disrupter criteria). The uncertainty for this to happen in future is of major concern to industry and seems to hamper introduction of new biocides.

### 5.4.2 Regulating differently

Regulation can be done by European directives, guidelines and national laws. But there are more ways to regulate. As indicated in paragraph 5.2 it is the preferred route by manufacturers for any change to take place via the market, i.e. customer demand. But in the example of Germany, large scale customer demand did not come by itself: it was semi-regulated by ecolabelling, after public information (by NGOs) got it started. Give power to ecolabels, inform customers. That way customers will make their decisions. This may also adhere to the industry's desire of regulation being more holistic, i.e. weighing the different aspects of alternatives together (e.g. energy consumption, health risk, etc.).

*"Regulation is not the solution; information is the solution."*

### 5.4.3 Conclusions

- So far, no support was found for the 'ban-approach' to be effective in achieving its goals of reduced use of biocides for this use in paints. On the short term, reducing the pool of available biocides may increase performance and health risks. It is on the longer term that the current BPR approach should have its effect.
- The approach of BPR – banning substances for large use categories as a whole - is generic, while paints and availability of alternative preservation technologies differ.
- Uncertainty is a major hurdle for investment. There appears to be a need to address evaluations in a different manner, with guarantees. Business cases for manufacturers of biocides in PT6 appear unattractive. But also the business case for paint manufacturers seeking biocide free alternatives appears to be unattractive.
- Regulatory scrutiny seems not to lavishly stimulate innovation for preservation. Paint manufacturers are putting RD&I efforts on formulation and compliance, and though these efforts are significant, they seem to be done predominantly in response to regulation.

Royal HaskoningDHV

# 6 Summary results

## 6.1 Opportunities and hurdles

Over the past decades, paint manufacturers have switched from solvent based paints to waterborne paints for a significant share of its portfolio. Main reason was the reduction of volatile organic compounds (VOC), aiming to perform better on health and environmental aspects. This switch however made paint vulnerable to spoilage. Biocides were and are added to avoid spoilage. Biocides are also used in the raw materials (e.g. binders) that paints are made of. Paint manufacturers have attention for the risks that biocides bare. Most manufacturers however see a role for biocides in an effective, sustainable in-can preservation strategy.

'Sustainability' is a theme for all paint manufacturers, largely influencing the RD&I agenda. Yet, 'reduction of biocides' is not an end goal for manufacturers, and it does not clearly or necessarily match manufacturer's other sustainability goals, e.g. energy or CO2 reduction. This results in a complex issue. And while industry efforts are high on many (sustainability) topics, efforts on reduction of biocide use do not always surface.

Manufacturer's RD&I is sufficiently organized, connected with partners and funded where needed. What is missing from a manufacturer's side when it comes to innovation on in-can preservation is 1) a clear match with company's ambitions, and 2) a solid business case.

Shelf life is a main factor determining the need for preservation: if shelf life is reduced, paint requires less preservation effort. It would require a system change, including manufacturer, retailer and user, to reduce shelf life.

Biocide-free paints are on average more costly than those containing biocides (up to 30%), though some manufacturers claim identical pricing. Therefore, and with customer demand for biocide-free paint lacking in most countries, there is not much biocide-free paint on the market. One example where preservative-free matured is white wall paint on the German DIY market. On this market 50% is estimated to be biocide free. On the German DIY market, ecolabels are very powerful and have played a crucial role in the maturing of the biocide-free paint market. In the Netherlands NGO's/ecolabels like Consumentenbond are not that powerful and are today not considering sustainability/health of paints in general, nor the use of biocides in particular. Steering on the use of biocides via customer demand is the preferred route according to manufacturers.

## 6.2 Role of legislation and regulation

So far, no support was found for the 'ban-approach' to be effective in achieving its goal of reduced use of biocides as in-can preservative in paints. On the short term, reducing the pool of available biocides may increase performance and health risks. It is on the longer term that the current BPR approach should have its effect.

The approach of BPR – banning substances for large use categories as a whole - is generic, while paints and availability of alternative preservation technologies differ. This variation results in that a ban could be suitable for one application but not for another.
Regulatory uncertainty is a major hurdle for investment. There appears to be a need to address evaluations in a different manner, with guarantees. Business cases for manufacturers of biocides in PT6 appear unattractive. But also the business case for paint manufacturers seeking biocide free alternatives appears to be unattractive.

Regulatory scrutiny seems not to lavishly stimulate innovation for preservation. Paint manufacturers are putting RD&I efforts on formulation and compliance, and though these efforts are significant, they seem to be done predominantly in response to regulation. It is the preferred route by manufacturers for any change to take place via the market, i.e. customer demand.

## 6.3 Technology - Lessons learned

There is a solution to go biocide-free for a large share of water-borne paints, namely white (and factory tinted) wall paints, with a high pH. New biocides from biocide producers for paints in the product type (PT6) are not expected (for the EU).

Paint manufacturers are putting RD&I effort to several technologies, both process and formulation controls. It is indicated that a combination of technologies will be applied (hurdle technology) in future to address spoilage.

Not all (water borne) paint is equal. While there are possibilities for some segments (white wall paint), there are no feasible options (yet) for others (e.g. lacquers, technical/industrial coatings).

In this research many different technological developments have been discussed. Though it is not the goal of this research to point out which technology is more suitable than another, it is deemed helpful to have an insight in the chances of success of technologies known today. The following table lists which opportunities in material and product development are considered fruitful and can be further enhanced towards application and sizing.

Royal HaskoningDHV

*Table 6-1: Overview of technological developments / measures*

| Technology/measure | Benefit | Remark |
|---|---|---|
| **BASICS** | | |
| Plant hygiene | Less biocide used in formulations | Adjustment of design will limited need to use biocides to clean facilities and less chance for carry-over microbes to formulations |
| Preservative-free ingredients | Prerequisite for preservative-free formulation of paint | Additional cleaning, with a.o. biocides, in plant may be required |
| Hurdle (combination) technology | Less need for biocide | Tailor made best performance |
| **COMMERCIALLY AVAILABLE TODAY** | | |
| High pH formulation (because of nature of ingredients, not by adding base) | Biocide free | Applicability is still limited to white (and factory tinted) decorative wall paints. High pH based on ingredients and not by adding base. |
| **BIOCIDAL ADDITIVES** | | |
| New suitable biocides in PT6 | More possibilities to select, less dependency | No realistic expectation from traditional biocide producers due to market size and specific needs for paints. No clarity on (regulatory) criteria to test safety for nanoforms of biocides. |
| Natural biocides / food preservatives | Potentially already tested for health. Generally anticipated as being less hazardous. | Uncertainty w.r.t. requirements under BPR. Paint and food are not egual (food generally more acidic), so a direct application to paint as is today is not expected. |
| Multifunctionals | Less/no biocides required | No need for BPR dossier, but risk that it will be in future |
| Biocide killers / biocide degradation | Biocide would be gone over time | Not discussed in interviews. It would still require to add the biocide at first. |
| Encapsulation of antimicrobial substances, incl peptides | Less / no biocides required | Controlled release allows for longer and more constant preservation, however focusses on the antimicrobial substance |
| **OTHER FORMULATION CONTROLS** | | |
| Dry / Powder | No need for biocides | Limited to certain products, not broadly applicable; also poses other health risks (dust). When need for adding water, potential for issues regarding performance (claims). |
| New binders / additives | Not a food source for microbes | Potential risk for non-biodegradable substances, with risk for persistency |
| **PROCESS CONTROLS** | | |
| Process controls, incl. e.g. microwave, ultrasound, UV, pulse electric field, instant controlled pressure drop, supercritical fluid processing | Less/no biocides required in can | Potentially high energy demand; limited applicability to paint as is today; loses function after opening. |
| Packaging (anti-microbial lining, inert gas in headspace, etc.) | Unfavourable circumstances for microbes to allow for growth | Likely increasing amount of waste (sustainability concerns): ratio surface of packaging to volume of paint will shift. |
| **SUPPLY CHAIN CONTROLS** | | |
| On demand production | Reduces shelf life. Less/no biocides required | Requires supply chain innovation, including retailer and customer |
| Best before date / reducing shelf life | Reduces shelf life. Less/no biocides required | Requires supply chain innovation, including retailer and customer. Potentially generates more waste and may contradict other sustainability objectives. |

# 7 Moving forward

In the previous chapter we conclude that, despite many industry efforts, today there are no commercially available alternatives to biocides other than high pH for (white) wall paint. Moreover, the use of biocides can be considered part of a sustainable solution for in-can preservation.
As outlined in the introduction, this research does not conclude on the use of biocides as in-can preservation itself. Given the regulatory reduction on the use and availability of biocides as in-can preservative for paint by the EU, this research concludes on alignment of industry with the EU ambitions. It is concluded that there is a discrepancy between timeframes of bans on traditional biocides on the one hand and availability of prospected alternatives on the other. In order to continue support of the safe and sustainable production and use of paints while also aiming to reduce substances with certain hazard profiles, alignment of these timeframes is a necessity.

This chapter presents ideas on how to move forward to achieve alignment between policy makers' and manufacturer's ambitions. The authors of this report by no means aim to prescribe certain actions, and carried out this analysis solely as a thought experiment.

## 7.1 Introduction

Overall we see that, though not necessarily agreed to by all companies, the issue of biocidal use as in-can preservative is very well understood. Alternatives can dominate specific markets - as in the German DIY white wall paint market - but a move to other markets is hardly made.

This is not because paint manufacturers are not sufficiently equiped. With RD&I structures, networks and funding in place, both smaller and larger paint manufacturers are able to innovate.
It is also not because of technical reasons. Alternatives to well-known biocides are available, at least for some applications.

That brings us to where moves can be made: the market. Biocide-free paints are generally more costly than those with biocides, while customers do not seem to demand biocide-free paints. Reaching or triggering the customer with claims is found difficult for companies as 'biocide-free' doesn't match their general sustainability or even health message.

Regulation such as BPR is designed to tilt the market. By generically restricting the (use of) biocides, companies are forced to innovate. Or not: the EU strategy so far has seen little effect on the DIY or wholesale shelves. It even poses the threat on the short term of increased use of more potent biocides, or manufacturers shifting back from water-borne to solvent based. Any resistance to the BPR though may be perceived as rear-guard actions, as there is no doubt where the EU is going. And though no details were disclosed in the interviews, all manufactures seem to have solutions up their sleeve or ongoing.

## 7.2 Main questions

Given the results as discussed, we see two major questions governments are faced with when having the ambition to steer the process of innovation in in-can preservation.

**Together or Alone?**
Governments may facilitate the structured, organised communication, c.q. debate and consensus on the way to go. This can be small, with little governmental facilitation and little communication (intercompany, intergovernmental (NL/EU) and/or between governments, companies, knowledge institutes and public

(NGO)). Little communication and facilitation can be depicted as ‘going alone’, and pretty much reflects the highly competitive market of (decorative) paints we see today. In an environment where companies see perspective to move, such setting would result in pioneering: companies finding (patented) solutions for themselves and ways to bring this forward. But in an environment with little perspective, the lack of communication and consensus will result in resistance. Facilitation on consensus can also be big. Though this may take time, it gives most clarity and perspective to all parties involved, which in turn may therefore be more willing to move.

**Enforcing or Seducing?**

Enforcing relates to regulation in the sense of restriction of use of substances. Seducing relates to regulation or other measures that positively impacts market demand.

Enforcing is the EU strategy we have seen so far with the BPR, and is mostly cross-market. Seducing is very much related to the specific market selected. The latter is discussed below.

*How to seduce / create a market*

The seductive approach can be illustrated with the example of electrical cars. For decades the emission of fuel engine cars has been reduced, by restrictions on emission limits. But radical innovation has taken quite some time. Only until recently, in the Netherlands most newly sold cars will be electrical. Today, every car manufacturer has or will have their flagship model. Analysing this transition, the following items can be identified:

a) A clear message: no CO2 emission (while driving)
b) Fiscal advantages: 0% addition; subsidised when bought or in use
c) Technical development, resulting in improved driving performance (battery range not so much of an issue anymore)
d) A pioneer: Tesla, who made driving electrically ‘cool’ so people identify and are attracted.

On all four items there is work to be done for the market of paints and in-can preservatives.

Starting with the first item: What would be an appealing message for the transition? This strongly relates to the message companies / governments have on sustainability, such as CO2 emissions.

On fiscal advantages authorities can contribute or consider options like different VAT or subsidies. This may be of special interest for consumer markets as these, more than professional markets, are highly price driven.

The third item regarding quality/performance is not straightforward for paints. The transition to waterborne paints had quality issues as well, but today these have been overcome or are accepted. Current biocide-free (high pH) paints perform similar to those containing biocides, although opinions differ, but in anyway there is no improvement in product performance.

For the fourth item, it is relevant to note that today the positioning of biocide-free paints is by identifying them as hypoallergenic. This does not appeal to a big audience.

*Which market?*

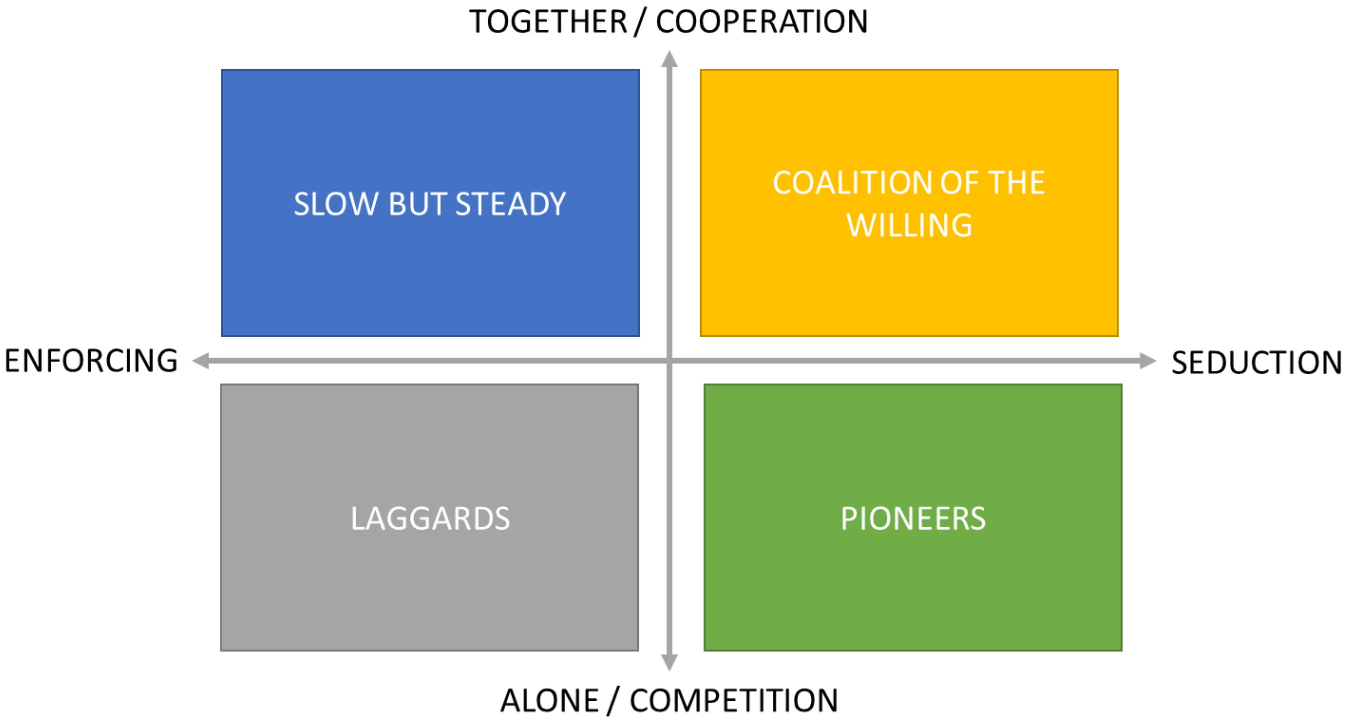
If to play via the market, a main question is which market to start with. Largest volume? Largest influence? Most technologically viable?

In Germany it started with the DIY (consumer) white wall paint market, because of volume, technological viability and locus of power (influence): labelling present in DIY shops. In the Netherlands, such powerful labelling is not present today. Another idea is to start with the professional market, specifically for governmental projects (influence). Perceived cost impact in the professional market is lower than in the consumer market because the professional’s cost is predominantly hours x tariff and materials are only a minor share. Also, professionals are more used or can be trained to apply technical means (application equipment & personal protection equipment PPE) which may allow for a wider window of alternative technologies.

Industrial customers may also be an interesting market. Like furniture (large home decoration stores) or pre-fab construction work (e.g. branded window frames). Such parties, more than DIY stores, are thought to have the knowledge on sustainability, the size and spotlight to act responsibly, plus the market to serve. However, in these markets the applied paints are lacquers, for which today there are no alternative preservation methods.
Lastly, the market may determine which are the first movers. Analogue to the developments in Germany, it is likely that first movers are those companies for which the selected market is significant.

Given these main options for intervention, we come to the following scenarios.

## 7.3 Scenarios




The two questions explained in the previous paragraph combined bring the following 4 scenarios.

**Laggards.** Restrictions are enforced by law, communication / consensus is hardly facilitated or pursued. With little consensus on the approach (between EU and industry) the result is a rather reactive response to restrictions. Innovation will take place, but mostly with a strong competitive angle and therefore any development is done behind closed doors. This route is likely to be a slower route. And as clear alternatives do not become widely available for all paints, a generic ban on effective biocides may force paint manufacturers to (temporarily) go back to solvent based paints for a certain share of its portfolio.

