ANALYSIS OF ALTERNATIVES

and

SOCIO-ECONOMIC ANALYSIS

Public version

Name of applicant:	TCL Manufacturing Ltd (trading as Perrin & Rowe)
Submitted by:	TCL Manufacturing Ltd
Prepared by:	TCL Manufacturing Ltd Technology Sciences Group Consulting Ltd (TSG Consulting)
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Substance:	Chromium trioxide (EC no. 215-607-8, CAS no. 1333-82-0)
Use title:	Industrial use of chromium trioxide for functional chrome plating with decorative character for sanitary applications
Use number:	1

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Declaration

We, the Applicant (TCL Manufacturing Ltd), are aware of the fact that further evidence might be requested by the Health and Safety Executive ('the Agency') to support the information provided in this document.

Also, we request that the information blanked out in the "public version" of the combined Analysis of Alternatives and Socio-Economic Analysis is not disclosed. We hereby declare that, to the best of our knowledge as of today (28th June 2022), the information is not publicly available, and, in accordance with the due measures of protection that we have implemented, a member of the public should not be able to obtain access to this information without our consent or that of the third party whose commercial interests are at stake.

Signature:

Andy Hampson
Director of Operations (EMEAA), FBHS WI

Date, Place:
28th June 2022
TCL Manufacturing Ltd
Wolverhampton

List of abbreviations

AfA	Application for Authorisation
AFUS	Applied-for use scenario
AoA	Analysis of Alternatives
ARN	Assessment of regulatory needs
BS	British Standard (published by the British Standards Institution, BSI)
BS EN	British Standard, European Norm, i.e. a British Standard that implements a European Standard
BS EN ISO	British Standard which implements an identical European and International Standard
CAGR	Compound annual growth rate
CAS	Chemical Abstracts Service
CLP	Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures (Please note that references in this report to CLP should be taken as referring to GB CLP, as retained EU law following Brexit and the end of the Implementation Period on 31 December 2020, unless otherwise specified.)
CMR	Carcinogenic, mutagenic or toxic to reproduction
COGS	Cost of goods sold
COSHH	Control of Substances Hazardous to Health Regulations 2002
Cr(O)	Metallic chromium
Cr(III)	Trivalent chromium
Cr(VI)	Hexavalent chromium
CrO_3	Chromium trioxide
CSR	Chemical Safety Report
CTACSub	Chromium Trioxide REACH Authorisation Consortium
CVD	Chemical vapour deposition
DLC	Diamond-like carbon
EBITDA	Earnings before Interest, Taxes, Depreciation and Amortization
EC	European Commission
ECHA	European Chemicals Agency
EEA	European Economic Area, i.e. the EU plus Norway, Iceland and Liechtenstein
ELR	Excess Lifetime Risk
EN	European Norm, i.e. European Standard (published by the European Committee for Standardisation, CEN)
ERC	Environmental Release Category
ERY	Excess risk per year
ES	Exposure scenario
EU	European Union
FB	Fortune Brands

FTE	Full-time equivalent
GB	Great Britain
GDP	Gross domestic product
HSE	Health & Safety Executive
IAPMO	International Association of Plumbing & Mechanical Officials
IARC	International Agency for Research on Cancer
ISO	International Standard (published by the International Organisation for Standardisation, ISO)
IUPAC	International Union of Pure and Applied Chemistry
LCI	Labour cost index
LEV	Local exhaust ventilation
MOQ	Minimum Order Quantity
NPV	Net present value
NSF	National Sanitation Foundation
NUS	Non-use scenario
OC	Operational Conditions
OEM	Original equipment manufacturer
ONS	Office for National Statistics
PC	Chemical product category
PEC	Predicted environmental concentration
PFAS	Per- and polyfluoroalkyl substances
PPE	Personal protective equipment
PPM	Parts per million
PROC	Process category
PVD	Physical vapour deposition
R&D	Research and development
RAC	Risk Assessment Committee
RAR	Risk assessment report
RCR	Risk characterisation ratio
REACH	Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (Please note that references in this report to REACH should be taken as referring to UK REACH, as retained EU law following Brexit and the end of the Implementation Period on 31 December 2020, unless otherwise specified.)
RMM	Risk Management Measures
RMOA	Regulatory management options analysis
RPE	Respiratory protective equipment
SAGA	Suitable alternative generally available
SDR	Social discount rate
SDS	Safety data sheet

SEA	Socio-economic analysis
SEAC	Committee for Socio-Economic Analysis
SKU	Stock keeping unit
SP	Substitution Plan
STP	Sewage treatment plant
SU	Sector of use
SVHC	Substance of very high concern
UV	Ultraviolet
VCM	Value of cancer morbidity
VSL	Value of a statistical life
WCS	Worker Contributing Scenario
WEL	Workplace exposure limit
WI	Water Innovations (part of Fortune Brands)
WQA	Water Quality Association
WRAS	Water Regulations Approval Scheme
WTP	Willingness to pay

1. Summary

Chromium trioxide is listed in Annex XIV of REACH (entry 16) and is subject to authorisation. Its latest application date was 21 March 2016 and its sunset date was 21 September 2017.

TCL Manufacturing Ltd (trading as Perrin & Rowe and referred to as such in this report) designs and manufactures high-quality bathroom and kitchen products for the luxury sector. Their product portfolio includes kitchen taps, bathroom and basin brassware, kitchen and bathroom accessories, and chinaware. Perrin & Rowe's products are all handmade in their UK manufacturing facility in Wolverhampton, combining state-of-the-art manufacturing technology with traditional processes and methods.

Perrin & Rowe's brassware products are available in a number of different finishes, the hardest and most durable of which is chrome. Perrin & Rowe achieves this finish by electroplating brass products using chromium trioxide to create a metallic chrome coating which has a brilliant silver appearance with a hint of blue. This means Perrin & Rowe's use of chromium trioxide is subject to the authorisation requirements in REACH.