**Slow but steady.** A scenario where the main means is enforcement, but consensus between companies, governments and NGOs/consumer on e.g. risks, concentration limits, acceptable alternatives, 'best before dates' / use, etc. is facilitated.
For example, working with a 'best before date' (i.e. less preservation) would lead to more paint being discarded / returned, and/or in the case of moving to smaller packages to more packaging waste. It

requires consumer behavioural change, and a change in the way of working for most retailers. Both can be expected to be lasting processes.
Reaching consensus may take time, making it even slower than the ‘laggards’ scenario. But with more certainty of biocides being replaced with better alternatives. And, with a more holistic and weighted approach.

**Pioneers**. Governments, together with NOGs / consumers, can also create market. When creating a market without a lot of framing, a competitive setting is created, attracting pioneers and subsequently followers / the majority. This route has great potential in the sense of speed: pioneers can act fast. Most determining factor will be the speed with which markets can be created, and possibly any registration / procedures pioneers would have to go through for applying their alternative technologies.
In Germany, the market is created via labelling organization Blaue Engel, basically mimicking regulatory restrictions, yet on the demand side. In the Netherlands there is no such labelling power present today. If a labelling power is not present / cannot be created, fiscal advantages are an option. Governments may also create market by including ‘preservative free’ in their criteria for sustainable procurement.
Or find ways to stimulate large retailers directly. This also happens in other markets, e.g. IKEA applies a restricted substance list to avoid having certain substances in their products.

**Coalition of the Willing.** A combination of both: facilitating both market demand and consensus on the approach. It is similar to the ‘slow but steady’ scenario in the sense of certainty of widely applied alternatives – e.g. agreements on limits, joint research on alternatives, patent-free alternatives -, yet likely to be faster because demand is waiting. Opposite to these two advantages is the disadvantage that this scenario requires the largest governmental intervention / facilitation/ organisation. Plus, the (decorative) paints market is a highly competitive market. We hear that collaboration between competitors – in general and on the topic of preservation specifically – is low, i.e. less than seen in other sectors. Getting the paint manufacturers to work together may require quite some cultural change.

# 8 Reference list


Alarfaj, A. et al. (2016).Development of biomaterial surfaces with and without microbial nanosegments. J Polym Eng 2016; 36(1): 1–12

BAuA (2020). Survey on alternatives for in-can preservatives for varnishes, paints and adhesives. 1st edition 2020 Dortmund/Berlin/Dresden.

Bechthold et al. (2020). Synthesis and application of silver nanoparticles as biocidal agent in polyurethane coating. J Coat Technol Res **17,** 613–620 (2020). https://link.springer.com/article/10.1007/s11998-019-00297-0

Chemat, F. et al. (2017). Review of Green Food Processing techniques. Preservation, transformation, and extraction. Innovative Food Science and Emerging Technologies, Elsevier, 2017, 41, pp.357-377.

Ctgb, (2013). Evaluation Manual for the Authorisation of plant protection products and biocides. Chapter 7 Efficacy version 1.1; January 2013

Danish EPA (2018). Reducing biocide concentrations for preservation of water-based paints. Environmental Project No. 2014

EFSA, (2021). Food additives. Food additives | EFSA (europa.eu)

Fraunhofer (2020). Thermal conservation instead of using biocides? COATINGS TECHNOLOGIES, August 2020. https://www.european-coatings.com/articles/archiv/thermal-conservation-instead-of-using-biocides

Gokoglu, N. (2018). Novel natural food preservatives and applications in seafood preservation: a review. Journal of the Science of Food and Agriculture, October 2018.

Hodges, T. et al., (2018). Proteins and Peptides As Replacements for Traditional Organic Preservatives. Part I. Coatings Tech, 15(4), 45-50.

Kurovski, G. et al. (2017). Paint-degrading microorganisms TECHNICAL TRANSACTIONS Chemistry 12/2017.

Levin, J. et al. (2019). Challenging Preservation Options: Towards Biocide-free Waterborne Coatings via Innovative Binders and Additives. https://www.paint.org/coatingstech-magazine/articles/challenging-preservation-options-towards-biocide-free-waterborne-coatings-via-innovative-binders-and-additives/

Mahmoud,H. et al. (2017). Mycrofence technology for a safe and durable protection against micro-organisms. Croda paper 124. Paper_124.pdf (abrafati2019.com.br), MyCroFence A Novel Antimicrobial Coating Technology | Croda.

McDaniel, S. et al., (2019). Biotechnology meets coatings preservation. Enhancing and reducing biocide use while expanding markets. Coatings World, December 2019.

NVWA (2016). Letter to the Dutch Minster of Health, Wellbeing and Sport. Advies over mogelijkheden voor de uitbreiding van de lijst met producten die uitgezonderd zijn van de verplichting voor een vermelding van een houdbaarheidsdatum. NVWA/BuRO/2016/152.

Piemonte, V. et al. (2016). A Criteria for Evaluating the Microbiological Contamination of Acrylic Paints. CHEMICAL ENGINEERING TRANSACTIONS VOL. 49, 2016

Saini, A. et al. (2021). Encapsulation of functional ingredients in lipidic nanocarriers and antimicrobial applications: a review. Environmental Chemistry Letters volume 19, p. 1107-1134 . https://link.springer.com/article/10.1007/s10311-020-01109-3

Smelt, J. & S. Brul (2014). Thermal Inactivation of Microorganisms. *Critical Reviews in Food Science and Nutrition*, 54:1371–1385.

Tkaczewska, J. (2020). Peptides and protein hydrolysates as food preservatives and bioactive components of edible films and coatings - A review. Food Science & Technology, Volume 106, 298-311.

Yeung King Lun, (2020). HKUST Develops New Smart Anti-Microbial Coating in the Fight Against COVID-19. Hong Kong University of Science and Technology. https://hkust.edu.hk/news/research-and-innovation/hkust-develops-new-smart-anti-microbial-coating-fight-against-covid-19

Royal HaskoningDHV

# A1 Preservation – organisms & biocidal activity

Non-edited or discussed information / text parts described in main text from the references mentioned.

**Identity of microorganisms which spoil the paint**
Kurovski
Bacillus brevis, Bacillus laterosporus, Bacillus polymyxa, Lactobacillus gasseri, Lactobacillus brevis, Proteus mirabilis, Escherichia coli and fungi Aspergillus niger, Aspergillus flavus, and Penicillium citrinum. Samples from water-based paints indicated a strain of Pseudomonas aeruginosa.
McDaniel
Pseudomonads, and gram negative Enterobacter, gram positive Bacillus
Danish EPA
Paints are contaminated by different organisms, both fungi and Gram-positive and Gram-negative organisms, bacteria of the genus Pseudomonas, were isolated from several paints.
Ctgb manual efficacy testing:

**Table 1. Common spoilage micro-organisms associated with in-can products**

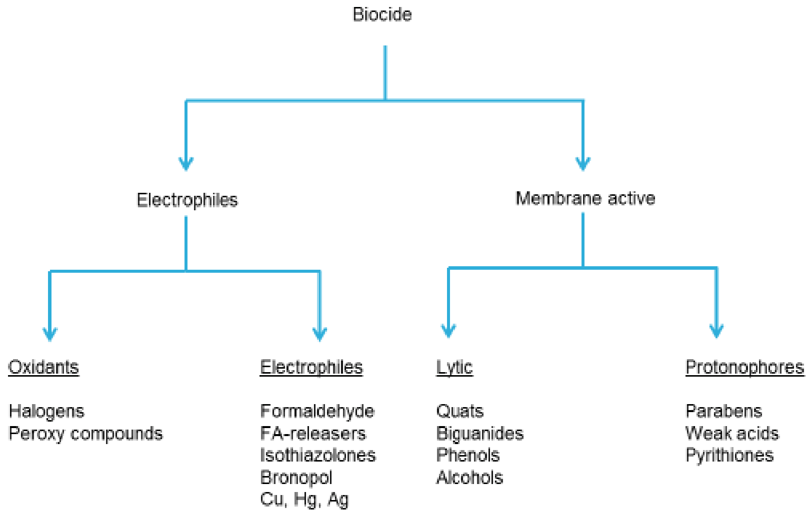
| Bacteria | Fungi | Yeast |
|---|---|---|
| Alcagenes species | | Candida albicans |
| Micrococcus luteus | Aspergillus spp. | Rhodotorula rubra |
| Escherichia coli | Geotrichium candidium | Saccharomyces cerevisiae |
| Proteus vulgaris | Penicillium spp. | - |

Piemonte
An acrylic paint can also be contaminated by bacteria (and rarely fungi), due to the presence of microbiological residuals on the container.

The cellulose ethers they contain as thickening agents are often attacked by enzymes produced by fungi and bacteria, which enter the paint at the manufacturing stage together with contaminated ingredients.

Royal HaskoningDHV

**Types of biocides -Mahmoud (2018) figure, DK EPA text**




(1) Membrane-active microbiocides. Their first mode of action is by adsorbing to the microbial cell wall. This adsorption causes changes in the cell wall and outer membrane, prompting loss of cell wall and membrane integrity. This causes disorder in the semi-permeable properties of the membrane and inhibition of enzymes localized here. Desintegration of the cell wall and membrane can furthermore prompt the escape of essential components from cytoplasm, precipitation in periplasm and finally disintegration of the cells.
Examples: alcohols, quaternary ammonium compounds.
(2) Electrophilically active microbiocides.
These compounds react with molecules with heightened electron density hereby resulting in electrophilic addition or substitution. In and on microbial cells, these nucleophilic reaction partners are thiol, amino and amid groups.
(3) Chelating agents Many enzymes contain metallo-catalytic sites where divalent metal ions like iron or copper are essential for enzymatic function. Chelating agents have strong affinity for divalent metal ions, making these ions unavailable for the microorganisms and thereby removing these vital micronutrients. In addition to their competition for di-valent metal ions, chelators are also reported to have membrane activity.
Examples: zinc pyrithione, thiohydroxamic acids
(4) Inorganic bactericides Metal ions have different modes of mechanism: They can influence the electro-chemical potential between internal and external parts of the cells, and inside the cell where they compete with other ions and aggregate with thiol groups of proteins.
Examples: silver, copper, zinc

**Other biocidal techniques**
**Biotechnology coatings**
**McDaniel** (2019) - uses data from Hodges.
Examples of biobased molecules include enzymes like lysozyme and glucose oxidase, small peptides similar in activity to natural antimicrobial peptides like defensins, but smaller in molecular weight and even whole cells containing such molecules. By retaining the natural biological function (in either direct antimicrobial activity or synergistic activity with a traditional biocide) it is possible to utilize these molecules in liquid and dry film coating systems.
Glucose oxidase (GRAS in food – generally recognized as safe) works with traditional biocides synergistically. AMP7 (7 amino acid peptide) works on its own.

**Hodges** weblink https://www.paint.org/coatingstech-magazine/articles/proteins-and-peptides-as-replacements-for-traditional-organic-preservatives-part-i/
Modern microbiological screening methods were used for selection of candidates. A rapid cell viability assay that quantitatively measures the metabolic ability of living cells. This preliminary screening allows quick down selection of biomolecules that inhibit metabolic activity for subsequent correlation with the traditional ASTM D2574 “Standard Test Method for Resistance of Emulsion Coatings in the Container to Attack by Microorganisms” microbiological assay when tested alone or combined with traditional chemical biocides. This approach can then be used to evaluate the ultimate efficacy of antimicrobial formulations, providing the formulation chemist and microbiologist with the largest and most complete database from which to control microbes from raw materials introduction, through production, into the marketed container, and ultimately into dry films. Coating challenges were conducted as described in the ASTM International Standard procedure D2574-16.24 Pseudomonas aeruginosa, Pseudomonas putida, Pseudomonas fluorescens, Alcaligenes faecalis, Bacillus cereus, and Enterobacter aerogenes cultures were grown in 5 mL TSB broth for 24 h at 30°C with agitation.
From an initial panel of 30 enzymes, peptides, and small molecule natural products, 23 were selected for evaluation. These were screened against individual members of a microbial contamination panel using the XTT assay. Nine of the 23 bio-based additives were found to reduce cellular metabolism in the XTT assay by ≥ 50%. Bio-based additives, much like traditional biocides, should be selected to protect a given type of coating formulation or category of raw material against the microbial challenges encountered in a particular application. One rationale to overcome a resistant contaminant is to select disruptive properties impacting distinct cellular components to achieve synergistic effects, with a lysozyme, AMP-7, glucose oxidase, and alginate lyase combination as an example. Alginate lyase targets the extracellular polysaccharide layer, AMP-7 disrupts cellular membranes, lysozyme cleaves bacterial cell wall peptidoglycans, and glucose oxidase produces hydrogen peroxide that can induce cellular damage.

**Levin** weblink https://www.paint.org/coatingstech-magazine/articles/challenging-preservation-options-towards-biocide-free-waterborne-coatings-via-innovative-binders-and-additives/
Examples of commercially available, non-sensitising biocidal chemistries registered for coatings use include cationic nitrogen-based, silver-based, or zinc-based biocides. Quaternary/cationic nitrogen amines have been used in commercial paints as biocides. As the majority of waterborne coatings are anionically stabilized, it is challenging to incorporate the cationic biocide into a formulation. Silver ion is a well-known antimicrobial agent used in the textile and coatings industries to inhibit microbial growth. It is more commonly used for dry-film preservation, which only requires the actives to be present at the surface. For in-can preservation, the concentration of silver ion needs to be high enough to inhibit microbial growth in the wet state. Due to the high cost of silver, using silver ion technology for in-can preservation of coatings has been limited. Zinc complexes are other potential preservation candidates. For example, zinc oxide has been used as a dry-film preservative in exterior coatings to reduce fungi and algae growth. However, zinc oxide and other zinc complexes are not without controversy, given the recent opinion of the risk assessment committee of the European Chemicals Agency (ECHA) to classify zinc pyrithione as a repro-developmental toxicant.

In addition to the above-discussed solutions that are approved for coatings preservation, there are also a few emerging technologies that could be the next-generation biocides. The first technology direction is biological-based solutions. Examples include kimchi fermentation peptides or an amino acid-based antimicrobial system. A second future direction is antimicrobial polymers, which incorporate functional ingredients into a polymer structure. The last direction for biocide-free coatings is through packaging.

Experimental acrylic and styrene acrylic binders and experimental specialty HEUR rheology modifiers have lower potential for microbial spoilage than traditional products. Levin? have developed several experimental binders that pass microbial challenge tests and have formulated these binders into simple

Royal HaskoningDHV

paints that also pass challenge testing. By optimizing the HEUR polymer and formulation, the HEURs were able to pass at least three challenge tests. Together, these results provide encouragement that there is a path forward to create sustainable and robust raw materials that can reduce spoilage without the addition of biocides.

**Bechtold (abstract) at** https://link.springer.com/article/10.1007/s11998-019-00297-0
Nanostructured materials have become increasingly widespread, and in recent decades, the processing industries have shown a great interest in coating materials with antibacterial properties. In this research, the biocidal effect of silver nanoparticles in the water-soluble polyurethane paint composition was evaluated. Silver nanoparticles in the aqueous phase were prepared by chemical reduction at 500 ppm using polyvinyl alcohol. The material was characterized by UV–Vis, inductively coupled plasma mass spectrometry, dynamic light scattering, zeta potential, and transmission electron microscopy. The effect of silver nanoparticles in terms of yellowing and gloss variation was evaluated by a UV-B radiation test. Silver nanoparticles had no effect on the gloss and yellowing paint film. In addition, positive results were obtained for the protection and resistance against bacteria but not satisfactory resistance against fungi.

**Chemat - Review Green food techniques**
These techniques (such as microwave, ultrasound, pulse electric field, instant controlled pressure drop, supercritical fluid processing) in the frontiers of food processing, food chemistry, and food microbiology, are not new.
Instant Controlled Pressure-Drop (DIC) is based on the main principle of the thermodynamics of instantaneity and auto-vaporization processing combining with hydrointensification. thermo-mechanical evolution of many biopolymers for food, cosmetic, and pharmaceutical purposes. DIC is recognized as a process for decontamination, debacterization of foodstuffs. The treatment allows DIC the elimination of micro-organisms (even in spore forms) through two main mechanisms: a controlled thermal treatment; pressure relaxation excessively stressed on microorganisms that cause their explosion.
Pulsed Electric Field (PEF) treatment, also referred to as electroporation or electropermeabilization, is a nonthermal process where an external electric field is applied to a living cell for a very short duration. Non-thermal PEF processing in liquid foods and beverages preservation has been thoroughly studied as an alternative method to heat preservation. A wide variety of vegetative microorganisms and enzymes have been successfully treated in different food matrices. Because of their rigid structures, bacterial spores can survive harsh environments for a long period of time. The combination of temperature and electric fields > 60 °C and 30 kV/cm respectively was effective on spore inactivation.
Supercritical fluids (SCF) represent an alternative to organic solvents in processes using solvents. A fluid is considered to be in its critical state when it is both heated above its critical temperature (Tc) and pressurized above its critical pressure (Pc). The use of SCF or high-pressure gases for preservation by sterilization, for microbial, virus and spore inactivation has been the subject of some extended reviews.

Microwave heating results from the dissipation of the electromagnetic waves in the irradiated medium. The majority of food heating applications use a multimode resonance cavity applicator because it permits large volumes. Pasteurization is a thermal inactivation of pathogenic microorganisms, notably vegetative cells, yeasts and moulds. Sterilization is the inactivation of microorganisms and their spores, which are generally more thermo-resistant than vegetative cells. The microwave heating of food provides an excellent opportunity to pasteurize or sterilize the products. Products such as sweet mash potato , a biphasic food product (salsa con queso), green beans and mash carrot, were treated and the feasibility of microwave sterilization was confirmed. The continuous pasteurization and sterilization of liquids with microwave equipment are a useful alternative processing approach but the price and the energy consumption are relatively high.
Ultrasound is a sound frequency in the range between 18 and 100 kHz that is above hearing of the human ear. The effectiveness of the ultrasound depends to the acoustic frequency, temperature and pressure

applied. Ultrasound is one of the new preservation techniques that could eliminate microbial activity. High power ultrasound alone is known to disrupt biological cells. When combined with heat treatment, it can accelerate the rate of sterilization of foods. The inactivation of Staphylococcus aureus, Pseudomonas fluorescens, Listeria monocytogenes and E. coli has been proven in water and phosphate buffers, as well as in foods such as UHT milk. Ultrasound produced a good level of inactivation under different treatment conditions and media for Bacillus species.