Perrin & Rowe is currently in compliance with REACH as a result of the application for authorisation (AfA) made by the Chromium Trioxide REACH Authorisation Consortium (CTACSub). The CTACSub AfA is the joint upstream application submitted by seven applicants under EU REACH that covers all their downstream users for six defined uses of chromium trioxide[1]. Perrin & Rowe are one such downstream user and use chromium trioxide for functional plating with decorative character (use group 3). The European Commission has published its decision on the CTACSub application for use groups 1, 2, 4, 5 and 6, but not use group 3 (application ID 0032-003). The transitional arrangements under UK REACH are such that this route to compliance is only available until 30 June 2022. To continue operations beyond this date, Perrin & Rowe must submit an AfA to the Health & Safety Executive (HSE) under UK REACH.

This combined Analysis of Alternatives (AoA) and Socio-Economic Analysis (SEA) relates to Perrin & Rowe's use of chromium trioxide in the electroplating process. It forms part of the demonstration made in support of Perrin & Rowe's application for authorisation (AfA) to allow for continued use of chromium trioxide following the end of the transition period on 30 June 2022.

Using chromium trioxide in functional chrome plating with decorative character provides many advantages due to the resulting properties of coatings deposited from chromium trioxide during electroplating. Key functionalities include[2]:

- enhanced corrosion protection and chemical resistance of finished products;
- highly desirable aesthetic qualities (a brilliant, mirror-like surface);
- good adhesion performance when used with brass substrates; and
- excellent wear and abrasion resistance.

Since chromium trioxide became subject to authorisation under REACH, it has been very challenging for industry to find a single suitable alternative (substance or process) which provides the same multi-functionality of coatings generated from chromium trioxide. In other words, there is no 'drop-in' alternative at the current time[3].

[1] The uses covered are: (1) formulation (2) functional chrome plating (3) decorative chrome plating (4) surface treatment for aeronautics & aerospace industries (5) miscellaneous surface treatment and (6) passivation of tin-plated steel.

[2] EIPPCB, 2006, p48, and TURI, 2006, ch6, p6.

[3] Müller et al., 2020, p17.

1.1. Analysis of alternatives (AoA)

The AoA seeks to determine whether there are any suitable alternative substances and technologies to the use of chromium trioxide in functional chrome plating with decorative character for sanitary applications, such as taps, showerheads and bathroom and kitchen accessories. In particular, the AoA considers:

a) the technical feasibility of alternatives to chromium trioxide;
b) the economic feasibility of alternatives to chromium trioxide;
c) whether transferring to alternatives would result in reduced overall risks to human health and the environment; and
d) whether the alternatives are available to Perrin & Rowe, i.e. whether they would be of sufficient quality and accessible in sufficient quantities.

The objective is to provide input for the substitution plan (SP) and the socio-economic analysis (SEA) to help identify the most likely non-use scenario (NUS) in the event that chromium trioxide can no longer be used by Perrin & Rowe. To this end, the AoA also considers the technical and economic feasibility of alternative business models including transferring the use of chromium trioxide outside of Great Britain (GB) and the European Union (EU).

The AoA considers a range of potential alternatives to chromium trioxide. The most promising and realistic for future development is electroplating based on trivalent chromium-based solutions (chromium sulphate and chromium chloride). Other potential alternatives considered include processes based on trivalent chromium and lacquer and physical vapour deposition (PVD) with chromium. However, all of these alternatives currently fail because they are not technically and economically feasible. If products had to be manufactured using such alternatives, this would result in a very significant loss of sales and market share, with customers switching to more durable and reliable product that had been manufactured using chromium trioxide, most likely manufactured outside GB and the EU.

This means that if Perrin & Rowe's use of chromium trioxide were to cease then its only options are 'managerial' in nature, such as ceasing the production and supply of chrome-plated products entirely, relocating manufacturing operations currently undertaken in GB to a non-UK/EU facility, or outsourcing electroplating using chromium trioxide to a third party based outside the UK and the EU. These options are analysed further in the SEA in terms of considering the most likely NUS for Perrin & Rowe.

1.2. Socio-economic analysis (SEA)

Chrome-based finishes are by far the biggest part of Perrin & Rowe's market, accounting for approximately [redacted] (public range 40-60%) of total sales over the last three years. Even though Perrin & Rowe and other manufacturers have sought to extend the range of colours and finishes for sanitary ware in recent years, chrome plated sanitary ware is by far the leading choice. It provides both superior technical performance, such as corrosion protection and chemical resistance and unmatched aesthetics. The existing use of chromium trioxide for electroplating therefore forms the 'applied-for use' and, should authorisation be granted, Perrin & Rowe will continue with R&D efforts aiming to substitute the use of chromium trioxide in the longer term.

Perrin & Rowe has assessed what it would do if it were required to cease the use of chromium trioxide in the UK. Cr(III)-based and other technologies are not currently technically or economically feasible and substitution to them would result in a loss of market share to importers of sanitary ware from the EU and the rest of the world which has been produced using chromium trioxide. However, shutting its UK business would not be acceptable to Perrin & Rowe nor its parent company, Fortune Brands Home & Security, Inc. Relocating the business outside of the UK is not considered feasible due to its brand being heavily associated with British craftsmanship, expertise and experience.

For this reason, Perrin & Rowe would seek to continue to supply chrome plated product until such time acceptable alternatives were available. The non-use scenario (NUS) is associated with the outsourcing of a substantial proportion of Perrin & Rowe's manufacturing process to a low-cost base to enable the business to continue to operate until such time (estimated mid-2032) as a viable alternative to chromium trioxide-based plated products acceptable to the market can be implemented.

The SEA evaluates potential impacts to the health of workers at and the public in the vicinity of the Wolverhampton facility that may be exposed to chromium trioxide because of ongoing chrome plating. It also evaluates the economic and social benefit relating to these activities. The assessment focuses on impacts within the UK and the impacts are described quantitively or qualitatively, depending on the complexity of the issue and the availability of data. Impacts beyond the UK are also discussed for context.

A period of 10 years (from mid-2022 to mid-2032), the minimum possible length of time within which Perrin & Rowe could adequately identify a suitable replacement for chromium trioxide is used for the purpose of the assessment. This is the requested review period. The SEA also considers the period between the estimated date of a refused decision, assumed for the purpose of this assessment to be 1 January 2024, in terms of the assessment of certain economic impacts. 2022 is used as the base year for calculations.

Continued use would avoid societal costs associated with the NUS estimated at [redacted] per year (public range £5.7 million to £11.4 million) or [redacted] over 2 years (public range £11.4 million to £22.7 million). The health risks associated with continued use are estimated at less than £1,000 per year, meaning that the benefits outweigh the costs by several orders of magnitude.

This means that the remaining risk of continued use is 'low' and the socio-economic benefits are 'high', a situation which is unlikely to change in the next decade. This application therefore meets the criteria for a longer review period, as per RAC/SEAC guidance[4], and the review period requested by Perrin & Rowe is comparable with those requested by competitor firms in recent authorisation applications under EU REACH.

1.3. Substitution plan (SP)

In spite of the failings of potential alternatives, Perrin & Rowe continues to devote time and resources to research and development (R&D) into them. These efforts centre on trivalent chromium processes, in an attempt to address their current performance weaknesses. It is hoped that the issues with trivalent chromium-based alternatives can be resolved in the future although this is far from clear and not guaranteed. The Substitution Plan (which forms a separate report to this combined AoA-SEA) considers the steps proposed to switch to a hexavalent chromium-free alternative in more detail, along with the associated timescales, complexities and uncertainties. The plan involves substantial R&D effort for the investigation and qualification of shortlisted alternatives, further detailed investigation of process variables, scale-up of the chosen alternative process to production trials, conducting those trials and gathering feedback, then ultimately transitioning from hexavalent chromium processes to the chosen alternative process. As a result, **a review period of 10 years is requested**.

[4] ECHA paper SEAC/20/2013/03 '*Setting the review period when RAC and SEAC give opinions on an application for authorisation*' (13 September 2013, agreed at SEAC-20), available at https://echa.europa.eu/documents/10162/13580/seac_rac_review_period_authorisation_en.pdf/c9010a99-0baf-4975-ba41-48c85ae64861

2. Aims and scope

2.1. Aims

This combined AoA and SEA report supports the AfA, which aims to demonstrate the following:

- Exposure from the use of chromium trioxide has been minimised (as described in the CSR).
- Perrin & Rowe has been conducting significant and appropriate R&D efforts, and continues to do so, to identify suitable alternatives to the use of chromium trioxide for electroplating. However, R&D efforts so far have not provided a suitable alternative.
- An AoA has been conducted for the purpose of this application to examine the technical and economic feasibility of potential alternatives, their availability and the level of risk reduction they present. The AoA has found that:
    - none of the identified alternatives are suitable to replace the current Cr(VI)-based technology without significant loss of technical and economic performance; and
    - while substitution to the most promising (Cr(III)-based) alternative would, on balance, lead to an overall reduction in risk, the reduction is not as significant as may be first thought.
- A SEA has been conducted for the purposes of this application to describe and analyse all relevant impacts (positive and negative effects) of granting an authorisation compared to refusing to grant the authorisation. The SEA has found that the benefits of continued use of chromium trioxide by Perrin & Rowe outweigh the risks of continued use for human health and the environment.
- Granting the authorisation would allow Perrin & Rowe to continue to use chromium trioxide while continuing its search for a more sustainable alternative. Perrin & Rowe foresees that the substitution of chromium trioxide will not be feasible before mid-2032, i.e. at least 10 years after submission of the application for authorisation.
- Perrin & Rowe has developed and is in the process of executing a substitution plan which sets out, based on the current state of technology, the actions and timetable foreseen to substitute chromium trioxide with a suitable alternative substance and technology. The SP describes the complexities associated with substitution and provides detail about why the review period requested is necessary.

2.2. Scope

2.2.1. The substance

The substance subject to this combined AoA and SEA is chromium trioxide (Table 1), an inorganic, soluble salt of hexavalent chromium (Cr(VI)). Chromium trioxide was included in the EU candidate list of substances of very high concern (SVHC) on 15 December 2010 (ECHA Decision ED/95/2010) and was included in Annex XIV of EU REACH on 17 April 2013 (by virtue of Commission Regulation (EU) 348/2013). This was because of intrinsic properties relating to carcinogenicity and mutagenicity. It was given a latest application date of 21 March 2016 and a sunset date of 21 September 2017. EU REACH (and the EU candidate list) was retained in UK law from 1 January 2021. Transitional arrangements under UK REACH are directly relevant for Perrin & Rowe, as explained below.

Substance name	CLP classification	Intrinsic properties [5]	Regulatory deadlines
Chromium trioxide EC no. 215-607-8 CAS no. 1333-82-0	Ox. Sol. 1; H271 Carc. 1A; H350 Muta. 1B; H340 Repr. 2; H361f Acute Tox. 3; H301 Acute Tox. 2; H310 Acute Tox. 2; H330 Resp. Sens. 1; H334 Skin Sens. 1; H317 Skin Corr. 1A; H314 STOT RE 1; H372 Aquatic Acute 1; H400 Aquatic Chronic 1; H410	Carcinogenic (cat. 1A) Mutagenic (cat. 1B)	*UK REACH sunset date and latest application date:* [6] 30 June 2022

***Table 1**: About chromium trioxide and its entry on Annex XIV*

Under UK REACH transitional arrangements, Perrin & Rowe are able to continue using chromium trioxide as GB-based downstream users covered by an AfA made further up their supply chain, in this case, by the CTACSub (application ID 0032-003). In line with Article 56(1)(d) of UK REACH, the application was made prior to the latest application date but a decision on that application has still not yet been taken. In addition, following the UK's withdrawal from the EU on 31 January 2020 and the end of the Implementation Period on 31 December 2020, Perrin & Rowe is covered by the transitional provisions under Article 127GA of UK REACH, which extend the sunset date to 30 June 2022. Perrin & Rowe must therefore apply for authorisation before then to continue its use of chromium trioxide for electroplating during the production of kitchen and bathroom products (functional chrome plating with decorative character for sanitary applications).