**Table 6**
Characteristics, main disadvantages and advantages of green extraction techniques.

| Technique | Investment | Sample size | Processing time | Main disadvantages | Main advantages |
|---|---|---|---|---|---|
| Ultrasound | Low | 600 L | Low | Problem for separation | High cell disruption |
| Microwave | Medium | 150 L | Low | Hot spots | Cell disruption |
| DIC | High | 100 L | Low | High energy consumption | High cell disruption |
| SFE | High | 300 L | Medium | Need of know-how | Enhance mass transfer |
| PEF | High | Continuous | Medium | Difficult ease of operation | Electroporation of wall cells |

**Gokoglu seafood preservation review**

Besides traditional preservation methods such as chilling, freezing, salting, drying, preservative additives also extend their shelf life. Benzoates, sorbates, propionates and nitrites are commonly used antimicrobials in foods. Despite working for many years, there are still some potentially dangerous effects for health in most of them.

Natural preservatives can be obtained from different sources such as plants, bacteria, fungi, animals and algae. Herbs and spices are considered alternative sources for novel antimicrobial compounds although they are mostly isolated from bacteria and fungi.

Plant extracts have antimicrobial activity due to their phytochemical components. Various plant extracts possess antimicrobial activity against a range of bacteria, yeast and molds.

Animal based. Enzymes may exert antibacterial activity by a number of different mechanisms. Lysozymes and other antimicrobial enzymes mainly elicit their antibacterial activity by inducing bacteriolysis via catalytic cleavage of cell-surface polymers or cell-wall junctions. Lactoperoxidase, and other peroxidase systems, work antimicrobially via oxidative catalysis that releases or produces toxic or inactivating products given that the right substrates are present.

Antimicrobial peptides (AMPs) are oligopeptides containing amino acids in various numbers. AMPs are small biological molecules with a broad-spectrum of activity against bacteria, fungi, protozoa, and some viruses. They are naturally found as part of the defense system of living organisms (including humans, animals, plants, and insects).

Bacteria produce many compounds that can be used to prevent potential spoilage or growth of pathogenic microorganisms. Food-grade microorganisms can form a large number of different substances that inhibit other microorganisms. Bacteriocins, organic acids, hydrogen peroxide, carbon dioxide and diacetyl produced by LAB are their antimicrobial components. Both gram-negative and gram-positive bacteria produce bacteriocins. The LAB bacteriocins have greater antibacterial activity at lower pH values. They have applications in hurdle technology, and utilize synergies of combined treatments to enhance effectiveness in food preservation. It is reported that application of chemical preservatives, thermal or non-thermal physical treatments [pulsed electric field (PEF), High Hydrostatic Presure (HHP), vacuum, or MAP] positively affects the activity of many bacteriocins by increasing the permeability of cell membranes. Recently researchers have been focused on incorporating bacteriocins into food packaging films to control food pathogens. Antimicrobial packaging film prevents the growth of microorganisms on the food surface by contact of packaging material with the surface. Nisin with lactic acid showed synergistic effect in inhibition of Pseudomonas spp.

Royal HaskoningDHV

**Surface/packaging**

**Mahmoud** – physical interaction with microbes existing paints/coatings

Until now the most commonly used antimicrobial approach in the coatings market is the use of leachable biocides, which will gradually leach out from the coating. These biocides contain toxins which will enter the microbe and kill it via chemical way. Although this is an effective process, there are a few important drawbacks such as being harmful to humans and animals, a decreasing activity over time due to the leaching mechanism, environmentally unfriendly and last but not least, the development of microbial resistance against these biocides. Unlike traditional biocides, MyCroFence does not poison microbes but interacts with microbes in a physical way. MyCroFence modifies the binder (acrylic polymer) in such a way that the binder itself becomes anti-microbial and forms the physical barrier.

**(HKUST)** have developed a Multilevel Antimicrobial Polymer (MAP-1) coating that is effective in killing viruses, bacteria and even hard-to-kill spores. https://hkust.edu.hk/news/research-and-innovation/hkust-develops-new-smart-anti-microbial-coating-fight-against-covid-19 . The essence of new coating technology lies with the creation of surface moieties that actively disrupts the microbial envelope and biomolecules, rendering the microorganisms nonviable upon contact. The coating also prevents microbial adhesion on the surface and thus keeping it clean from microbial contaminants. Using a special blend of antimicrobial polymers, the new coating effectively kills up to 99.99 per cent of bacteria and viruses through contact killing and anti-adhesion technology.

**Alarfaj:** The antimicrobial surfaces can reject the attachment of microbes and/or kill microbes in the vicinity and can be designed to kill microbes on contact.

**Heat**

**Smelt & Brul** (food) dry heat vs wet heat resistance

Traditional canning methods aim at destruction of all spores (sterilization) or of all spores that can grow in the container below 40◦C (commercial sterilization or appreciation). Microorganisms are far more resistant to dry heat than to wet heat. Whereas dry heat resistance is relevant in particular for disinfection of materials such as devices for surgery, in food microbiology most attention has been paid to wet heat resistance. In dry heat treatment, microorganisms seem to be inactivated by oxidation, whereas protein denaturation and membrane damage seems to play an important role. in wet heat inactivation. Bacterial spores are generally the most heat-resistant forms, although the heat resistance of bacterial spores varies considerably.

**Table 1** Steps in quantitative risk assessment

1. Hazard identification
   Which microorganisms are relevant for that type of food?
2. Exposure assessment
   What are the steps in the process where microorganisms enter, Multiply or decrease?
3. Dose response assessment (hazard characterization)
   What are the health problems at different level of exposure?
4. Risk characterization
   Estimation of the probability of occurrence and severity of known or potential adverse health effects in a population

**Fraunhofer IPA** has carried out promising preliminary tests to preserve emulsion paints thermally. Partners are being sought to participate in a research project. https://www.european-coatings.com/articles/archiv/thermal-conservation-instead-of-using-biocides

**pH & water activity**
**NVWA** Summary letter to the Dutch Minister (2016) on pH and water activity for preservation of foodstuff. Food products which do not require a best before date.

**Protein hydrolysates and biologically active peptides**
**Tkaczewska**
Protein hydrolysates and biologically active peptides isolated from food proteins, due to their antioxidant and antimicrobial activity, can be used as natural food preservatives. In addition, it is possible to include them in packaging materials as active ingredients.
The full implementation of bioactive peptides and protein hydrolysate is postponed by some challenges such as their low chemical stability, bitter taste and short-term effectiveness. Encapsulation, which is also discussed in this work, could help overcome these limitations.
Antimicrobial peptides are typically composed of less than 50 amino acids, nearly half of which are hydrophobic. Moreover, these peptides have low molecular weight, usually less than 10 kDa. The antimicrobial peptide mechanism of action is mainly based on the electrostatic interaction of peptides with the cell membrane of microorganisms. Antimicrobial peptides are characterized by membrane permeabilizing action.
The type of food matrix to which bioactive peptides are added, may limit their industrial use. Proteins, proteases, fats and metal ions may interfere in the interaction of antimicrobial peptides with their target pathogen, either by reacting to the antimicrobials directly or by interacting with the cellular target(s) for antimicrobials.
The integration of natural derivatives such as protein hydrolysates, bioactive peptides and bacteriocins in edible films, applied to inhibit the growth of microorganisms, has been successfully executed. Casein hydrolysates have pronounced antimicrobial and antioxidant properties. Their antimicrobial effectiveness is mainly due to litholytic activity of amphipathic peptides.
Peptides are continuously released from the coating to the surface of the product, thereby helping to maintain effective concentrations. In addition, the use of peptides as active ingredients of coatings requires smaller amounts of these substances compared with direct addition to the entire volume of the product.
Active coatings with the addition of bioactive peptides can be obtained in three ways:
1. Direct inclusion of the peptide into the polymer matrix;
2. Peptide coating on the polymeric surface;
3. Peptide immobilization in the polymer.
Microencapsulation process can be applied for various purposes such as to release the core material slowly over time and at a constant rate, protecting the core material from degradation and reducing the evaporation rate of the core material or to the surrounding environment.

**Encapsulation antimicrobial agent**
**Saini** review abstract https://link.springer.com/article/10.1007/s10311-020-01109-3
There is an urgent need for efficient techniques to preserve food for a long time. This can be done by encapsulation in nanocarriers such as nanoemulsions, nanoliposomes and nanolipid carriers. These nanocarriers protect functional ingredients such as polyphenols, vitamins, minerals, flavors and antimicrobial agents. Nanocarriers improve stability, functionality, entrapment efficiency and controlled-release of functional ingredients. Antimicrobial ingredients are among the most promising tools for food preservation.

Royal HaskoningDHV

## A2 Alternatives found in literature

The following lists the alternatives found in literature.

**Biocides**

1. Like for like: new yet similar synthetic biocide
2. Other type of biocide (e.g. natural)
3. Antimicrobial polymers
4. Biocide-killers / Biocide degradation

**Formulation**

5. Powder paint (Dry; add water before use)
6. New binders and additives
7. pH

**Non-formulation**

8. Heat treatment of canned product
9. Antimicrobial Packaging
10. Supply chain optimization: on demand production

**Food Tech**

11. Thermo-mechanical (instant controlled pressure drop)
12. Pulsed Electric Field treatment
13. Super critical fluid
14. Micro-wave
15. Ultra-sound

Royal HaskoningDHV

## Biocides

| Name | Like for like |
|---|---|
| Description | New yet similar (synthetic) biocide.<br><br>No alternative biocides are on the market; all biocides are listed in the BPR. To be able to use a new biocide, it needs to be listed in the BPR. |
| TRL | - |
| Effectiveness of preservation | If similar to current biocides the effectiveness of preservation is high |
| Influence on product | If similar to current biocides the influence on product is low |
| Costs | Industry claims that R&D costs are high |
| Toxicity | high |
| Legislation | BPR |
| References | https://www.kennisnetwerkbiociden.nl/conserveermiddelen-worstelen-met-wetgeving |

| Name | Natural biocides |
|---|---|
| Description | Natural biocides are still biocides, i.e. impeding microbial growth, but have a less sensitising / toxic effect to other / larger organisms.<br><br>As natural biocides often last shorter, the use of these may involve encapsulation of the biocide (i.e. controlled release) to extend its effectiveness. |
| TRL | 1-2<br><br>Several start-up companies have looked into sensitiser-free preservatives for consumer products, mostly FMCG like food and cosmetics. Examples include kimchi fermentation peptides or an amino acid-based antimicrobial system.<br><br>Tests are performed for use in paints. |
| Effectiveness of preservation | The antimicrobial efficacy in various coating raw materials and formulations still needs to be validated. |
| Influence on product | - |
| Costs | It might be too expensive for coatings use |
| Toxicity | They remain biocides, but have a less sensitising effect |
| Legislation | These actives are not yet approved for coatings use |
| References | https://www.paint.org/coatingstech-magazine/articles/challenging-preservation-options-towards-biocide-free-waterborne-coatings-via-innovative-binders-and-additives/<br><br>Hodges, T.W., et al. “Proteins and Peptides as Replacement for Traditional Organic Biocides: Part I,” CoatingsTech, 15 (4), 44–50 (2018).<br><br>Crovetto, A., In-Cosmetics Global Presentation. Transforming the Face of Preservation: Peptide Technology in the Personal Care Industry (2018). Available at: http://www.in-cosmetics.com/RXUK/RXUK_InCosmetics/2014-website/Documents/Active%20Concepts%20Presentation.pdf?v=635340184796784783 |

| | |
|---|---|
| | https://greenchemistryandcommerce.org/documents/gc3rt-becker.pdf<br><br>https://www.paint.org/coatingstech-magazine/articles/proteins-and-peptides-as-replacements-for-traditional-organic-preservatives-part-i/<br><br>https://link.springer.com/article/10.1007/s10311-020-01109-3 |

| **Name** | **Antimicrobial Polymers** |
|---|---|
| **Description** | Antimicrobial polymers incorporate functional ingredients into a polymer structure. This alternative avoids the use of lower molecular weight biocides, which can reduce the sensitisation potential and improve the long-term effectiveness. The antimicrobial properties can be achieved either through the use of a functional monomer in the polymerization or post-functionalization of the polymer. A variety of functional groups could be incorporated into the polymer, including cationic nitrogen, halogen, phospho/sulfo derivatives, phenol and benzoic derivatives, organometallic groups, etc. |
| **TRL** | - |
| **Effectiveness of preservation** | - |
| **Influence on product** | - |
| **Costs** | - |
| **Toxicity** | Reduced sensitisation potential |
| **Legislation** | - |
| **References** | https://www.paint.org/coatingstech-magazine/articles/challenging-preservation-options-towards-biocide-free-waterborne-coatings-via-innovative-binders-and-additives/<br>Muñoz-Bonilla, A., Fernández-García, M., "Polymeric Materials with Antimicrobial Activity," *Progress in Polymer Science,* 37, 281–339 (2012). |

| **Name** | **Biocide degradation / Biocide-killer** |
|---|---|
| **Description** | A biocide-killer can be added to the formulation to (slowly) degrade the biocide. |
| **TRL** | - |
| **Effectiveness of preservation** | The preservation is limited in time. |
| **Influence on product** | - |
| **Costs** | - |
| **Toxicity** | The biocide-killer itself is deemed non-toxic |
| **Legislation** | - |
| **References** | https://www.paint.org/coatingstech-magazine/articles/challenging-preservation-options-towards-biocide-free-waterborne-coatings-via-innovative-binders-and-additives/ |

Royal HaskoningDHV

## Formulation

| Name | New Binders (and organic additives) |
|---|---|
| Description | Experimental REACH-compliant acrylic and styrene acrylic binders have been developed (not indicated how) that are inherently less susceptible to spoilage without biocide addition.<br><br>Rheology modifiers can be made less hospitable to microbes by adding VOCs, adjust the pH towards environments unfavourable to microbes or by different design of the HEUR thickener/polymer (not indicated how).<br><br>See also anti-microbial polymers above. Because of making these substances less susceptible for microbial growth, they might become longer lasting or even persistent. |
| TRL | 1<br><br>Although this study lacks the complexity of a fully formulated paint, it indicates that the experimental binders and rheology modifiers are promising candidates to enable coatings manufacturers to reduce or, in certain areas, eliminate in-can preservatives in their formulations. |
| Effectiveness of preservation | First results are promising to reduce or eliminate biocide use |
| Influence on product | Based on experiments, the experimental binder functioned well in a coating's formulation |
| Costs | - |
| Toxicity | - |
| Legislation | - |
| References | https://www.paint.org/coatingstech-magazine/articles/challenging-preservation-options-towards-biocide-free-waterborne-coatings-via-innovative-binders-and-additives/ |

| Name | pH |
|---|---|
| Description | Traditional paints and coatings are formulated around a pH range of 7–10. At a high pH, conditions are antagonistic to microbial growth. |
| TRL | **9**<br><br>There are high pH (> 10–11) silicate paints on the market that claim to be biocide-free |
| Effectiveness of preservation | |
| Influence on product | Although inorganic, silicate-based paints are biocide-free and durable for exterior application, these coatings are limited to certain substrates, including masonry, mineral plasters, and concrete coatings. |
| Costs | - |
| Toxicity | The corrosive nature of the pH > 10–11 paints has the potential to be harmful to consumers and may require protective equipment, such as goggles, for application. |
| Legislation | - |
| References | https://www.paint.org/coatingstech-magazine/articles/challenging-preservation-options-towards-biocide-free-waterborne-coatings-via-innovative-binders-and-additives/ |

Royal HaskoningDHV

| Name | Powdered Polymer |
| --- | --- |
| Description | ‘Add water before use’: a powdered polymer paint that is mixed into a water borne paint right before application. Paints can be redispersed in water shortly before use and work without any biocides or preservatives. Small amounts can be shaken by hand, while larger amounts can be blended in a paint can with a mixer.<br>This alternative does not concern electrostatic powder coating (which is a different coating technology suitable for (metal) objects, not for the built environment).<br><br>Many traditional paints come in powdered form, based on clay, limestone or silicates cement, potassium water glass or hydrated lime. These paints are characterized by excellent vapor permeability. The benefits of these traditional powder paints often come at a steep price, however. Processing them can be complicated, coverage is poor, and they produce less attractive results. The alternative mentioned here concerns powdered (spray dried) polymer paint.<br>Thanks to the polymers, the paint adheres well and has good spreading properties. In addition, paints are easier to transport and store when they are in powder form, as they weigh less and can be packaged differently from liquid paints. Unlike traditional wall paints, powdered versions do not freeze in the cold, nor do they thicken when exposed to heat. The base is polyvinyl acetate and vinyl acetate copolymers. |
| TRL | **7** |
| Effectiveness of preservation | It claims a longer shelf life (also because heat and cold will have less impact during storage) |
| Influence on product | It claims good spread and coverage for interior wall paint |
| Costs | - |
| Toxicity | No biocides or preservations used |
| Legislation | - |
| References | https://www.wacker.com/cms/en-us/insights/architectural-coatings-powder-paints.html<br>https://www.rawpaints.com/ |