2.2.2. The applicant

TCL Manufacturing Ltd (trading as Perrin & Rowe and referred to throughout this report as such) designs and manufactures high-quality bathroom and kitchen products for the luxury sector. Their product portfolio includes kitchen taps, bathroom and basin brassware, chinaware and kitchen and bathroom accessories. Perrin & Rowe's products are all handmade in their UK manufacturing facilities in Wolverhampton, Rainham and Tamworth, combining state-of-the-art manufacturing technology with traditional processes and methods. Perrin & Rowe provides several different surface finishes to the market, several of which require the use of chromium trioxide during plating. 'Chrome' and chrome variants (finishes that require chromium trioxide) account for [redacted] (public range 40-60%) of total plated sales by value over the last three years.

[5] Intrinsic properties are those referred to in Article 57 of REACH that result in the substance being included in Annex XIV.

[6] Article 127GA of UK REACH sets out transitional arrangements for GB-based downstream users of authorisable substances who were previously covered by an application for authorisation made under EU REACH by an actor further up their supply chain but where the European Commission had not yet finalised its decision on that application. Under Article 127GA, if the application for authorisation had been made to ECHA before the latest application date under EU REACH, the latest application date was before the end of the Implementation Period and the sunset date was on or after 29 March 2017, then the latest application date and sunset date under UK REACH is moved to 18 months after the end of the Implementation Period for those covered by this Article's provisions.

***Figure 1**: Perrin & Rowe's flagship showroom in the Design Centre at Chelsea Harbour, London*

Perrin & Rowe do not mass produce, instead taking a small batch bespoke approach. All brassware is cast, machined and electroplated at its Wolverhampton and Rainham sites, all under one roof. Perrin & Rowe's focus is on quality of production, precision engineering and attention to detail, combining modern production methods with time-tested techniques. British craftsmanship is a key aspect of the brand, as is longevity and a unique aesthetic that aims to combine designs of the present and the past. This fusion of technology and craftmanship is the source of Perrin & Rowe's unrivalled reputation for quality. A global luxury brand, Perrin & Rowe's products are known by architects and design professionals for their quality and durability, and appear in famous hotels such as the Savoy, the Langham and Claridges.

Perrin & Rowe is part of Fortune Brands Home & Security, Inc. (trading as FBHS), an American manufacturer of home and security products and a Fortune 500 company. Fortune Brands is built on industry-leading brands and innovative products for kitchens, bathrooms, entryways, and outdoor living spaces, and for protection and security. It has 25,000 employees, annual global sales of over US $7.78 billion in 2021 and a strong track record of double-digit year-over-year financial growth.

Fortune Brands supports brands across three reporting divisions: Outdoors & Security, Cabinets, and Water Innovations. The plumbing division, Water Innovations (WI), has six brands with annual global sales of over US $2.78 billion in 2021. The House of Rohl is a concept that unites these distinctive luxury brands within FBHS. Perrin & Rowe forms part of WI where it sits alongside other luxury brands such as Rohl, Riobel and Shaws, under the 'House of Rohl' banner. WI also includes Moen, the number one tap brand in the North American market.

2.2.3. The supply chain

Perrin & Rowe purchases brass bar/billet, chemicals and precious metals to support the plating process, as well as dedicated components such as valves, hoses, aerators and packaging. Suppliers are in Europe, the Americas and Asia as well as the UK. UK suppliers account for [redacted] (public range 30-50%) of supplies by value. Perrin & Rowe also purchases services including distribution and specialist processing support from local suppliers.

Perrin & Rowe supplies to residential, non-residential (hospitality) and original equipment manufacturer (OEM) markets. As an average over the last three years, the residential (retail) market has accounted for [redacted] (public range 80-95%) of sales, the non-residential (hospitality) market for [redacted] (public range <10%) of sales and the OEM market for [redacted] (public range <10%) of sales.

Within the UK and Australasia markets, most sales occur via major distributors with whom Perrin & Rowe has built up longstanding relationships over many years. Perrin & Rowe also supplies directly to a growing network of retailers and independent showrooms throughout the UK and Europe.

Perrin & Rowe supplies directly to the non-residential (hospitality, property developer and housebuilder) markets and to OEM customers who brand Perrin & Rowe products as their own. Perrin & Rowe also supplies directly to end users, predominantly for after-sales service and spares. An online sales capability has recently been established within the UK. In addition, Perrin & Rowe supplies directly to subsidiaries of FBHS for the US, China and Canadian markets.

Generally, the market for kitchen and bathroom taps and mixers is mature and very competitive. Over 50 brands in the UK, German and French markets have a share of 0.01% or more of the market, with 24 companies having a market share of 1% or more in the UK in 2018. Perrin & Rowe had around 0.22% of the UK market share for sanitary taps and mixers in 2017 and 2018, the 37th largest brand, and a market of <0.01% by volume in the German and French markets. Similarly, it has a niche presence (<0.01% by volume) in the kitchen taps and mixers market, where around 25 brands have a share of the market over 0.01%.

The sanitary tap and mixer market can be more specifically characterised according to price segment, for example, economy, lower, middle, upper and luxury market segments. In the case of bathroom fittings, the economy, lower and middle price segments account for the majority of the market, representing around 83-85% by volume in 2017 and 2018 while the upper price segment represents around 12-13% and the luxury around 3-4% of the UK market. In the kitchen taps and mixers market, the lower, middle and upper price segments account for around 86% by volume in 2017 and 2018 while the economy price segment represents around 8% and the luxury around 6% of the UK market.

Perrin & Rowe is positioned in the upper end of the luxury segment of the market. Perrin & Rowe products are continually specified and installed in the most luxurious hotels, resorts and spas in every continent around the world. Perrin & Rowe has an estimated 2% share of this luxury market segment in the UK and 1% share in the EU and the rest of the world. It exports approximately [redacted] (by sales) (public range 50-70%) of its overall production and [redacted] (by sales) (public range 25-50%) of products that rely on chromium trioxide to around 50 countries beyond the UK. Major markets include North America, Canada, Australia and New Zealand ([redacted] of total sales) (public range 45-65%) with other significant markets including the Netherlands, Germany, Denmark, Sweden, Belgium, South Africa and China.

Perrin & Rowe products are renowned for their reliability, quality, precision engineering, leadership in innovation[7], and for being designed and manufactured to the highest technical standards. Durability and

[7] For example, Perrin & Rowe invented and patented the world's first three-way tap.

longevity of performance is expected of Perrin & Rowe products. The products are not mass produced; rather a small-batch, bespoke approach and stringent criteria for excellence are used to manufacture products that 'define perfection'. Each product is individually tested before leaving the factory.

The Perrin & Rowe promise includes 'a commitment to UK manufacturing' and the brand logo includes explicit reference to the UK, 'Perrin & Rowe, London'. The Perrin & Rowe brand is strongly associated with being 'Crafted' or 'Made in Britain' and 'Made to last, with quality and integrity'. Perrin & Rowe is recognised as a luxury consumer brand in the US and Australia and a luxury trade brand in the UK. UK marketing efforts are focused on building Perrin & Rowe into a luxury consumer brand. While the value of Perrin & Rowe's market identity as 'the height of British craftmanship' is difficult to measure, customer feedback indicates it contributes strongly to market appeal in countries such as the US and Australia.

Perrin & Rowe also supplies to certain OEMs such as [redacted] who market products under their own brand.

2.2.4. Financial performance and trends

Perrin & Rowe's compound annual growth rate (CAGR) calculated over the last 3 years (2019 to 2021) is [redacted] (public range <15%) for chrome and [redacted] (public range <15%) for non-chrome products. Volume growth in the taps and mixers luxury sector worldwide is robust. Volume growth across the luxury sector as a whole is forecast at 6.4% per annum until 2026 [8]. Perrin & Rowe is also driving price increases of [redacted] or more (public range <10%) per annum. FBHS is investing heavily in the Perrin & Rowe manufacturing facilities, and in branding, to underpin sales targets which rise significantly through to 2030. More generally, Perrin & Rowe is a global supplier of a niche luxury product which has relatively high barriers to entry (due to the level of bespoke craftsmanship involved, the capital intensity of Perrin & Rowe's manufacturing facilities, the complexity of international compliance requirements around products conveying drinking water and the quality accreditations that underpin the products) and has a relatively low market share in all our markets. All these factors indicate significant potential for growth.

The next few years are forecast to support continued growth for the Perrin & Rowe brand. Year on year sales of chrome plated products increased [redacted] (public range 10-25%) in 2021, and [redacted] (public range 5-10%) in the first quarter of 2022.

2.2.5. Market analysis and regulatory context

Perrin & Rowe's products are targeted at the luxury end of a competitive marketplace for kitchen and bathroom sanitary ware. In more recent years, that market has developed to offer different colours and finishes for such products, but it remains the case that Cr(VI)-based products dominate overall customer demand. For the purposes of assessing the implications of a non-granted authorisation and determining the NUS, it is necessary to understand regulatory and market factors concerning the continued availability of Cr(VI)-based products despite chromium trioxide being subject to authorisation under REACH both in the UK and EU.

According to VPA Research, commissioned in 2020 to conduct market analysis on behalf of FB WI, the global brassware (tap) market was US $20.40 billion in 2020, estimated to have been US $21.47 billion in 2021, and is expected to continue to grow year on year to reach US $34.84 billion by 2030 (at a CAGR of 5.5%) – see Table 2 below.

[8] Statista (2020), as cited in CN Logistics (2020).

(US $ billion)	2020	2021	2030
Bathroom	9.47	9.92	15.54
Kitchen	6.63	7.01	11.88
Other	4.30	4.53	7.42

***Table 2**: Trends in the global brassware (tap) market (US$ billion)*

The European brassware (tap) market was $5.41 billion in 2020, is estimated to have been $5.63 billion in 2021, and is expected to continue to grow year on year to reach $8.19 billion by 2030 (at a CAGR of 4.24%) – see Table 3 below.

(US $ billion)	2020	2021	2030
Bathroom	2.38	2.47	3.4
Kitchen	1.77	1.86	2.84
Other	1.25	1.30	1.93

***Table 3**: Trends in the European brassware (tap) market (US$ billion)*

The UK brassware (tap) market was $0.52 billion in 2020, is estimated to have been $0.54 billion in 2021, and is expected to continue to grow year on year to reach $0.79 billion by 2030 (at a CAGR of 4.24%). Perrin & Rowe estimates that, in total, chrome plated product accounts for approximately 55-60% of the brassware market in the UK.

Data on UK manufacturers' sales by product from the Office of National Statistics (ONS)[9] shows year on year increases in total UK manufacturer sales of mixing valves and taps for sinks, wash basins, bidets, water cisterns, baths and similar fixtures – see Table 4 below.

	2013 Sales	2014 Sales	2015 Sales	2016 Sales	2017 Sales	2018 Sales	2019 Sales	2020 Sales
28141233 (CN 84818011) - Mixing valves for sinks, wash basins, bidets, water cisterns, baths and similar fixtures EXCLUDING: - pressure-reducing valves - valves for oleohydraulic or pneumatic power transmissions - check valves - safety or relief valves								
Value £000's	81,208	87,491	86,931	85,245	98,409	98,980	101,611	96,036
Volume (kgs)	671,706	721,931	701,180	677,566	788,693	779,130	794,193	745,727
£ per Kilogram	120.90	121.19	123.98	125.81	124.77	127.04	127.94	128.78
28141235 (CN 84818019) - Taps, cocks and valves for sinks, wash basins, bidets, water cisterns, baths and similar fixtures INCLUDING: - float valves (domestic) EXCLUDING: - mixing valves								
Value £000's	74,797	97,548	109,967	119,640	123,502	129,563	123,825	76,008
Volume (kgs)	1,558,700	2,504,913	2,921,966	3,582,328	3,637,757	3,718,651	3,572,372	1,892,223
£ per Kilogram	47.99	38.94	37.63	33.40	33.95	34.84	34.66	40.17

***Table 4**: ONS data on total UK manufacturer sales of mixing valves and taps*

[9] ONS, 2021.

In 2021, the UK imported £195M plumbing, heating and lighting fixtures (consumer), the vast majority of which was from China, with proportions from Hong Kong, India, Poland and the United States. More than 90% imported products under this code originated in the EU. It exported over the same period £23M plumbing, heating and lighting fixtures (consumer) to countries including USA, Germany, France, Ireland and Saudi Arabia[10].