## Non-Formulation

| Name | Heat Treatment |
| --- | --- |
| Description | Heating (< 150°C) of canned product for short period of time (< 1h) |
| TRL | **3**<br><br>The Fraunhofer Institute for Manufacturing Engineering and Automation IPA has carried out (promising) preliminary tests to preserve emulsion paints thermally. Partners are being sought to participate in further research.<br><br>Heating is a common preservation technology in the food sector. |
| Effectiveness of preservation | To be researched.<br><br>Further research is to be carried out, including the limits of the thermal resistance (depending on the chemical composition), the biological durability of thermally treated paint and its application properties. |

| | |
|---|---|
| **Influence on product** | First test show no to minor influence on product ('paintability'). Further research is to be carried out. |
| **Costs** | - |
| **Toxicity** | Non-toxic preservation method |
| **Legislation** | - |
| **References** | https://www.european-coatings.com/articles/archiv/thermal-conservation-instead-of-using-biocides |

| **Name** | **Packaging** |
|---|---|
| **Description** | Antimicrobial surfaces can reject the attachment of microbes and/or kill microbes in the vicinity and can be designed to kill microbes on contact.<br><br>Development of contact-active antimicrobial surfaces by grafting antimicrobial nano-segments onto the material surface can be an important topic for the future. Preparation methods are only valid on specific material surfaces with special conditions of usage. It is required to develop a novel type of contact-active antimicrobial surfaces in which effective antimicrobial nano-segments are grafted at an adequate surface density. |
| **TRL** | **2**<br><br>Antimicrobial packaging is commonly used in the food industry, yet not in coatings. |
| **Effectiveness of preservation** | It implies a new model of coatings supply and consumption: once the paint can is opened, it will be susceptible to microbial contamination. |
| **Influence on product** | - |
| **Costs** | To achieve biocide-free materials via antimicrobial packaging is challenging for the coatings industry, as it requires significant investment in plant hygiene and packaging materials. |
| **Toxicity** | Toxicity of the paint itself will be reduced. |
| **Legislation** | - |
| **References** | https://www.paint.org/coatingstech-magazine/articles/challenging-preservation-options-towards-biocide-free-waterborne-coatings-via-innovative-binders-and-additives/<br><br>Alarfai et al. 2016.Development of biomaterial surfaces with and without microbial nano-segments. J Polym Eng 2016; 36(1): 1‑12 |

| **Name** | **On-demand production** |
|---|---|
| **Description** | On-demand production of canned paint reduces the need for long shelf life, in which canned paints are waiting for a customer to finally pick its specific colour. (It also reduces the amount of unsold paint.) |
| **TRL** | **9**<br><br>Larger DIY stores in the Netherlands have a paint mixing facility, being able to formulate a limited number of paints in a large variety of colours. These are usually the low- to middle-end domestic paints. Online on-demand formulation shops are also spotted for high-end domestic paints. |

| | |
|---|---|
| **Effectiveness of preservation** | The duration of preservation is reduced |
| **Influence on product** | No direct influence on product. Post-formulation shifts hygiene responsibilities from the original manufacturer to the formulator. |
| **Costs** | - |
| **Toxicity** | The need for preservation – and thus preservatives – is reduced. The method itself does not entail any toxic or hazardous effects. |
| **Legislation** | - |
| **References** | https://www.verfmenger.com/over-ons |

## Food Tech

| **Name** | **Food Tech** |
|---|---|
| **Description** | This table is a joint description of several food treatment technologies, including Thermo-mechanical (instant controlled pressure drop), Pulsed Electric Field treatment, Super critical fluid, Micro-wave, and Ultra-sound.<br>This table concerns the application in the food sector, as these technologies are not (yet) applied in the coatings industry. |
| **TRL** | 9 within food; **2** within coatings |
| **Effectiveness of preservation** | High; treated canned food can last for years without preservatives. Effectiveness for coatings is to be proven. |
| **Influence on product** | *Food*<br>In general, these technologies work well on product with high water content and high heat resistance, e.g. cooked products like soup.<br><br>*Coating*<br>Though there are evident similarities between coatings and food (main consistency being water and organics), there are several key differences as well. A main difference between food and coatings is the binder in the coating. The binder should not polymerize before it is applied. |
| **Costs** | As these are treatment technologies, the scalability is high, and so costs are considered to be relatively low. |
| **Toxicity** | Non-toxic |
| **Legislation** | - |
| **References** | - |

The TRLs used are as follows:

**TRL 1** – Basic principles observed

**TRL 2** – Technology concept formulated

**TRL 3** – Experimental proof of concept

**TRL 4** – Technology validated in lab

**TRL 5** – Technology validated in relevant environment
(industrially relevant environment in the case of key enabling technologies)

**TRL 6** – Technology demonstrated in relevant environment
(industrially relevant environment in the case of key enabling technologies)

**TRL 7** – System prototype demonstration in operational environment

**TRL 8** – System complete and qualified

**TRL 9** – Actual system proven in operational environment
(competitive manufacturing in the case of key enabling technologies; or in space)

## A3 ANNEX 3: List of Paint Industry Associations for Web Search

This annex is a list of mainly national paint industry associations, as used in the web search to locate paint manufacturers. It does not aim to be a complete list of national, global or regional associations.

| Country | Website |
|---|---|
| Netherlands | https://www.vvvf.nl/bedrijven |
| Germany | https://www.wirsindfarbe.de/verband/mitglieder |
| Scandinavia | https://hagmansnordic.com/en/ |
| France | https://syndicats.fipec.org/index.php/adherents |
| France | https://syndicats.fipec.org/index.php/afei/accueil-afei/liste-des-adherents |
| France | https://syndicats.fipec.org/index.php/le-syndicat-introduction/adherents |
| Italy | https://www.assovernici.it/associati/ |
| Spain | http://www.asefapi.es/asociados.php |
| Belgium | https://www.europages.fr/entreprises/Belgique/fabricant-de-peintures.html |
| Belgium | https://www.europages.fr/entreprises/Belgique/Fabricant%20Producteur/peintures.html |
| Norway | https://choice-no.techinfus.com/remont-i-nedvizhimost/624-samye-ustojchivye-i-dolgovechnye-kraski-dlya-potolka.html |
| Norway | https://www.norskindustri.no/kampanjesider/malingoglakk/om-oss/medlemmer/ |
| Sweden | https://colorex.se/en/ |
| Sweden | https://sv.wikipedia.org/wiki/Kategori:F%C3%A4rgtillverkare |
| Sweden | https://www.beckers-group.com/ |
| Finland | https://tyopaikat.oikotie.fi/avoimet-tyopaikat/maalinvalmistajia/1393605 |
| Finland | https://www.tikkurilagroup.com/fi/vastuullisuus/ymparisto |
| Denmark | https://www.scandipaint.dk/ |
| Denmark | https://www.danskindustri.dk/medlemsforeninger/dfl/om-dfl/dfl-medlemmer/ |
| Denmark | https://da.wikipedia.org/wiki/Kategori:Malingfabrikker_i_Danmark |
| UK | https://www.coatings.org.uk/directory/directory-of-members.aspx?membership=1 |
| VS | https://en.wikipedia.org/wiki/Category:Paint_and_coatings_companies_of_the_United_Stat |
| VS/Canada | https://www.graco.com/us/en/contractor/solutions/articles/coatings-manufacturers.html |
| Japan | https://www.toryo.or.jp/eng/regular.html |
| Japan | https://www.toryo.or.jp/eng/support.html |
| China | https://zh.wikipedia.org/wiki/Category:%E5%A1%97%E6%96%99%E5%85%AC%E5%8F%B8 |
| China | https://www.listofcompaniesin.com/china/industrial-paint/ |
| China | https://daxueconsulting.com/wall-painting-industry-under-a-new-profitable-revolution/ |
| India | https://dir.indiamart.com/impcat/industrial-paints.html?biz=10 |
| India | https://www.fundoodata.com/learning-center/top-10-paint-companies-india/ |
| World | https://www.coatingsworld.com/buyersguide/additives-/biocides-/ |

# A4 ANNEX 4: List of company websites reviewed

| Company | Working/New URL |
|---|---|
| 3m | https://www.3m.com/3M/en_US/design-and-specialty-materials-us/ |
| A. Bok en Zonen | https://bok-en-zn.nl/ |
| A. Stelling | https://www.stelling.dk/ |
| ABC TRADING CO., LTD. | https://www.abc-t.co.jp/ |
| ACC BEKU Herstellung und Vertrieb chemischer Spezialerzeugnisse GmbH | https://www.acc-beku.de/en/ |
| ACE Paint | https://www.acehardware.com/departments/paint-and-supplies |
| ACTEGA RHENACOAT | https://www.actega.com/others/en/ |
| Addev Materials | https://www.addevmaterials-aerospace.com/ |
| ADLER Deutschland GmbH | https://www.adler-colorshop.com/en |
| ADLER-Werk Lackfabrik Johann Berghofer GmbH & Co. KG | https://www.adler-lacke.com/ |
| Adolf Wagner GmbH Lackfabrik | http://www.buntsteinputz.de/ |
| Advanced Chemical Specialties Ltd | https://www.acslimited.co.uk/ |
| AFCONA JAPAN CO., LTD. | https://www.afcona.com.my/ |
| AFM JAPAN CO., LTD. | http://www.afm-j.com/ |
| AGC COAT-TECH CO., LTD. | https://www.agccoat-tech.co.jp/english/ |
| AICA KOGYO CO., LTD. | http://www.aica.co.jp/ |
| Akzo Nobel | |
| Akzo Nobel Coatings GmbH | https://www.hammerite.com/products/ |
| AKZO NOBEL COATINGS K.K. | https://www.sikkensvr.com/ |
| Akzo Nobel Deco A/S | https://www.akzonobel.com/en#tabId=item_1607610754127_c |
| Akzo Nobel Deco GmbH | https://www.akzonobel.com/#tabId=item_1607610754127_c |
| Akzo Nobel Decorative Coatings | https://www.sikkens.nl/ |
| Akzo Nobel Packaging Coatings GmbH | https://packagingcoatings.akzonobel.com/en/ |
| AKZO NOBEL POWDER COATINGS | Site cant be reached |
| Akzo Nobel Powder Coatings GmbH | https://www.akzonobel.com/en/ |
| AkzoNobel | http://akzonobel.co.in/ |
| AkzoNobel Automotive & Aerospace Coatings | https://aerospace.akzonobel.com/ |
| AkzoNobel Industrial Coatings Ltd | https://www.coatings.org.uk/directory/akzo-nobel-industrial-coatings-ltd_188.aspx?DirectorySearchPageId=1 |
| AkzoNobel Packaging Coatings Ltd | https://packagingcoatings.akzonobel.com/ |
| AkzoNobel Powder Coatings Ltd | https://www.interpon.com/gb |
| Alabastine Holland | https://www.alabastine.nl/ |
| Alfix A/S | https://www.alfix.com/da |
| Alfred Clouth Lackfabrik GmbH & Co. KG | https://www.clou.de/ |
| ALLIOS | http://www.allios.fr/?lang=en |
| ALLNEX JAPAN INC. | https://allnex.com/en |
| AMAKASU CHEMICAL INDUSTRIES | https://www.amakasu-chem.co.jp/ |
| AMC TECHNOLOGY CORP. | https://www.amct.co.jp/eng/index.html |
| Andura Coatings | https://www.andura.com/ |
| Anhui Fir Sen Brush Co.,Ltd. | http://www.ahsszs.com/en/ |
| Anhui Kailin New Material Co., Ltd. | http://www.klhg.net/ |
| Anhui Longda Environmental Sanitation And Machinery Co., Ltd. | https://www.listofcompaniesin.com/visit-1-2929883.html |
| Anhui Qianshan Yongxing Special Brush Company | http://www.ahyxsy.com/ |
| Anhui Qianshan Yongxing Special Brush Industry Co., Ltd. | http://www.xsbrush.comwww.ahyxsy.comqsyxzs.cn.alibaba.com/ |
| Anker Stuy Verven | https://www.ankerstuy.nl/en/ |
| Annie Sloan Interiors Limited | https://www.anniesloan.com/ |
| Anqiu Eagle Cellulose Co., Ltd. | http://www.xycmc.com/ |
| Apollo Colours Ltd | https://www.apollocolours.co.uk/ |
| Aquarius Marine Coatings | https://www.coatings.org.uk/directory/aquarius-marine-coatings_100087.aspx?DirectorySearchPageId=1 |
| ARAKAWA CHEMICAL INDUTRIES, LTD. | https://www.arakawachem.co.jp/en/ |

| | |
|---|---|
| ARAKAWA TORYO INDUSTRY CO., LTD. | http://www.arakawa-toryo.co.jp/ |
| Ardagh Group | https://www.ardaghgroup.com/ |
| ARDEX SKANDINAVIA A/S | http://www.ardex.dk/ |
| Aristo Technology Corporation Limited | http://www.aristoindustries.com/ |
| Arizona Chemical | non-secure sight |
| AS PAINT CO., LTD. | https://www.aspaint.co.jp/ |
| ASADA IRON WORKS CO., LTD. | https://www.asadatekko.co.jp/ |
| ASAHI GLASS CO., LTD. | https://www.agc.com/en/index.html |
| ASAHI GRAPHIC CORPORATION | https://www.asahi-ghs.com/en/index.html |
| ASAHI SUNAC CORP. | https://www.sunac.co.jp/en/ |
| ASAHIKASEI CORPORATION | https://www.asahi-kasei.com/ |
| ASAHIPEN CORPORATION | https://www.asahipen.jp/ |
| Aschaffenburger Lack- und Farbenfabrik Dr. Wilh. Kohlhaus GmbH + Co. | https://alfa-lacke.de/ |
| ASIA INDUSTRY CO., LTD. | http://www.asia-kogyo.co.jp/eng.html |
| Asian Paints | https://www.asianpaints.com/ |
| aspxEASTMAN CHEMICAL JAPAN LTD. | not found |
| ASTEC PAINTS JAPAN INC. | https://astecpaints.jp/ |
| ATCOAT GmbH | http://en.atcoat.com/ |
| ATOMIX CO., LTD. | http://www.atomix.co.jp/ |
| AVKO Limited | https://www.avko.co.uk/ |
| AXALTA COATING SYSTEMS | https://www.axalta.com/corporate/en_US.html |
| Axalta Coating Systems Denmark ApS | http://www.standox.com/ |
| Axalta Coating Systems Huthwaite UK Ltd (Formerly Spencer Coatings) | https://www.coatings.org.uk/directory/axalta-coating-systems-huthwaite-uk-ltd_2013.aspx?DirectorySearchPageId=1 |
| Axalta Coating Systems Tewkesbury UK Ltd (formerly Performance Paints) | https://www.coatings.org.uk/directory/performance-paints-ltd_100150.aspx?DirectorySearchPageId=1 |
| Axalta Coating Systems West Bromwich UK Ltd (Formerly Protega Paints) | https://www.coatings.org.uk/directory/protega-paints_100151.aspx?DirectorySearchPageId=1 |
| AXALTA COATING SYSTEMS, LLC | https://www.axalta.com/jp/ja_JP.html |
| Axalta Powder Coating Systems UK Limited | https://www.coatings.org.uk/directory/axalta-powder-coating-systems-uk-limited_100097.aspx?DirectorySearchPageId=1 |
| AXALTA SHINTO COATING SYSTEMS CO., LTD. | https://www.shintoacs.com/english/index.html |
| B.O. CHEMICAL CO., LTD. | http://www.bochemical.co.jp/ |
| Baden-Jensen A/S | https://www.baden-jensen.dk/ |
| Bare Conductive | https://www.bareconductive.com/ |
| Baril Coatings | https://www.barilcoatings.com/ |
| Baros Group Limited | http://www.barosgroup.com/ |
| BASF Coatings GmbH | https://www.basf-coatings.com/global/en.html |
| BASF Coatings Services | https://www.basf.com/gb/en.html |
| Basf Coatings Services, Filial Af Basf Coatings Services Ab | https://www.basf.com/dk/en.html |
| BASF Plc | https://www.basf.com/nl/nl.html |
| BASSERU CHEMICAL CO., LTD. | http://www.basseru.co.jp/enindex.html |
| BAUMIT | https://int.baumit.com/ |
| BB FABRICATION | https://renaulac.fr/ |
| Beck & Jørgensen A/S | http://www.bj.dk/ |
| Becker Industrial Coatings Ltd | https://www.beckers-group.com/ |
| Bedec Products Ltd | https://www.coatings.org.uk/directory/bedec-products-ltd_100063.aspx?DirectorySearchPageId=1 |
| Behr (paint) | https://www.behr.com/consumer |
| BEISSIER | http://www.beissier.eu/ |
| Belzona Polymerics Limited | https://www.belzona.com/en/index.aspx |
| BEMR | https://www.bemr.fr/ |
| Benjamin Moore | https://www.benjaminmoore.com/en-us/data-sheets/technical-data-sheets |
| Benjamin Moore & Co. | https://www.benjaminmoore.com/en-us |
| Berger Paints | https://www.bergerpaints.com/ |

| | |
|---|---|
| Berger-Lacke GmbH Industrial Coatings | https://berger-lacke.de/?lang=en |
| Bergolin GmbH & Co. KG | https://www.bergolin.de/en/ |
| BESCO CO., LTD. | https://besco.jp/ |
| BICCS Industrial Coatings | https://biccs.nl/en/ |
| BIOFA Naturprodukte W. Hahn GmbH | https://www.biofa-de.com/ |
| Bioni CS GmbH | http://www.bioni.de/landing_page/index.php?lang=en |
| biopin Vertriebs GmbH | http://biopin.com/ |
| BISHU KOSAN CO., LTD. | http://www.bishu-k.co.jp/ |
| BLANCHON | https://www.blanchon.com/ |
| bomix Chemie GmbH | https://www.bomix.com/en/ |
| BONNABAUD | https://www.bonnabaud.com/ |
| Bostik A/S | http://www.bostik.dk/ |
| BOUCHILLOU ALKYA | https://www.bouchilloualkya.com/ |
| Branth-Farben-Fabrik KG | https://www.branth-chemie.de/e-home.htm |
| Brenntag Nederland B.V. | http://www.brenntag.nl/homeen.php |
| BRIGHTON CO.,LTD | https://www.brigh-ton.co.jp/ |
| Bristol Coatings Holland | http://www.bristolcoatingsholland.nl/?page=home&lang=en |
| Britchem Products UK Ltd | https://www.soligardgb.com/ |
| British Paints | https://www.britishpaints.in/ |
| brocolor® LACKFABRIK GmbH | https://www.brocolor.de/en/company/ |
| Broekman Logistics | https://www.broekmanlogistics.com/en/Home |
| BRUNEL CHIMIE DERIVES | cant be reached |
| BS COATINGS | http://www.bs-coatings.com/ |
| Bühler Benelux | https://www.buhlergroup.com/content/buhlergroup/global/en/homepage.html |
| BYK JAPAN KK | https://www.byk.com/en |
| Caldic Nederland | https://www.caldic.com/ |
| CAPITAL PAINT CO., LTD. | https://www.capitalpaint.jp/ |
| CARBOLINE FRANCE | http://www.rpmpcg.com/ |
| CARDOLITE CORPORATION | https://www.cardolite.com/ |
| Carrs Coatings Limited | https://www.coatings.org.uk/directory/carr-coatings-limited_100113.aspx?DirectorySearchPageId=1 |
| CASHEW CO., LTD. | https://www.cashew.co.jp/english/ |
| CASHIWA PRODUCTS CO., LTD. | https://www.casiwa-inc.co.jp/ |
| CBC CO., LTD. | http://www.cbc.co.jp/en/index.html |
| CD PEINTURES | http://www.cdpeintures.com/ |
| CD-Color Nederland | https://www.cd-color.de/cdc-en/ |
| CELLIOSE | https://cin.com/performance-coatings/en/celliose/ |
| CERAMIC COAT CO., LTD. | http://www.spcoat.co.jp/ |
| Cetelon Nanotechnik GmbH | http://www.cetelon-nanotechnik.de/en/ |
| Cetelon-Lackfabrik GmbH | https://www.cetelon.de/en/ |
| CHANET PEINTURES | http://www.chanet.peintures.com/ |
| CHEMIPRO KASEI KAISHA, LTD. | http://www.chemipro.co.jp/en/ |
| Chemours International Operations Sàrl | https://www.chemours.com/en |
| Chestnut Products (Finishes) Ltd | https://www.coatings.org.uk/directory/chestnut-products-ltd_4156.aspx?DirectorySearchPageId=1 |
| China Guangdong Laya New Chemical Co.,ltd | http://www.laya.com.cn/ |
| China North Industries Dalian Corp. | No site available |
| China ShanXi Puhui Chemical CO.Ltd | http://www.puhuichem.com/ |
| Chongqing Haodong Technology Co., Ltd. | http://www.cqhdkj.cn/enwww.haodongheater.com |
| Chromaflo Technologies | https://chromaflo.com/ |
| CHUGAI SHOKO CO., LTD. | https://www.chugai-af.co.jp/ |
| CHUGOKU MARINE PAINTS, LTD. | https://www.cmp-chugoku.com/global.html |

| | |
|---|---|
| Chugoku Paints | https://maritimetechnology.nl/en/companies/chugoku-paints-bv/ |
| CHUO KASEIHIN CO.,INC. | http://www.chuo-chem.co.jp/en/ |
| CHUO PAINT CO., LTD. | http://www.chuo-paint.co.jp/ |
| Churchill Paints Limited | http://www.churchill-paints.co.uk/ |
| Clariant International Ltd. Industrial & Consumer Specialties - Segment Paint & Co | https://www.clariant.com/en/Corporate |
| CLARIANT PLASTICS & COATINGS(JAPAN)K.K | https://www.clariant.com/ja-JP/Corporate |
| Cloverdale Paint | https://www.cloverdalepaint.com/industrial/ |
| Coateq Coating Concepts | https://www.swarco.com/about-us/partnerships/coateq |
| Coates Screen Inks GmbH | https://www.sunchemical.com/ |
| COATING EQUIPMENT MANUFACTURES ASSOCIATION JAPAN | https://www.cema-net.com/index_en.html |
| COATTEC, INC. | http://coattec.com/ |
| COLART | https://www.colart.com/en/ |
| Coldec Productie | https://www.coldec.nl/?lang=en |
| COLLET | https://www.collet-sas.com/en/ |
| COLOR WORKS CO., LTD. | https://www.colorworks.co.jp/ |
| Colorcon No-Tox Products | https://www.colorcon.com/notox |
| COMPANY LIMITED AMAKENTECC | https://amakentecc.jp/ |
| CONDAT | https://www.condat.fr/ |
| CONNEL BROTHERS CO. | http://www.wilbur-ellis-japan.com/ |
| Conren Ltd | https://www.conren.com/ |
| CORSO MAGENTA | https://www.corso-magenta.com/ |
| Covestro Deutschland AG | https://www.covestro.com/ |
| Craig & Rose Ltd | https://www.craigandrose.com/ |
| CROMOLOGY | https://www.cromology.com/ |
| Cronolin Paint | https://cronolin.nl/nl |
| Crown Paints Ltd | https://www.crownpaints.co.uk/ |
| CWS Powder Coatings GmbH | https://www.cws-powder.de/en |
| Dacrylate Paints Ltd | https://www.dacrylate.co.uk/ |
| DAI NIPPON TORYO CO., LTD. | https://www.dnt.co.jp/english/ |
| DAICEL CORPORATION | https://www.daicel.com/ |
| DAIDO CORPORATION CO., LTD. | https://daido-toryo.co.jp/ |
| DAIHO PAINT CO., LTD. | https://www.daiho-paint.co.jp// |
| DAIKEN CHEMICAL INDUSTRY CO., LTD. | http://daikenkagaku.co.jp/ |
| DAIKIN INDUSTRIES LTD. | https://www.daikin.com/ |
| DAIMATSUSANGYOU CO., LTD | http://www.daikin.co.jp/ |
| DAINICHISEIKA COLOR & CHEMICALS MFG. CO., LTD. | http://www.daicolor.co.jp/ |
| DAISHIN CHEMICAL CO., LTD. | http://www.daishin-chemical.co.jp/ |
| DAISHIN PAINT CO., LTD. | https://daishin-paint.co.jp/ |
| DAISO CHEMICAL CO., LTD. | http://www.daiso-chem.co.jp/ |
| DAITAI KAKO CO., LTD. | https://daitai.co.jp/ |
| Dana Lim A/S | https://www.danalim.dk/forside |
| Dandong Anbang Coating Co.,Ltd. | http://www.ddabtl.com/en/ |
| DataLase Ltd | https://www.coatings.org.uk/directory/datalase-ltd-100198.aspx |
| DAW FRANCE | http://www.daw.fr/ |
| DAW Nederland | https://www.dawnederland.nl/home.html |
| DAW SE | https://www.daw.de/en/home.html |
| Day-Glo Color Corp. | https://www.dayglo.com/ |
| De IJssel Coatings | https://www.de-ijssel-coatings.nl/en/home |
| De Monchy International BV | https://monchy.com/en/home/ |
| Decorative Resins International Ltd | http://www.decorativeresins.com/ |

| | |
|---|---|
| DIA-WYTE LTD. | https://www.dia-wyte.com/ |
| DIC CORPORATION | https://www.dic-global.com/en/ |
| Diessner GmbH & Co. KG Lack- und Farbenfabrik | https://www.diessner.de/node/106 |
| Digo Products | https://www.digo.nl/en/ |
| Dinova GmbH & Co. KG | https://www.dinova.de/ |
| DKF KLOZ GmbH | https://dkf-kloz.com/ |
| Domino Printing Sciences Plc | https://www.domino-printing.com/en/home.aspx |
| Doneck Euroflex S.A. | https://www.doneck.com/ |
| Dong Yuan Science & Technology Co., Ltd. | https://www.alibaba.com/?spm=a2700.7699653.scGlobalHomeHeader.10.7bc23e5f46NKDm |
| Dongguan Feidi Mould&plastic Trade Co., Ltd. | http://www.feidi-mould-plastic.com/ |
| Dongguan Tyresealant Auto Tech Co., Ltd. | http://www.ktcig.com/ |
| Donglai Coating Technology (Shanghai) Co., Ltd. | http://www.onwings.com.cn/en |
| Dörken Coatings GmbH & Co. KG | https://www.doerken.com/global/en/home |
| DOW CHEMICAL JAPAN LTD. | https://jp.dow.com/ja-jp.html |
| Dr. A. Conrads Lacke GmbH & Co. KG | http://www.conrads-lacke.de/aktuell/index.php |
| Dr. Albert Lauber KG | https://lackfabrik-lauber.de/ |
| Dr. Demuth Derisol Lackfarben GmbH & Co. KG | https://www.dr-demuth.com/flycms/Home/hlnt5.html |
| Dracholin GmbH | https://www.dracholin.de/ |
| Drost Coatings | https://drostcoatings.nl/ |
| DSL Coatings | https://dslcoatings.nl/ |
| DSM Resins | https://www.dsm.com/corporate/home.html |
| Dulux | https://www.dulux.co.uk/en |
| Dulux Group | https://www.duluxprotectivecoatings.com.au/resources/product-data-sheets/ |
| Dunn Edwards | https://www.dunnedwards.com/products/product-data-sheets-and-sds |
| DURALEX PEINTURES | http://www.duralex-peintures.com/ |
| DURIEU | https://www.durieu.com/ |
| Dutch Boy Paint | https://www.dutchboy.com/ |
| DYFLEX CO., LTD. | https://www.dyflex.co.jp/ |
| Dyrup | http://www.dyrup.com/ |
| E & R | https://www.er-bv.com/en/ |
| E.H. Worlée & Co. | https://www.worlee.de/en/ |
| ECKART GmbH | https://www.eckart.net/de/en/ |
| ECO PERFECT INC. | https://www.ep-coat.com/ |
| ECRIDOR | https://www.carandache.com/us/en/ |
| EDOGAWA GOSEI CO., LTD. | https://www.edog.co.jp/english/ |
| einzA Lackfabrik GmbH | https://www.einza.com/ |
| ELANTAS Europe GmbH | https://www.elantas.com/ |
| Emil Frei GmbH & Co. KG | https://www.freilacke.com/ |
| EMULSION TECHNOLOGY CO., LTD. (E-TEC) | https://www.etec.jsr.co.jp/english/ |
| Envirograf | https://envirograf.com/ |
| Epple Druckfarben AG | https://www.epple-druckfarben.com/en/ |
| Epson Deutschland GmbH | https://www.epson.de/en |
| EPSON Europe | https://www.epson.eu/country-selector |
| Epson UK Ltd | https://www.epson.co.uk/ |
| Ernst Diegel GmbH Creative Coatings | https://www.ferro.com/about/ferro-companies/ernst-diegel-gmbh |
| Esbjerg Farve- & Lakfabrik a/s | http://www.esbjergpaints.dk/ |
| Eskens Tinting Solutions | https://www.eskens.com/en/ |
| ESTCHEM CO., LTD. | http://www.estchem.co.jp/en/index.html |
| Etex Germany Exteriors GmbH | https://www.eternit.co.uk/en-gb/ |
| EUROQUIMICA | http://euroquimica.com/en/ |

| | |
|---|---|
| EVONIK JAPAN CO, LTD. | https://corporate.evonik.jp/en |
| F. Junckers Industrier A/S | http://www.junckers.dk/ |
| Fakolith-Farben GmbH | https://fakolith.de/en/ |
| Farben-Kiroff-Technik | https://www.farben-kiroff.de/ |
| FARROW & BALL | https://www.farrow-ball.com/ |
| Farrow & Ball Ltd | https://www.coatings.org.uk/directory/farrow-ball-ltd_100012.aspx?DirectorySearchPageId=1 |
| Feidal GmbH Lacke + Farben | https://www.meffert.com/en/index/ |
| FELOR | https://www.felor.fr/ |
| FERON | https://www.osca.fr/ |
| Feycolor GmbH | https://en.feycolor.com/?PHPSESSID= |
| Finalin GmbH | https://www.mankiewicz.com/english/home/ |
| Fine Paints of Europe | https://www.finepaintsofeurope.com/ |
| Firwood Paints Ltd | https://www.firwood.co.uk/ |
| Flexchemie | https://www.flexchemie.nl/ |
| Flexible Magnet (Dongguan) Co., Ltd. | http://www.flexiblemagnetchina.com/ |
| Flint CPS Group | https://www.flintgrp.com/ |
| Flügger Denmark A/S | https://www.flugger.dk/ |
| Flügger farver | https://www.flugger.com/en/ |
| Follmann Chemie GmbH | https://www.follmann.com/en |
| Foshan Caboli Painting Material Co., Ltd. | http://www.caboli.netwww.caboli-cn.com/ |
| Friedrich Pietzcker KG Lackfarbenfabrik | https://www.pietzcker.com/ |
| FSi Ltd | https://www.coatings.org.uk/directory/fsi-ltd_100187.aspx?DirectorySearchPageId=1 |
| FUJI PAINT INDUSTRY INC. | http://fujitoryo.co.jp/ |
| Fujian Sannong Calcium Carbonate Co., Ltd. | http://www.dongnanpai.com/ |
| Fujichem Sonneborn Limited | https://www.fcsonneborn.com/ |
| Fujifilm Speciality Ink Systems Ltd | https://www.fujifilm.eu/eu |
| FUJII YOKI KOGYO CO., LTD. | http://www.fujiiyohki.co.jp/ |
| FUJIIYOSHI & CO., LTD. | http://www.fujiiyohki.co.jp// |
| FUJIKURA KASEI CO., LTD. | https://www.fkkasei.co.jp/english/index_e.html |
| FURUKAWA AGENCY CO., LTD. | https://furukawa-agency.co.jp/ |
| FUTABA PAINT CO., LTD. | https://www.futaba-paint.co.jp/ |
| G & G-Lacke GmbH | unavailable website |
| G. E. Habich`s Söhne GmbH & Co. KG Farbenfabriken | https://www.habich.de/de/ |
| G.C. Rutteman & Co. BV | https://rutteman.com/ |
| Ganzlin Beschichtungspulver GmbH | https://www.ganzlin.com/en/ |
| Gardiner Colours Ltd | https://www.gardinercolours.com/ |
| GEHOLIT | http://www.geholit.com/ |
| Geholit + Wiemer Lack- und Kunststoff-Chemie GmbH | https://www.geholit-wiemer.de/en/ |
| GEN GEN CORP. | http://www.gen2.co.jp/ |
| GIFU SHELLAC MANUFACTURING CO., LTD. | http://www.gifushellac.co.jp/?cat=eng |
| GIRMES SPECIAL TEXTILES ZHANGJIAGANG CO.,LTD | http://www.gstz.com/ |
| Glas- en Verfimport A. v/d Kwast | website not found |
| Glidden (paints) | https://www.glidden.com/ |
| Glixtone | http://www.glixtone.com/ |
| GODO CO., LTD. | http://www.c-godo.co.jp/ |
| Golden Artist Colors | https://www.goldenpaints.com/ |
| GRACE PRODUITS DE CONSTRUCTION | http://www.hotelsseminyak.net/graceconstructioncom/ |
| GRACO K.K. | https://www.graco.com/us/en.html |
| GREBE Holding GmbH | https://www.weilburger.com/en/ |
| GREEN JAPAN CO., LTD. | http://www.green-japan.co.jp/ |

| | |
|---|---|
| Grolman Benelux | https://www.grolman-group.com/ |
| Gross & Perthun GmbH & Co. KG | https://www.gross-perthun.de/?L=1 |
| Grumbacher | http://grumbacher.chartpak.com/ |
| GSB Wahl GmbH | http://www.gsb-wahl.de/home.html |
| Guangdong Hualong Coatings Industrial Co., Ltd. | http://www.hualong.gd.cn/ |
| Guangdong Jingzhongjing Industrail Painting Equipment | http://en.gz-btb.com/ |
| Guangdong Yatu Auto Paint Co.,Ltd | http://www.ytchem.com.cn/ |
| Guangdong Yatu Chemical Co., Ltd. | https://www.yatupaint.com/ |
| Guangdong Yele New Material Manufacturing Co., Ltd. | http://www.yele-chem.com/%20www.yelechem.com |
| Guangzhou Baoyue Electromechanical Equipment Co., Ltd. | http://www.baoyues.com/index.html |
| Guangzhou Hexin Industry Co., Ltd. | http://www.hxfcsy.com/ |
| Guangzhou Nanoshine Automotive Co., Ltd. | https://ceramic-pro.com/ |
| Guangzhou Yoki Machinery Import & Export Co., Ltd. | https://www.yokistarspraybooth.com/ |
| Guangzhou YOKI Machinery Manufacturing Co., Ltd. | http://www.yoki-spraybooth.com/ |
| Guangzhou Zhenroumei Paint Co., Ltd. | http://www.topwingspaint.com/ |
| H S Richards | https://www.richards-paints.co.uk/ |
| H.B. Fuller | https://www.hbfuller.com/en/north-america/products-and-technologies/markets-and-applications/building-and-construction/ |
| HAERING GmbH | https://www.haering.de/ |
| HAGHEBAERT ET FREMAUX | https://haghebaert-fremaux.com/ |
| HARIMA CHEMICALS, INC. | https://www.harima.co.jp/en/ |
| Harold Scholz & Co. GmbH | https://www.harold-scholz.de/en |
| Hebei Orient Rubber & Plastic Co., Ltd. | http://www.orientrubber.comwww.hydraulichose-china.com/ |
| Hefei Mingze Chemicals Co.,Ltd | http://www.mingzechem.com/en |
| Heinrich van Megen GmbH & Co. KG | https://www.hvm-coatings.de/en/ |
| Helio Beit Pigmentpasten GmbH | https://heliobeit.com/?lang=en |
| Helios Coatings Deutschland GmbH | https://www.helios-coatings.de/en/ |
| Hempel | https://www.hempel.com/ |
| HEMPEL (GERMANY) GmbH | https://www.hempel.com/en-gb |
| HEMPEL A/S | https://www.hempel.com/da-dk |
| Henkel | https://www.henkel-adhesives.com/in/en/products/industrial-cleaners.html |
| Henkel AG & Co. KGaA | https://www.henkel.com/ |
| Henkel KGaA | https://www.henkel.co.uk/ |
| Herfst en Helder | https://www.herfstenhelder.nl/ |
| herkula Farben GmbH | http://www.herkula.com/en/home/ |
| Herlac Coswig GmbH | https://www.herlac.com/content/index-gb.htm |
| Hermadix Coatings | https://www.hermadix.nl/ |
| HIGASHI NIPPON TORYO CO., LTD. | https://www.hnt-net.co.jp/ |
| HMG Paints Ltd | https://www.hmgpaint.com/ |
| HMG Powder Coatings Ltd | http://www.hmgpowdercoatings.com/ |
| HOBUM Oleochemicals GmbH | https://www.hobum.de/ |
| Hoefer GmbH Lackfabrik | http://hoefer.de/en/1173-2/ |
| HOFFMANN-MINERAL GmbH | https://www.hoffmann-mineral.com/ |
| HOKKO CHEMICAL CO., LTD. | https://www.hokkou-kagaku.com/ |
| HOKUSAN, LTD. | https://www.hoxan.co.jp/english/ |
| HOLBEIN WORKS, LTD. | https://www.holbein.co.jp/english/index.html |
| Holland Colours Europe | https://www.hollandcolours.com/ |
| HOPE HOUSE SYSTEM CO., LTD. | http://www.hopehouse.co.jp/ |
| Höpner Lacke GmbH Lackfabrik | https://www.hoepner-lacke.de/ |
| HP Deutschland GmbH | https://www8.hp.com/uk/en/home.html |
| HP Inc UK LTD | https://www.coatings.org.uk/directory/hp-inc-uk-ltd_100121.aspx?DirectorySearchPageId=1 |