Eurostat data[11] on UK production and imports from EU and non-EU sources for the same two Combined Nomenclature (CN) codes (8481 80 19 (28141235) and 8481 80 11 (28141233) presented in Table 5 below supports the picture that imports form a very large proportion of the UK market for sanitary ware.

Year	CN code	Import quantities (kg)	Production quantities (kg)	Import values (€)	Production values (€)
2015	8481 80 19	11,319,200	2,918,056	177,158,170	150,180,481
	8481 80 11	15,810,600	657,246	246,626,390	111,025,846
2016	8481 80 19	11,529,000	3,581,917	150,700,550	145,977,937
	8481 80 11	14,722,900	677,566	234,254,630	104,023,283
2017	8481 80 19	10,737,400	3,554,796	130,037,440	137,662,975
	8481 80 11	16,702,300	788,693	257,938,320	112,253,185
2018	8481 80 19	10,494,500	3,702,320	125,707,520	145,803,710
	8481 80 11	15,826,800	781,364	254,617,650	112,199,478
2019	8481 80 19	10,793,100	3,573,020	127,490,420	141,092,769
	8481 80 11	17,278,300	794,193	281,370,720	115,760,393

***Table 5**: UK imports of taps and mixers 2015-2019*

It is appreciated that these CN codes are broad and cover more products and finishes than those in Perrin & Rowe's product range. They will also include parts and unfinished components that may be further processed for subsequent resale, which likely explains why imports are a smaller proportion of the value of production than of the quantity of production, i.e. some of those imports are components which receive further finishing which increases their resale value. However, the data suggest that imports form a very large proportion of the UK market for sanitary ware.

Perrin & Rowe's competitors in the luxury price segment of the market include Dornbracht, Gessi, Axor, Neopearl, Hansgrohe, THG, Grohe, Vado, Lefroy Brooks, Samuel Heath, Quooker, Zip, Abode, Franke and Caple. In relation to EU-based competitors, chromium trioxide is also subject to authorisation under EU REACH, although many EU-producers of sanitary ware using Cr(VI) processes have applied for authorisation. Grohe and Hansgrohe have already secured authorisations to continue to use chromium trioxide to manufacture chrome plated brassware for bathrooms and kitchens until 2027 and 2031 respectively. In a number of other cases, authorisation seems likely to be granted, given the positive nature of opinions already made or opinions under development. Many other applications for authorisation are in process.

This means that the use of chromium trioxide to produce sanitary ware in the EU will continue at the very least until a decision is taken on these applications and, if granted, until the end of the relevant review period. Cr(VI)-based sanitary products manufactured in the EU will therefore likely be available for import

[10] ONS, 2021.
[11] Eurostat, 2022

into the UK for a considerable period of time from now. Table 6 below provides further information on applications for authorisation made under EU REACH for functional chrome plating with decorative character relevant to plating in the sanitary sector.

AfA ID	Applicant name	Quantity (tonnes per year)	Review period requested	Review period recommended	Review period granted
0032-03	CTACSub	3,000	7 years	4 years	-
0034-01	Grohe	34.1	12 years	12 years	12 years (until Sept 2027)
0095-03	Novotroitsk	<1,000	7 years	4 years	-
0114-01	Hansgrohe	<20	12 years	12 years	12 years (until Feb 2031)
0130-01	Dornbracht	1-10	12 years	12 years	-
0131-01	Schell	1-10	12 years	12 years	-
0132-01	KEUCO	1-10	12 years	12 years	-
0133-01	Ideal Standard	10-100	12 years	12 years	-
0212-02	CP4C Consortium	40-50	12 years	End of 2028	-
0215-01	Oras	1-10	12 years	12 years	-
0216-01	Viega	1-10	12 years	12 years	-
0231-01	Kesseboehmer	16	12 years	-	-
0241-01	Gessi, San Marco	1.325	12 years	-	-
0245-01	Newform	1-10	12 years	-	-
0259-01	ST	5-15	10 years	-	-
0261-01	Metalbrass	6	12 years	-	-
0262-02	Cromoplastica	10-15	7 years	-	-
0264-01	Cristina	<1	12 years	-	-
0268-01	Rubinetteria Paffoni	1-10	12 years	-	-
0271-01	Villeroy & Boch Mattsson Mora Group	<10	12 years	-	-
0272-01	Righi	1.04	12 years	-	-

***Table 6**: Applications for authorisation under EU REACH to use chromium trioxide for electroplating of sanitary ware*

The quantities applied for suggests that a significant proportion of the EU market for Cr(VI)-based sanitary ware is covered by pending applications for authorisation or granted authorisations, with review periods that will last well into the next decade. Chrome plated products do not present a risk to human health or the environment and there are no regulatory barriers to the export of chromium-plated goods from non-UK countries to the UK, given that REACH authorisation requirements will not apply to imported articles.

Taking all the above into account, this means that there is, and will continue to be, a large source of Cr(VI)-based sanitary ware manufactured outside the UK which is readily available for import into the UK. Consequently, any attempt to substitute away from Cr(VI)-based products to alternatives that are currently inferior will always be hampered by the continued availability of Cr(VI)-based products from abroad. This problem is compounded for Perrin & Rowe who operate at the luxury end of the market, where customers will more readily notice and move away from inferior alternatives.

Given these regulatory and market factors, the dominance of Cr(VI)-based products is unlikely to change significantly over the next decade unless there is considerable improvements made in the quality of alternatives.

2.3. Annual quantity

The annual quantity for the use of chromium trioxide in functional chrome plating with decorative character is [redacted].

The non-confidential annual tonnage band for the use of chromium trioxide in functional chrome plating with decorative character is 100 kg – 1 tonne per year.

3. Analysis of substance function

Chromium trioxide is used for electroplating a wide variety of products across a number of different sectors, including sanitary ware, automotive parts, engineering equipment, tools, electrical goods, gun barrels, cosmetic products, furniture, kitchen utensils, white goods, musical instruments and various consumer products.

The thickness of electroplated chromium deposits falls into two classifications[12]: decorative chrome plating and hard chrome plating. In decorative applications, the chrome is plated as a thin (0.25–0.8 µm) layer over nickel, which provides an economical, durable and highly corrosion resistant deposit that is also aesthetically-pleasing. In hard chrome plating, usually used for engineering purposes, deposits usually have a thickness greater than 0.8 µm and are often plated directly onto the substrate. Again, such coatings provide excellent resistance to heat, wear, corrosion and erosion.

3.1. Perrin & Rowe's use of chromium trioxide

Perrin & Rowe uses chromium trioxide in an electroplating process to apply a metallic chrome coating on brass components to create a hard and durable finish of a brilliant silver with a hint of blue. The process is described as functional plating with decorative character. Production takes place at one site in GB (Wolverhampton) where a range of different articles for sanitary applications are produced. These include:

- Kitchen products, such as kitchen taps and mixers, pot fillers, soap dispensers, furniture handles and waste and overflow kits.

[12] Mandich & Snyder, 2011

- Bathroom products, such as bath and basin taps and mixers, shower mixers and diverters, shower heads and roses, shower hoses, rails and risers, and accessories such as towel rails, robe hooks, toilet paper holders, tumbler holders, shaving mirrors and corner baskets.

While many of its products are available in a variety of finishes, such as nickel, pewter, gold, bronze and brass, chrome-based finishes remain the biggest part of Perrin & Rowe's market, accounting for approximately [redacted] (public range 40-60%) of total sales over the last three years.

Figure 2*: Examples of Perrin & Rowe Cr(VI) plated products*

Electroplating of sanitary products using chromium trioxide creates a metallic chrome coating on brass substrates so that the finished product (sanitary products for kitchen and bathrooms) performs optimally under reasonably foreseeable conditions of use. It provides both superior technical performance, such as corrosion protection and chemical resistance and unmatched aesthetics. Although chromium trioxide is used during the electroplating process, no chromium trioxide residues are present on the finished chrome-plated products and therefore none of the hazards associated with the use of chromium trioxide will be carried forward to the finished products. To the contrary, one of the benefits of chrome-plated sanitaryware is that the finish is non-toxic and safe. Furthermore, the durability and protective properties of the finish means less damage due to corrosion and less maintenance, both of which introduce the potential for physical injuries.

For sanitary applications, functional chrome plating with decorative character is used to achieve a surface with high durability when used in aggressive and demanding environmental conditions, which also has a high, consistent and durable aesthetic value (brilliant silver appearance with a hint of blue). As Perrin & Rowe also make accessories such as shower rails, robe hooks, soap dispensers and so on, colours must match between products and over their complete lifetime, and for replacement parts / components as well.

3.2. Benefits of using chromium trioxide

While the science of modern electroplating dates back to the beginning of the 19th century, it took until the early 20th century for chromium plating to begin[13]. During World War II, the use of metals such as chrome was partly put on hold, but its use in applications including those with decorative qualities rapidly expanded during the 1950s and has remained popular ever since. The use of chromium trioxide is well-established, well-understood and achieves the key functionalities required for products used for sanitary applications, mainly based on the characteristics of the hexavalent chromium compound. These key functionalities are:

- **corrosion resistance**, needed to prevent corrosion of the products (the coating itself and the underlying layers) and therefore protect against degradation due to the process of oxidation of a metallic material, due to chemical reactions from the surrounding environment (e.g. water, increased humidity and temperatures commensurate with kitchen and bathroom environments).

- **wear and abrasion resistance**, to protect the coating and underlying layers from scratches and damage, as well as contribute to high corrosion resistance and to preserve decorative appearance.

- **adhesion**, to ensure metallic chromium deposited from chromium trioxide during electroplating successfully adheres to the underlying substrate, to prevent damage from cracks and/or blistering.

- **chemical resistance**, as chemicals in daily contact with the products (e.g. cleaning agents) can attack the surface, causing corrosion and adversely affecting surface aesthetics. Chemical resistance is all the more important for products likely to be cleaned on a frequent basis, such as those used in hotels and similar settings. Corrosion prevention prolongs product life and guarantees its decorative appearance.

- **resistance to temperature change and heat**, which has to be high to withstand demanding conditions the products are exposed to in kitchen and bathroom environments.

- **ultraviolet (UV) resistance**, whereby the coating must be sufficiently robust to withstand natural (sunlight) and artificial UV radiation.

- **colour and aesthetics**, in that the finish must achieve a specific aesthetic appearance to satisfy customer demands and expectations. This includes a requirement that products must be capable of colour-matching other products (or components of products) found in the same environment, e.g. where one product in a bathroom requires upgrading if it has reached end-of-life. Surfaces must also be free of any defects such as pores, cracks and blistering.

[13] Dubpernell, 1984, and Giurlani et al., 2018.

- **longevity**, in that products must be capable of satisfying a minimum period of service life, given product warranties and the often-demanding and aggressive environmental conditions of use, as well as satisfying customer expectations about the quality of the brand.

All of the above-mentioned key functionalities are highly interconnected with each other and therefore it is essential that a potential alternative sufficiently fulfils every minimum requirement to achieve a high-quality surface under the conditions of use.

Several alternatives are under assessment and these are described further in this AoA. While R&D efforts into substituting chromium trioxide continue (and which are hoped will ultimately be successful), this AoA demonstrates there is currently no alternative that meets all of the above functional requirements and which is economically feasible. In other words, at the present time, there is no 'drop-in' replacement available.

The most promising potential alternatives are those based on trivalent chromium (Cr(III)) technologies and these are subject to detailed analysis in this AoA. However, the investigation and testing undertaken to date by FB WI has shown that Cr(III) coated products are not technically a viable alternative to Cr(VI) electroplating for several reasons.

Cr(III) presents important critical problems with regards to corrosion and chemical resistance. Testing on components coated using Cr(III) processes reveals that the necessary functional requirements are not all met, with a significantly lower chemical and corrosion resistance than coatings derived from Cr(VI) based electroplating technology, reducing product longevity. This is especially problematic with long-term, high-quality, high-use applications, for example in hotels or other hospitality uses.