| | |
|---|---|
| hubergroup Deutschland GmbH | https://www.hubergroup.com/uk/en/ |
| Huelsemann Coatings GmbH | https://www.huelsemann.com/ |
| Hunan Jufa Technology Co., Ltd. | http://www.jufapigment.com/ |
| Hunter Douglas Europe | https://www.hunterdouglasgroup.com/ |
| Huzhou Golden Industrial Brush Co., Limited | https://www.brush-golden.com/ |
| I.T.P CO., LTD. | http://nanocray.com/ |
| IBARAKI TORYO CO., LTD. | site not found |
| IMCD Benelux BV | https://www.imcdgroup.com/en |
| Imparat Farbwerk Iversen & Mähl GmbH & Co. | https://www.imparat.de/en/ |
| INABATA & CO., LTD. | https://www.inabata.co.jp/english/ |
| Indestructible Paint Ltd | https://indestructible.co.uk/ |
| Industrial Protective Paints Ltd (Manufacturers of Regal Paint) | https://regalpaint.co.uk/ |
| Inktech Ltd | https://www.inktechinnovation.co.uk/ |
| INOUE MFG., INC. | https://www.inouemfg.com/en/company/ |
| INTERLOCUS, INC. | https://www.i-locus.com/ |
| International Farbenwerke GmbH | https://www.international-yachtpaint.com/en/gb/?selectLocale=1&_ga=2.248865095.1920123656.1618562950-113313622 |
| International Paint (Ned.) | https://www.vvvf.nl/home-en |
| INTERNATIONAL PAINT FRANCE | https://www.interpon.com/gb/article/cromadex |
| International Paint Ltd | https://www.akzonobel.com/international |
| Intrela GmbH Chemische Industrie Erlangen GmbH | https://www.ching-coatings.com/en/45-start-page?layout=blog |
| Intrela GmbH Paul Jaeger GmbH & Co. KG Lackfabrik | https://www.jaegerlacke.de/en |
| Intrela GmbH Pufas-Werk GmbH | https://pufas.com/ |
| INVER FRANCE | https://www.inver.com/en/index.html |
| INX International UK Ltd | https://www.coatings.org.uk/directory/inx-international-uk-ltd_4134.aspx?DirectorySearchPageId=1 |
| ISAMU PAINT CO., LTD. | http://www.isamu.co.jp/ |
| ISF Group Ltd | https://www.coatings.org.uk/directory/isf-group-ltd_100011.aspx?DirectorySearchPageId=1 |
| ISHIHARA SANGYO KAISHA, LTD. | https://www.iskweb.co.jp/eng/ |
| iSL-Chemie GmbH & Co KG | https://www.isl-chemie.de/en/ |
| ITOCHU CHEMICAL FRONTIER Corporation | https://www.itcchem.co.jp/en/ |
| ITOH OIL CHEMICALS CO., LTD. | https://www.itoh-oilchem.co.jp/en/ |
| IZUMI INDUSTRY CO., LTD. | http://izumi-kogyo.com/ |
| J. Sigel & Sohn GmbH Lack- und Farbenfabrik | https://sigel-lacke.de/en/qualitat-ist-zeitlos/ |
| J. W. Ostendorf GmbH & Co. KG Farbwerke | https://www.jwo.com/start/s_41/?language=en |
| James Briggs | https://jamesbriggs.co.uk/ |
| Jänecke + Schneemann Druckfarben GmbH | https://www.js-druckfarben.de/en/ |
| JAPAN BULDING COATING MATERIALS ASSOCIATION | https://www.nsk-web.org/ |
| JAPAN CARBOLINE CO., LTD. | https://enjp.carboline.com/ |
| JAPAN CHEMICAL DATABASE Ltd. | http://www.jcdb.co.jp/ |
| JAPAN PAINT COMMERCE ASSOCIATION | http://www.nittosho.or.jp/ |
| JAPAN PAINTING CONTRACTORS ASSOCIATION | https://www.nittoso.or.jp/ |
| JAPAN PRINTING INK MAKERS ASSOCIATION | https://www.ink-jpima.org/ |
| JAPAN SHIP TECHNOLOGY RESEARCH ASSOCIATION | https://www.jstra.jp/ |
| JAPAN U-PICA COMPANY, LTD. | http://www.u-pica.co.jp/en/ |
| JEFCO | http://www.jefco.fr/fr/ |
| Jiandu Mingzhu Stationers Goods Co.,Ltd | https://www.mzbrush.com/ |
| Jiangmen City Pengjiang District Hetang Wallyba Industry Co., Ltd. | https://www.vit.hkvit.en.alibaba.com/ |
| Jiangsu JingzhongJing Industrial Painting Equipment Co.,Ltd | https://alibaba.com |
| Jiujiang Yongxin Can Equipment Co.,Ltd | http://jjyxzgsb.cn/ |
| JNC CORPORATION | https://www.jnc-corp.co.jp/english/ |
| John Myland Ltd | https://mylands.com/ |

| | |
|---|---|
| Johnstone's Trade | https://www.johnstonestrade.com/ |
| JONAS Farben GmbH | https://jonas-farben.de/en/ |
| Jotun | https://www.jotun.com/in/en/b2c |
| JOTUN (Deutschland) G.m.b.H. | https://www.jotun.com/de/en/corporate |
| Jotun Danmark A/S | http://www.jotun.dk/ |
| Jotun Nederland | https://www.jotun.com/nl/en/b2b |
| Jotun Paints (Europe) Limited | https://www.jotun.com/uk/en/ |
| KADOTOKU CORPORATION | https://kadotoku.co.jp/maintenance/ |
| Kaiser Lacke GmbH | https://www.kaiser-lacke.de/en/home/ |
| KANAE PAINT CO., LTD. | https://www.kanaepaint.co.jp/ |
| KANEKA CORPORATION | https://www.kaneka.co.jp/en/ |
| KANPE HAPIO CO., LTD. | https://www.kanpe.co.jp/ |
| KANSAI PAINT CO., LTD. | https://www.kansai.com/?_ga=2.186940000.959396648.1618643142-779804549.1618643142 |
| KANSAI PAINT MARINE CO., LTD. | https://www.kp-marine.co.jp/en/ |
| KANSAI PUTTY MFG. CO., LTD. | http://www.kansaipate.co.jp/ |
| KANTO PAINT MANUFACTURES' ASSOCIATION | http://www.kantoko.com/ |
| KAPP-CHEMIE GmbH & Co. KG | https://www.stockmeier.com/en/kapp-chemie/ |
| Karl Bubenhofer AG Farbenfabrik | https://www.kabe-farben.ch/en/ |
| Karl Wörwag Lack- und Farbenfabrik GmbH & Co. KG | https://www.woerwag.com/en/ |
| KAWAKAMI PAINT MFG. CO., LTD. | http://www.kawakami-paint.co.jp/ |
| Keim Nederland | https://www.keim.com/en-gb/ |
| Kelly-Moore | https://kellymoore.com/safety-and-technical-data-sheets/ |
| Kelly-Moore Paints | https://kellymoore.com/ |
| KETT ELECTRIC LABORATORY | https://www.kett.co.jp/english/ |
| Keyser & Mackay | https://www.keysermackay.com/ |
| KH NEOCHEM CO., LTD. | http://www.khneochem.co.jp/en/ |
| KIKUCHI COLOR & CHEMICALS CORP. | site not available |
| KIKUSUI CHEMICAL INDUSTRIES CO., LTD. | https://www.kikusui-chem.co.jp/ |
| KITA-NIHON BOSHOKU CO., LTD. | http://kitabo.co.jp/ |
| Kluthe Benelux | https://www.kluthe.nl/ |
| KNAUF | https://www.knauf.fr/ |
| KNEHO-Lacke GmbH | https://www.kneho.com/en/ |
| KOBE PAINTS, LTD. | http://www.kpl.co.jp/ |
| KOJIMA KAKO | https://kojimakako.co.jp/ |
| Kon. Drukinktfabrieken Van Son | https://www.vanson.nl/ |
| Koninklijke Van Wijhe Verf | https://vanwijheverf.nl/en/home-english/ |
| KONISHI CO., LTD. | http://www.bond.co.jp/ |
| KONISHIYASU CO., LTD. | http://konishiyasu.xsrv.jp/ |
| Korthals Groep | https://www.korthals.nl/en/ |
| Krahn Chemie Deutschland GmbH | https://www.krahn.eu/en/de/ |
| KRÖNA COATINGS GmbH | http://www.kroena-coatings.com/ |
| KRONOS | https://kronostio2.com/en/ |
| KUBOKO PAINT CO., LTD. | https://www.kuboko.co.jp/english/index |
| KUSUMOTO CHEMICALS, LTD. | https://www.kusumoto.co.jp/ |
| KYOEISHA CHEMICAL CO., LTD. | https://www.kyoeisha.co.jp/ |
| KYOWA CORPORATION | http://www.mirror-coat.jp/ |
| Lackfabrik Bäder GmbH + Co. | https://baederlacke.eu/en/ |
| Lackfabrik Ernst Bub GmbH | https://www.bucolin.de/en/ |
| Lackfabrik J. Albrecht GmbH & Co. KG | https://www.lack-albrecht.de/ |
| LAFAZIT GmbH | not secured website |

| | |
|---|---|
| Lakfa Verffabriek | https://www.lakfa.com/en |
| LakGruppen A/S | https://lakgruppen.dk/ |
| Lankwitzer Lackfabrik GmbH | https://www.lankwitzer.com/en/ |
| LANXESS Deutschland GmbH | https://lanxess.com/en |
| LANXESS K.K. | https://lanxess.co.jp/ |
| Lawter | https://www.lawter.com/ |
| Lechler Coatings GmbH | http://uk.lechler.eu/en |
| LECHLER REFINISH | http://www.lechler.eu/ |
| Leyland Trade | https://leylandtrade.com/ |
| Liberon Ltd | https://www.coatings.org.uk/directory/liberon-ltd_100093.aspx?DirectorySearchPageId=1 |
| Linyi Lixing Chemicals Co., Ltd. | http://www.cnlxhg.com/en/index.html |
| Little Greene | https://www.littlegreene.com/ |
| LOBA GmbH & Co. KG | https://www.loba.de/en/ |
| LONZA JAPAN, INC. | https://www.lonza.com/ |
| Lord Corp. | https://www.lord.com/products-and-solutions/rubber-bonding/coatings |
| Lörken-Lacke GmbH & Co. KG | https://www.loerken-lacke.com/ |
| Lott-Lacke Produktions- und Handels GmbH | https://www.lott-lacke.de/en/ |
| LVH Coatings Ltd | https://www.lvh-coatings.com/ |
| Lysis Technologies | https://lysistechnologies.com/ |
| MAB Paints | https://www.sherwin-williams.com/ |
| MÄDER | http://www.mader-group.com/ |
| Magni Europe GmbH & Co. KG | https://magnicoatings.com/ |
| Maker Industrial Products Ltd | https://www.maker.co.uk/ |
| Mankiewicz UK LLP | https://www.mankiewicz.com/ |
| Manor Coatings Systems Limited | http://www.manorcoatingsystems.co.uk/home |
| Mapei UK Ltd | https://www.mapei.com/gb/en/home-page |
| Marabu (UK) Ltd | https://www.marabu-inks.co.uk/ |
| Marabu GmbH & Co. KG | https://www.marabu.de/en/index.html |
| MARUBENI CHEMIX CORP. | https://www.marubenichemix.co.jp/ |
| MARUISHI CHEMICAL TRADING CO., LTD. | https://www.maruishi-chem.co.jp/ |
| MATSUO SANGYO CO., LTD. | https://www.matsuo-sangyo.co.jp/ |
| MAULER SARL | https://www.mauler.fr/en/ |
| MAUVILAC | https://mauvilac.com/ |
| MAX PERLES | http://www.maxperles.com/ |
| MEIKOH CO., LTD. | https://www.meikoh.com/ |
| MERCK LTD. | https://www.merckgroup.com/jp-ja |
| MetroPaint | https://www.oregonmetro.gov/tools-living/healthy-home/metropaint |
| Meyer Chemie GmbH & Co. KG | https://www.meyer-chemie.de/ |
| MFAC Coating | http://eng.mfac-coating.com/ |
| MIKASA PAINT CO., LTD. | http://www.mikasa-p.co.jp/ |
| MIKUNI PAINT CO., LTD. | http://www.mikuni-paint.co.jp/ |
| MILLION PAINT CO., LTD. | https://www.coatings1.com/coating-suppliers/million-paint-co-ltd |
| Mipa Paints Limited | https://www.coatings.org.uk/directory/mipa-paints_100106.aspx?DirectorySearchPageId=1 |
| MIPA SE | https://www.mipa-paints.com/en/welcome/ |
| MIRACOOL CO., LTD. | https://www.miracool.jp/ |
| Mirage Inks Ltd | http://mirageinks.com/ |
| MITSUBISHI CHEMICAL CORPORATION | http://www.mcc-epoxy.jp/ |
| MITSUBISHI SHOJI CHEMICAL CORP. | http://www.mccml.co.jp/ |
| MITSUI BUSSAN CHEMICALS CO., LTD. | https://www.mb-chemicals.co.jp/ |
| MIYAKO KAGAKU CO., LTD. | http://www.miyakokagaku.co.jp/ |

| | |
|---|---|
| MIYAKO KOHSAN CO., LTD. | https://www.miyakokohsan.co.jp/ |
| MIZUTANI PAINT CO., LTD. | http://www.polyma.co.jp/en/index.html |
| MOCOPINUS GmbH & Co. KG | https://www.mocopinus.com/de/ |
| MOTIP DUPLI GmbH | https://www.motipdupli.com/en/INT/lang/home.html |
| Münzing International S.à.r.l. | https://www.munzing.com/en/home.html |
| Muralplast | https://www.muralplast.com/ |
| MUSASHI PAINT CO., LTD. | http://www.musashipaint.com/en/ |
| NAGASE & CO., LTD. | https://www.nagase.co.jp/ |
| NAGASHIMA PAINT CO., LTD. | http://www.musashipaint.com |
| NAGOYA KAGAKU KOGYOSHO CO., LTD. | https://cn.panjiva.com/Nagoya-Kagaku-Kogyosho-Co-Ltd/1606447 |
| Nanjing Chili International Trade Co., Ltd. | http://www.xiangbaochem.com/ |
| Nanocoat International / Chemona | https://chemonaworld.com/ |
| NATIOPEN KOGYO CO., LTD. | http://natiopen.com/ |
| NATOCO CO., LTD. | http://www.natoco.co.jp/english/index.html |
| NAUTIX | https://www.nautix.com/ |
| NCOI Techniek Trainingen BV | https://www.ncoi.nl/ |
| NELF Lakfabrieken | https://www.nelfpaints.com/ |
| Neogene Ltd | https://www.neogeneonline.com/ |
| Nerolac | https://www.nerolac.com/ |
| Neverlak | http://www.neverlak.nl/documents/home.xml?lang=en |
| Newlife Paints Ltd | http://www.newlifepaints.co.uk/ |
| Newpaintco Ltd | http://www.newpaintco.co.uk/ |
| NICHIA PAINT CO., LTD. | https://www.nichiapaint.co.jp/ |
| NICHILAY MAGNET CO.,LTD | https://www.nichilaymagnet.co.jp/ |
| NIHON BIOS CO., LTD. | http://www.nihonbios.jp/ |
| NIHON KOKEN KOGYO CO., LTD. | https://nihonkoken.co.jp/ |
| NIHON TOKUSHU TORYO CO., LTD. | https://www.nttoryo.co.jp/en.html |
| Ningbo Yinzhou Rilong Hardware Tools Factory | https://www.rilongtool.com/ |
| Ningbo Yinzhou Win-Today Electrical And Mechanical Technology Co., Ltd. | http://www.eftools.com/ |
| NIPPE HOME PRODUCTS CO., LTD. | https://gb.kompass.com/c/nippe-home-products-co-ltd/jp063209/ |
| NIPPON FIELD CO., LTD. | site cannot be reached |
| NIPPON KAKO TORYO CO., LTD. | https://www.nippon-kako.co.jp/ |
| Nippon Paint | https://www.nipponpaint.co.in/ |
| Nippon Paint | https://www.nipponpaint.com/china/ |
| NIPPON PAINT ANTI-CORROSIVE COATINGS CO., LTD. | https://www.np-boushoku.co.jp/ |
| Nippon Paint Automotive (UK) Limited | https://www.coatings.org.uk/directory/np-automotive-coatings-europe-ltd_1657.aspx?DirectorySearchPageId=1 |
| NIPPON PAINT AUTOMOTIVE COATINGS CO., LTD. | https://www.nipponpaint-automotive.com/en/ |
| NIPPON PAINT CO., LTD. | https://www.nipponpaint.co.jp/ |
| NIPPON PAINT HOLDINGS CO., LTD. | https://www.nipponpaint-holdings.com/en/ |
| NIPPON PAINT INDUSTRIAL COATINGS CO., LTD. | https://nipponpaint-industrial.com/en/ |
| NIPPON PAINT SURF CHEMICALS CO., LTD. | https://www.nipponpaint-surf.com/ |
| NIPPON PAPER INDUSTRIES CO., LTD. | https://www.nipponpapergroup.com/ |
| NISHIMURA CO., LTD. | http://www.nsmrp.com/ |
| NISSIN SANGYO CO.,LTD | https://www.gaina.co.jp/ |
| NITTO CHEMICAL CO., LTD. | http://www.nitto-c.co.jp/ |
| NITTO KASEI CO., LTD. | http://www.nittokasei.co.jp/ |
| NOF METAL COATINGS ASIA PACIFIC CO., LTD. | http://www.nofmetalcoatings.com/ |
| Nordcoll A/S | http://www.nordcoll.com/ |
| Norix Lackfabrik GmbH & Co. KG | https://www.mankiewicz.com/english/ |
| NOROO PAINT & COATINGS CO., LTD., Tokyo Branch | https://www.noroopaint.com/kor/index.asp |

| | |
|---|---|
| Norway Coatings | https://www.norwaycoatings.nl/ |
| Nowocoat Industrial A/S | https://nowocoat.dk/ |
| NTT ADVANCED TECHNOLOGY CORP. | https://www.ntt-at.co.jp/ |
| OHASHI CHEMICAL INDUSTRIES LTD. | https://www.ohashi-chem.com/ |
| OKABE CO., LTD. | https://e-okabe.jp/ |
| OKITSUMO INCORPORATED | https://www.okitsumo.co.jp/en/ |
| OLERONLAC | registered domanin |
| Oli Lacke GmbH | https://www.oli-lacke.de/en/ |
| Omya GmbH | https://www.omya.com/DE-EN |
| ONIP | https://www.onip.com/ |
| Online Logistic Solution GmbH | https://www.onloso.de/ |
| ONO FORWARDING AGENCY LTD. | http://www.ono-unso.co.jp/ |
| OOGI CHEMICAL INDUSTRY CO., LTD. | http://www.oogi-kagaku.co.jp/ |
| ORIGIN CO., LTD. | https://www.origin.co.jp/eng/ |
| OSAKA GAS CHEMICALS CO., LTD. | https://www.ogc.co.jp/ |
| OSAKA PAINT INDUSTRIAL COOPERATIVE ASSOCIATION | http://www.osakapaint.or.jp/ |
| OSAKA TORYO KOGYO CO., LTD. | http://osaka-toryo.com/ |
| OSMO & EDEL JAPAN CO., LTD. | https://osmo-edel.jp/ |
| Osmo Holz und Color GmbH & Co. KG | https://www.osmo.de/en/ |
| OSNATOL-Werk GmbH & Co. KG Belmer Lackfabrik | https://www.osnatol.de/en/ |
| Otto Bollmann GmbH & Co. KG Lack- und Farbenfabrik | https://www.otto-bollmann.de/ |
| Owatrol UK | https://www.coatings.org.uk/directory/owatrol-uk_100054.aspx?DirectorySearchPageId=1 |
| OZ INTERNATIONAL | http://www.oz-international.com/ |
| P. A. Jansen GmbH u. Co. KG | https://www.jansen.de/en/ |
| P.K. Koopmans Lakfabrieken | https://www.pkkoopmans.nl/ |
| Pack2Pack | https://www.envases.nl/ |
| Paint 360 Limited | https://www.paint360.co.uk/ |
| Palatine Paints | https://www.palatinepaints.co.uk/ |
| PANADUR GmbH | https://www.panadur.de/en.html |
| Paragon Inks (Holdings) Ltd | https://www.coatings.org.uk/directory/paragon-inks-holdings-ltd_100037.aspx?DirectorySearchPageId=1 |
| Paramount Powders (UK) Ltd | https://www.paramountpowders.co.uk/ |
| PCC Specialties GmbH | https://www.polyu.eu/?lang=en |
| PEBEO | http://en.pebeo.com/Pebeo |
| PEINTURES CIMENTOL | https://www.cimentol.com/fr |
| PEINTURES LAGAE | https://www.lagae.paris/13-peintures-professionnelles |
| PEINTURES VITEX | http://www.peintures-vitex.com/ |
| Pental Eterna Brushes And Tools Making Co., Ltd. | http://www.eternabrush.com%20www.eternatools.com/ |
| Peter Kwasny GmbH | https://www.kwasny.com/en/ |
| Peter-Lacke GmbH | https://www.peter-lacke.com/ |
| PETRO CHEMICALS, K.K. | http://www.petro-c.co.jp/index.html |
| Pettit Marine Paint | https://www.pettitpaint.com/ |
| Phoenix Coatings | http://www.phoenix.nl/ |
| Plascoat Systems Ltd | https://www.axalta.com/thermoplasticcoatings_global/en_GB.html |
| PLPcoatings | https://www.plpcoatings.com/en/ |
| Plyfit Industries China, Inc. | http://www.plyfit.com/ |
| Polyvine Ltd | https://www.polyvine.com/index.php/en/ |
| PPG (formerly Whitford) | https://www.coatings.org.uk/directory/ppg-formerly-whitford_2289.aspx?DirectorySearchPageId=1 |
| PPG Aerospace | http://www.ppgaerospace.com/Home.aspx |
| PPG Architectural Coatings UK Limited | https://www.coatings.org.uk/directory/ppg-architectural-coatings-uk-limited_4244.aspx?DirectorySearchPageId=1 |
| PPG Automotive Refinish | https://www.ppgrefinish.com.au/Home.aspx |

| | |
|---|---|
| PPG Coatings | website available but empty page |
| PPG Coatings Danmark A/S | https://dyrup.dk/ |
| PPG Coatings Deutschland GmbH | https://sigmaretail.de/ |
| PPG Coatings Europe B.V. Protective & Marine | https://www.ppg.com/ |
| PPG Coatings Nederland | https://www.sigma.nl/professional/home |
| PPG Industrial Coatings | https://www.ppgindustrialcoatings.com/en-US |
| PPG Industries | https://www.ppgpmc.com/ |
| PPG Industries (UK) Ltd | https://www.coatings.org.uk/directory/ppg-industries-uk-ltd_1292.aspx?DirectorySearchPageId=1 |
| PPG JAPAN LTD. | http://www.ppgpmcjapan.co.jp/ |
| PPG Scandinavia Filial af Ppg Industries(France)S.A. | https://scandinavia.ppgrefinish.com/ |
| Pratt & Lambert | https://www.prattandlambert.com/ |
| printec GmbH | http://www.printec-gmbh.de/index.php?lang=en |
| Pro-Glue A/S | http://www.proglue.dk/ |
| Pröll GmbH | https://www.proell-inks.com/en |
| Pronto Industrial Paints Ltd | https://prontopaints.co.uk/ |
| Pulse Printing Products Ltd | https://www.pulseppl.com/ |
| Pulse Roll Label Products Ltd | https://www.pulserl.com/ |
| Qianshan Xuzheng Brush Co., Ltd. | http://www.xzbrush.com/ |
| RECA | http://www.reca.tm.fr/ |
| Reincke Naturfarben GmbH | https://www.leinos.de/ |
| RELIUS Farbenwerke GmbH | https://www.relius.de/ |
| Remmers GmbH | https://en.remmers.com/en |
| RencoSolutions | https://www.rencosolutions.nl/ |
| RESAU Chemische Produkte GmbH & Co. | https://www.resau.de/ |
| Resino Trykfarver A/S | http://www.resino.dk/ |
| Resitex Ltd | https://www.resitexcoatings.co.uk/ |
| RESSOURCE | https://ressource-peintures.com/ |
| Rhenocoll-Werk eK Coatings and Adhesives | https://www.rhenocoll.de/en/ |
| RICHARD & CIE | http://www.sioenchemicals.com/ |
| Rickert GmbH & Co. | https://rickert-bocholt.de/en/ |
| Ricoh UK Products | https://www.ricoh.co.uk/ |
| RIGO Verffabriek | https://www.rigoverffabriek.nl/ |
| Rilit Lackfabrik GmbH | https://rilit.de/ |
| ROCK PAINT CO., LTD. | http://www.run-polycite.jp/ |
| Roco Chemical (Zhaoqing) Limited | http://www.roco-chem.com/ |
| Rodda Paint | https://www.roddapaint.com/ |
| Ronseal | https://www.ronseal.com/ |
| RPM International | https://www.rpminc.com/ |
| RSW Orga GmbH | https://www.dibac.de/ |
| RUCO Druckfarben A. M. Ramp & Co. GmbH | https://www.ruco-druckfarben.de/en |
| Rudolf Hensel GmbH Lack- und Farbenfabrik | https://www.rudolf-hensel.de/en/ |
| Rüdt Industrielacke GmbH & Co. KG | https://www.mankiewicz.com/english/contact/ |
| RUSTABOUT | http://www.rustabout.com/ |
| Rustins Ltd | https://www.rustins.ltd/rustins |
| Rust-Oleum | https://www.rustoleum.com/ |
| RUST-OLEUM FRANCE | https://www.rust-oleum.eu/ |
| Rust-Oleum Netherlands | https://www.rust-oleum.eu/nl/ |
| Rust-Oleum UK Ltd | https://www.coatings.org.uk/directory/rust-oleum-uk-ltd_3431.aspx?DirectorySearchPageId=1 |
| RÜTGERS Organics GmbH | https://impra.co.uk/home |
| RYOKO CO., LTD. | https://www.kkryoko.co.jp/ |

| | |
|---|---|
| Sadolin & Holmblad | http://www.sadolinpaint.com/ |
| Safic-Alcan Necarbo | http://www.safic-alcan.nl/en/ |
| SAICOS COLOUR GmbH | https://www.saicos.de/en/ |
| SAINT-GOBAIN WEBER | https://wecare.weber/ |
| SAITO & CO., LTD. | http://www.run-polycite.jp/index.html |
| SAITO PAINT CO., LTD. | https://www.saito-paint.co.jp/ |
| SAKAI CHEMICAL INDUSTRIAL CO., LTD. | https://chem.co.jp/sakaikagaku/ |
| SAKAI CHEMICAL INDUSTRY CO., LTD. | http://www.sakai-chem.co.jp/jp/ |
| SAKURA COLOR PRODUCTS CORP. | https://www.craypas.com/global/ |
| SAKURANOMIYA CHEMICAL CO., LTD. | http://sk1.co.jp/ |
| Samuel Cabot Incorporated | https://www.cabotstain.com/ |
| SAN NOPCO LTD. | https://www.sannopco.co.jp/ |
| SANBEST KOGYO CO., LTD. | https://sanbestkogyo.co.jp/ |
| SANKO ELECTRONIC LABORATORY CO., LTD. | http://www.sanko-denshi.co.jp/ |
| SANKYO PHARMACY CO.,LTD | http://www.sankyo-yakuhin.co.jp/ |
| SANSAI KAKO CO., LTD. | http://www.sansai.com/ |
| SANYO CHEMICAL INDUSTRIES, LTD. | https://www.sanyo-chemical.co.jp/ |
| SANYO COLOR WORKS, LTD. | http://www.sanyocolor.jp/ |
| SANYO TRADING CO., LTD. | https://www.sanyo-trading.co.jp/ |
| SANYU PAINT CO., LTD. | http://www.sanyu-paint.co.jp/ |
| Sarex Belgium AG | http://www.sarex.be/ |
| Scandi Supply A/S | http://www.scandisupply.dk/ |
| Schjerning Farver A/S | http://www.schjerning-farver.com/ |
| Schlenk Metallic Pigments GmbH | https://www.schlenk.com/ |
| Schloetter Company Ltd | https://www.schloetter.co.uk/ |
| Schoeller Allibert Swiss Sàrl | https://www.schoellerallibert.com/ |
| Schramm Coatings GmbH | https://www.akzonobel.com/en/our-locations |
| Schulz GmbH Farben- und Lackfabrik | https://www.schulz-farben.de/en/ |
| SCSO | https://unikalo.com/ |
| Seagulls Re-Use | https://seagullsreuse.org.uk/ |
| SEVEN CHEMICAL | https://www.seven-chemical.co.jp/index.html |
| SG Bailey Paints Ltd | https://www.baileypaints.co.uk/ |
| Shalimar Paints | https://www.shalimarpaints.com/ |
| Shandong Digao Paint Co., Ltd. | http://www.dbgj.comwww.sdlcchem.com/ |
| Shandong King Mechanical Coating Technology Co., Ltd. | http://www.kexingcoating.com/ |
| Shandong Longxiang Machinery Co.,Ltd | http://www.sdlongyao.com/ |
| Shanghai Baolijia Chemical Co., Ltd. | http://www.baolijia.com.cn/ |
| Shanghai Inner Beauty Electronic Technology Co.... | http://www.myuvled.net/ |
| SHARP CHEMICAL IND. CO., LTD. | https://www.sharpchem.co.jp/ |
| Shawcor | https://www.shawcor.com/products/bredero_shaw.html |
| SHELL CHEMICALS JAPAN LTD. | https://www.shell.co.jp/ |
| Shenzhen Crown Paint Company Limited | http://www.crownpaint.net/ |
| Shenzhen Deer Hunter New Technology CO.,Limited | http://www.cndeerhunter.com/ |
| Shenzhen I-Like Fine Chemical Co., Ltd | https://www.ilikegroup.com/ |
| Shenzhen Rainbow Fine Chemical Industry Co., Ltd. | http://www.7cf.com/ |
| Shenzhen Top Rank Investment Co., Ltd. | http://www.toprankindustries.com/ |
| Sherwin-Williams | https://www.sherwin-williams.com/painting-contractors/products/data-sheets |
| Sherwin-Williams (Valspar) | https://www.valsparauto.com/automotive/default.jsp |
| Sherwin-Williams ARTI GmbH | https://oem.sherwin-williams.com/eu/en/home |
| Sherwin-Williams Consumer Brands Limited | https://www.coatings.org.uk/directory/sherwin-williams-consumer-brands-limited-1861.aspx#:~:text=Sherwin%20Williams% |

| | |
|---|---|
| Sherwin-Williams General Industrial Coatings | https://www.coatings.org.uk/directory/sherwin-williams-general-industrial-coatings_3166.aspx?DirectorySearchPageId=1 |
| Sherwin-Williams Packaging Coatings | https://industrial.sherwin-williams.com/na/us/en/packaging.html |
| Sherwin-Williams Protective & Marine Coatings | https://www.coatings.org.uk/directory/sherwin-williams-protective-marine-coatings_1414.aspx?DirectorySearchPageId=1 |
| Sherwin-Williams UK Coatings | https://www.coatings.org.uk/directory/sherwin-williams-uk-coatings_1218.aspx?DirectorySearchPageId=1 |
| SHIBATA CO., LTD. | http://www.shibata-net.co.jp/ |
| SHIN MATERIAL ONE CO., LTD. | http://www.shinmate1.com/ |
| SHIN NIHON KAKEN INC. | http://www.snk-kaken.com/ |
| SHINTO PAINT CO., LTD. | https://www.shintopaint.co.jp/english/ |
| SHOEI CHEMICAL CO., LTD. | https://www.shoei-chem.jp/ |
| SHOWA CHEMICAL INDUSTRY CO., LTD. | https://www.showa-chemical.co.jp/ |
| Sichuan Auspicious Coatings Co.,Ltd | http://www.scchem86.com/ |
| SI-Coatings GmbH | https://www.huehoco.com/en/company/si-coatings |
| Siegwerk Benelux | https://www.siegwerk.com/en/home.html |
| Sika Deutschland GmbH | https://gbr.sika.com/ |
| Sika Nederland | https://nld.sika.com/ |
| SIMACO GmbH | https://simaco.com/en/ |
| SINLOIHI CO., LTD. | http://www.sinloihi.co.jp/wp/ |
| SK KAKEN CO., LTD. | https://www.sk-kaken.co.jp/ |
| Snowcem | https://www.snowcempaints.com/ |
| SOB | https://www.sob.fr/ |
| SOFEC | https://www.sofec.net/fr/ |
| SOFRAMAP | https://www.soframap.com/ |
| SOJITZ CORPORATION | https://www.sojitz.com/jp/ |
| SOLAR CO., LTD. | https://www.kobe-solar.co.jp/ |
| Solar Inks Ltd | http://www.earth.ink/ |
| SOLVAY NICCA, LTD. | https://www.solvay.com/en/ |
| SOPPEC | https://technimafrance.com/gb/ |
| SOVA GmbH | https://www.sova-online.de/home-en.html |
| SPS | https://sps.nl/ |
| STAEDTLER Mars GmbH & Co. KG | https://www.industrial-products.com/en/ |
| Steelpaint GmbH | https://www.steelpaint.de/en/ |
| STERMA | http://www.peinture-sterma.com/ |
| Steyport Ltd | https://www.steyport.co.uk/ |
| STO | https://www.sto.fr/ |
| STO SE & Co. KGaA | https://www.sto.de/s/ |
| Strikolith | https://www.strikolith.com/en/ |
| Sudarshan Europe B. V. | https://www.sudarshan.com/ |
| SUDLAC | https://sudlac.com/ |
| SÜDWEST Lacke + Farben GmbH & Co. KG | https://www.suedwest.de/ |
| SUMIKA COVESTRO URETHANE CO., LTD. | https://www.covestro.jp/ja-jp |
| SUMITOMO RUBBER INDUSTRIES, LTD. | http://www.sri-hybrid.co.jp/ |
| SUMITOMO SHOJI CHEMICALS CO., LTD. | https://www.sc-chem.co.jp/ |
| SUNWAY CO., LTD. | http://sunway1963.com/ |
| SUZUKA FINE CO., LTD. | https://www.suzukafine.co.jp/?p=251 |
| SW Color Lackfabrik GmbH | https://www.swcolor.de/sw-color-lackfabrik.html |
| T & R Williamson | http://www.trwilliamson.co.uk/ |
| TAIHEI KASEI CO., LTD. | http://www.taiheikasei-cdr.co.jp/ |
| TAINETSU CHEMICAL CO., LTD. | https://tainetsu.jp/ |
| TAISEI CHEMICAL INDUSTRIES CO., LTD. | https://www.taisei-kako.co.jp/ |
| TAISEI FINE CHEMICAL CO., LTD. | https://www.taisei-fc.co.jp/ |

| | |
|---|---|
| TAIYO CHEMICAL CO., LTD. | http://www.taiyo-solvent.com/ |
| TAIYO TORYO CO., LTD. | https://www.taiyotoryo.co.jp/ |
| Taizhou Huangyan Magic Mould Co., Ltd. | http://www.magic-mould.com/ |
| TAKEYA CHEMICAL LABORATORY STOCK CORP. | http://www.takeyakagaku.com/ |
| TALENS FRANCE | https://www.royaltalens.com/ |
| TAYCA CORPORATION | http://www.tayca.co.jp/ |
| TC UNION CO., LTD. | https://www.tcunion.co.jp/home/ |
| Teal & Mackrill Ltd | https://www.coatings.org.uk/directory/teal-mackrill-ltd_2066.aspx?DirectorySearchPageId=1 |
| Technico Surface Coatings Ltd | https://www.coatings.org.uk/directory/technico-surface-coatings-ltd_4129.aspx?DirectorySearchPageId=1 |
| Teknos | https://www.teknos.com/en-GB/industrial-coatings/ |
| Teknos (UK) Ltd | https://www.coatings.org.uk/directory/teknos-uk-ltd_100085.aspx?DirectorySearchPageId=1 |
| Teknos A/S | http://www.teknos.com/ |
| Teknos Deutschland GmbH | https://www.teknos.com/en-GB/ |
| Teleplast GmbH & Co. KG | https://www.teleplast.de/en/ |
| Tetrosyl Limited | https://www.coatings.org.uk/directory/tetrosyl-limited_4081.aspx?DirectorySearchPageId=1 |
| TETSUTANI & CO., LTD. | https://www.tetsutani.co.jp/ |
| THE JAPAN SOCIETY OF COLOUR MATERIAL | http://www.shikizai.org/ |
| THE KOUYOH TRADING CO., LTD. | http://www.kouyoh.co.jp/ |
| THEOLAUR PEINTURES | https://www.theolaur.com/ |
| Thermaset Ltd | https://www.thermaset.co.uk/ |
| Thomas Howse Ltd | https://www.howsepaints.co.uk/ |
| Thor GmbH | https://www.thor.com/ |
| THREEBOND UNICOM CO., LTD. | https://www.threebond-uc.co.jp/ |
| Tianjin Yida Tools International Trade Co., Ltd. | http://www.yidaworld.comyidatools.en.alibaba.comyidatool.manufacturer.globalsources.comwww.aliexpress.com/store/914 |
| Tiger Coatings GmbH & Co. KG | https://www.tiger-coatings.com/ |
| Tikkurila Danmark A/S | https://beckers.dk/ |
| TITAN KOGYO, LTD. | http://www.titankogyo.co.jp/ |
| TNEMEC | https://tnemec.com/products/ |
| TOA GOSEI CO., LTD. | https://www.toagosei.co.jp/ |
| TODA PIGMENT CORP. | http://www.todapigment.co.jp/ |
| TOHO METAL INDUSTRIES CO., LTD. | https://www.tohometal.co.jp/ |
| TOHPE CORPORATION | https://www.tohpe.co.jp/ |
| TOKYO PAINT CO., LTD. | non working website |
| TOKYO THERMO CHEMICAL INDUSTRY CO., LTD. | http://thermosin.jp/en/ |
| TOMATEC CO.,LTD. | https://www.tomatec.co.jp/ |
| Tor Coatings Ltd | https://www.tor-coatings.com/ |
| TOSHIN KAGAKU CO., LTD. | http://www.toshinkagaku.co.jp/ |
| TOSOH CORPORATION | https://www.tosoh.co.jp/ |
| TOTO LTD. | https://jp.toto.com/ |
| TOUPRET | https://www.toupret.co.uk/ |
| Touwen & Co. | https://www.tenco.nl/ |
| TOYO ALUMINIUM K.K. | https://www.toyal.co.jp/ |
| TOYO CHEMICALS CO., LTD. | http://www.toyochem.co.jp/ |
| TOYO COLOR CO., LTD. | https://www.toyo-color.com/ja/index.html |
| TOYO KOGYO TORYO CO., LTD. | http://www.toyo-jupiter.co.jp/english-top/ |
| TOYO MATERIA CORP. | http://www.office-web.jp/toyomateria/pc/ |
| TP GIKEN CO., LTD. | https://tp-giken.co.jp/ |
| TQC | https://vito.be/en |
| Tremco CPG UK Limited | https://www.cpg-europe.com/en-gb/?utm_source=https://www.tremco-illbruck.com/en_GB/&utm_medium=301_redirect&ut |
| Trimite Global Coatings | https://www.trimite.com/ |

| | |
|---|---|
| Troy GmbH | https://www.troycorp.com/ |
| TrustMost Industries, Inc. | http://www.trustmost.com.cn/ |
| TURNER COLOUR WORKS LTD. | https://www.turner.co.jp/ |
| UMCO Umwelt Consult GmbH | https://www.umco.de/en.html |
| Union (Foshan) Chemical Co., Ltd. | http://www.misppon.com/ |
| Unipak A/S | https://unipak.dk/en |
| UPG HOLDINGS CO., LTD. | https://www.unionpaintgroup.com/home/ |
| U-POL | https://www.u-pol.com/us/en/home#.YHhH5Gf7Q2w |
| V.33 | https://www.v33.com/ |
| Valspar | https://industrial.sherwin-williams.com/na/us/en/general-industrial/catalog/category/products-by-industry.11543145.html |
| Veluvine | https://www.veluvine.nl/en/ |
| Verffabriek H. de Vos & Zn. | https://www.devosverf.nl/ |
| VESTOCOR GmbH | http://www.vestocor.com/ |
| Veveo Coatings | https://www.veveo.nl/veveo/home |
| VISTAPAINT | https://www.vistapaint.nl/ |
| Vliegenthart | https://shop.vliegenthart.com/ |
| Votteler Lackfabrik GmbH & Co.KG | https://www.votteler.com/en/ |
| W + S GmbH Lackchemie und Aerosoltechnik | http://www.ws-lackchemie.de/en/ |
| W S Jenkins | http://www.wsjenkins.co.uk/ |
| W. Heeren & Zoon | https://www.epifanes.nl/ |
| W.R.GRACE JAPAN K.K. | https://grace.com/en-us |
| Wacker Chemie AG | https://www.wacker.com/cms/en-gb/home/home.html |
| Warnecke & Böhm GmbH Lack- und Farbenfabrik | https://www.wb-coatings.de/home-en-gb/ |
| WASH PERLE | site under maintenance |
| WASHIN CHEMICAL INDUSTRY CO., LTD. | https://www.washin-chemical.co.jp/english/index.html |
| WASHIN PAINT CO., LTD. | https://www.washin-paint.co.jp/ |
| Watco Ltd | https://www.watco.co.uk/ |
| Weckerle Lackfabrik GmbH | https://www.weckerle-lacke.de/en/ |
| Weilburger Graphics GmbH | https://www.weilburger.com/en/products/graphics/ |
| Westco International China Limited | http://www.westcomfg.com/ |
| Wibol-Lacke GmbH | http://www.wibol-lacke.de/en/home/ |
| Wikoff Colour (UK) | https://www.wikoff.com/ |
| Wilckens Farben GmbH | https://www.wilckens.com/en/ |
| WING-R CO.,LTD | https://moegu.jp/ |
| Witham Oil and Paint (Lowestoft) Ltd | https://www.withamgroup.co.uk/ |
| Wöllner GmbH | https://www.woellner.de/en/home.html |
| WSB Finishing Equipment | https://www.wsb-benelux.eu/nl/ |
| Wuhan Golden Wing Industry & Trade Co., Ltd. | http://www.golden-wing.com.cn/ |
| Xiamen Power Light Ind. Co., Ltd | http://www.ctbc.com.tw/ |
| Xiamen Sunrui Ship Coating Co., Ltd. | http://www.xmsunrui.com/ |
| YAMAICHI CHEMICAL INDUSTRIES CO., LTD. | https://www.yamaichikagaku.com/en/ |
| YAMAMOTO TRADING CO., LTD. | http://www.ytc-j.co.jp/ |
| Yancheng Youda Tech Co., Ltd. | http://www.youda-tech.com/ |
| Yingde Smach Chemical Industry Co., Ltd. | http://www.ydsmq.com/ |
| Zandleven Coatings | https://www.zandleven.com/ |
| Zeller + Gmelin GmbH & Co. | https://www.zeller-gmelin.de/ |
| Zeller and Gmelin UK Limited | http://zeller-gmelin.co.uk/ |
| Zhejiang E.J. Brush Ind. Co., Ltd. | http://www.chinapaintbrush.com/ |
| Zhejiang Huier Coating Environmental Protection Equipment Co., Ltd1098 Zhiyuan | http://www.hui-er.comwww.cdtsafe.cnwww.hui-er-mq.com/ |
| Zhongshan Autokem Industry Co., Ltd. | http://www.auotkem.com/ |

| | |
|---|---|
| Zhongshan Baochi Automobile Maintenance And Tes… | http://www.zs-baochi.com/ |
| Zhongshan Dimur Electrical Equipment Co., Ltd. | http://www.dimurmill.com/ |
| Zhongshan Michel Chemical Co., Ltd. | http://www.usamichel.com/ |
| Zhuhai Feiyang Novel Materials Co., Ltd. | http://www.feiyang.com.cn/ |
| Zobel Chemie GmbH | http://www.zobel-coatings.de/english/ |
| Zuelch Industrial Coatings GmbH | https://www.zuelch.com/ |
| | |

Royal HaskoningDHV

## A5 ANNEX 5: List of Key Words

| Goal Key Words | Tech Key Words |
|---|---|
| Preserv | * |
| Conserv | Natur |
| Micro | Protein |
| Spoil | Peptide |
| Biocid | Enzyme |
| In-can | Killer |
| fungi | Degradation |
| bacteria | Dry |
| houdba | Packag |
| beder | Surface |
| | On-demand |
| | supply |
| | process |
| | Heat |
| | Micro-wave |
| | Electric |
| | pH |
| | Acid |
| | alkaline |
| | Super critical fluid |
| | Ultra |
| | Pressure |
| | Green |
| | Safe |
| | Sustainab |
| | Free |
| | polymer |
| | binder |
| | modifier |
| | afbraak |
| | Poeder |
| | powder |
| | verpak |
| | hitte |
| | drukveilig |
| | Groen |
| | veilig |
| | duurza |
| | zonder |

key words are on purpose not all complete words as to give more hits (variations of the same word), e.g. 'preserv' = 'preservation' and 'preserve'

key words are intended case-insensitive

Royal HaskoningDHV

# A6 ANNEX 6: Example of output web scraper

The following table displays results from the web scraper. The results given are for members of VVVF (Dutch paint association), showing a hit on both ‘biocid’ and ‘free’.

| Company Name | Location | URL | Goal | paragraph |
|---|---|---|---|---|
| BASF Coatings Services | Maarssen | http://www.basf.com/global/en/in | Biocid | dispersions. basf offers an attractive alternative acronalÂ®Â 6292. acronalÂ®Â 6292 is a styrene-acrylate binder that makes it possible to produce environÂ-mentally friendly, biocide-free and low-voc paints. solution based on basf irgatecÂ®Â technology for advanced hygiene applications filter and personal hygiene proÂ-ducts such as |
| BASF Coatings Services | Maarssen | http://www.basf.com/global/en/in | Biocid | offers an attractive alternative acronalÂ® 6292. acronalÂ® 6292 is a styrene-acrylate binder that makes it possible to produce environmentally friendly, biocide-free and low-voc paints. last updateÂ june 8, 2021 top follow us company career media sustainability products product finder industries innovation |
| E.H. WorlÃ©e & Co.Â | Kortenhoef | http://www.worlee.de/nc/zh/chen | Biocid | a styrene-butadiene copolymer - used to manufacture food can sealing compositions. does not contain any antioxidant. it is free of biocides. litexÂ® s 9076 flÃ¼ssig styrene butadiene latex - textiles and fibre bonding litexÂ® sbv 600 flÃ¼ssig styrene butadiene latex |
| Jotun Nederland | Spijkenisse | http://www.jotun.com/hu/hu/b2b | Biocid | tapadÃ¡s, Ã¶ntisztulÃ³ Ã©s algÃ¡sodÃ¡sgÃ¡tlÃ³ jÃ³ rozsda elleni vÃ©delem hozzÃ¡adÃ¡s a listÃ¡hoz sealion resilient tipus algÃ¡sodÃ¡sgÃ¡tlÃ³ bevonat efficient dockings simple application biocide free hozzÃ¡adÃ¡s a listÃ¡hoz seamate m tipus silyl antifouling excellent fouling protection and long term hull performance long term |
| Jotun Nederland | Spijkenisse | http://www.jotun.com/be/en/b2b | Biocid | tie coat good adhesion beteen epoxy primer and antifouling add to list sealion resilient type antifouling efficient dockings simple application biocide free add to list seamate m type silyl antifouling excellent fouling protection and long term hull performance long term |
| Jotun Nederland | Spijkenisse | http://www.jotun.com/be/en/b2b | Biocid | sealion resilient type antifouling efficient dockings simple application biocide free |
| Jotun Nederland | Spijkenisse | http://www.jotun.com/ru/ru/b2b/ | Biocid | Ð»ÐµÐ³ÐºÐ¾ Ð½Ð°Ð½Ð¾ÑÐ¸Ñ‚ÑŒ Ð¼Ð¾Ð¶ÐµÑ‚, Ð¸ÑÐ¿Ð¾Ð»ÑŒÐ·Ð¾Ð²Ð°Ñ‚ÑŒÑÑ Ð² Ð»ÑŽÐ±Ð¾Ðµ Ð²Ñ€ÐµÐ¼Ñ Ð³Ð¾Ð´Ð° Ð´Ð¾Ð±Ð°Ð²Ð¸Ñ‚ÑŒ Ð² ÑÐ¿Ð¸ÑÐ¾Ðº sealion resilient Ñ‚Ð¸Ð¿ Ð¿Ñ€Ð¾Ñ‚Ð¸Ð²Ð¾Ð¾Ð±Ñ€Ð°ÑÑ‚Ð°ÑŽÑ‰ÐµÐµ Ð¿Ð¾ÐºÑ€Ñ‹Ñ‚Ð¸Ðµ efficient dockings simple application biocide free Ð´Ð¾Ð±Ð°Ð²Ð¸Ñ‚ÑŒ Ð² ÑÐ¿Ð¸ÑÐ¾Ðº seamate m Ñ‚Ð¸Ð¿ silyl antifouling excellent fouling protection and long term hull performance long term |
| Jotun Nederland | Spijkenisse | http://www.jotun.com/cz/cs/b2b/ | Biocid | ochrana proti korozi pÅ™idat k seznamu sealion resilient druh antifouling efficient dockings - efektivnÃ- dokovÃ¡nÃ- simple application - jednoduchÃ¡ aplikace biocide free - bezbiocidnÃ- pÅ™idat k seznamu seamate m druh antifouling excellent fouling protection and long term hull performance - |
| Jotun Nederland | Spijkenisse | http://www.jotun.com/cz/cs/b2b/ | Biocid | pÅ™idat k seznamu sealion resilient druh antifouling efficient dockings - efektivnÃ- dokovÃ¡nÃ- simple application - jednoduchÃ¡ aplikace biocide free - bezbiocidnÃ- |
| Jotun Nederland | Spijkenisse | http://www.jotun.com/br/pt/b2b/ | Biocid | universal es type tie coat good adhesion beteen epoxy primer and antifouling sealion resilient type antifouling efficient dockings simple application biocide free seamate m type silyl antifouling excellent fouling protection and long term hull performance long term fuel saving alternative |
| Jotun Nederland | Spijkenisse | http://www.jotun.com/sk/en/b2b/ | Biocid | seaquantum pro ace type silyl antifouling uses selektope which is highly efficient towards barnacle fouling biocide release during outfitting period can allow up to 8 months of barnacle free hull optimised polishing rate to provide |

# A7 ANNEX 7: List of interviewees

- Holger Buchholz, J. W. Ostendorf GmbH & Co. KG – A part of Hempel
- Thomas Fangmeyer, Remmers GmbH
- Helge Kramberger, DAW SE
- Jolanda Neeft, VVVF
- Norbert Pietschmann, Fraunhofer-Institut für Produktionstechnik und Automatisierung (IPA)
- Maarten Ramp, Maxeda DIY Group BV
- Florian Rzeha, J. W. Ostendorf GmbH & Co. KG – A part of Hempel
- Paul Salverda, Havo BV
- Joel Tickner, Green Chemistry & Commerce Council (GC3)
- Christoph Walter, VdL

Also, people were interviewed from two large multinational paint manufacturers who wish not to be named.