The appearance of articles produced with Cr(III) also present aesthetic problems due to a darker, yellowish/brownish hue of the coating. This can be caused both by iron ions incorporated into the metallic chrome deposition from bath constituents, as well as other impurities entering the Cr(III) process chemistry. This darker, yellower appearance does not meet the high aesthetic standards required by customers.

3.3. Process description

Perrin & Rowe manufactures brass sanitary ware at its sites in Wolverhampton (electroplating) and Rainham (machining and assembly). Brassware is cast, machined, hand polished, plated, assembled, tested and finished, using a combination of state-of-the-art manufacturing technology and time-tested, traditional methods and skills.

The electroplating process is a multi-step, automated process carried out in multiple treatment baths. Process steps are performed by immersing the brass substrates in baths containing an aqueous solution specific to the individual process step. Process steps are performed in a continuous operation within the plating line. Intermediate rinsing steps are performed in the process to prevent the carry-over of chemicals from one bath into another, which would lead to contamination of the subsequent process step. The chrome plating layer is applied as the final coating on top of a multi-layer system. The combination of all the layers results in the final appearance and performance properties of the finished product.

In general, the electroplating process can be divided in three sub-processes, summarised in Figure 3 and Table 7 below, namely pre-treatment (removal of impurities, surface activation), the main process (functional chrome plating) and post-treatment (rinsing, drying, inspection). For brass substrates, only the main process requires the use of chromium trioxide. The functional chrome plating process is performed in open baths by immersing the metal substrates in an aqueous solution of chromium trioxide.

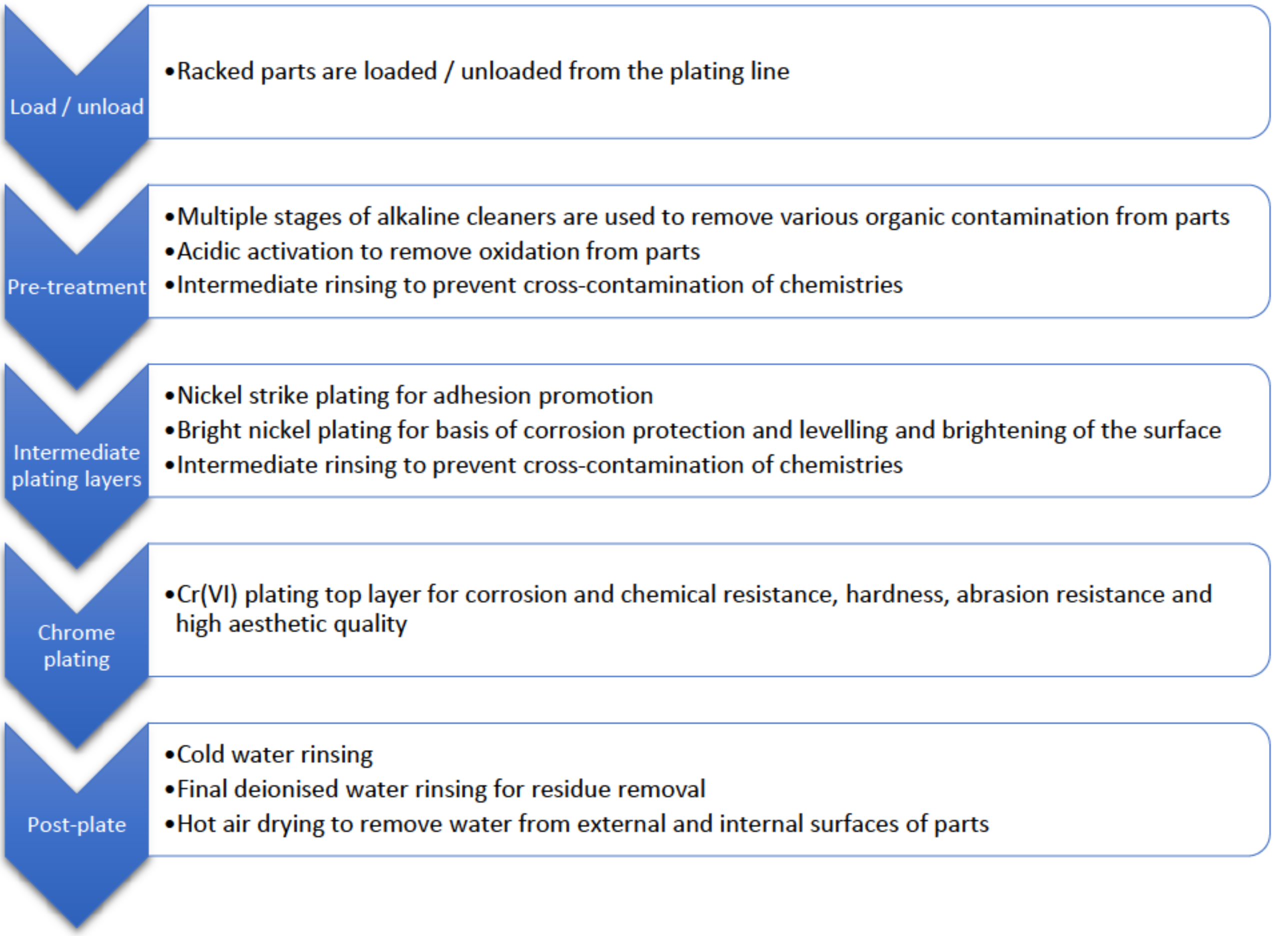


***Figure 3**: Overview of the Cr(VI) plating process*

	Pre-treatment	Plating		Post-treatment
		Nickel	Chrome	
Activity	Cleaning	Application of multiple intermediate nickel layers Rinsing	Application of surface chrome layer Rinsing	Rinsing Drying Inspection
Purpose	Prepares surface of substrate. Ensures appropriate adhesion between coating and substrate.	Required to ensure the key appearance and performance requirements of the final product	Cr(VI) plating top layer for corrosion and chemical resistance, hardness, abrasion resistance and high aesthetic quality	Removing process chemicals and water Ensuring high quality of finish
Use of CrO_3	No	No	Yes	No

***Table 7**: Steps involved in electroplating of brass substrates*

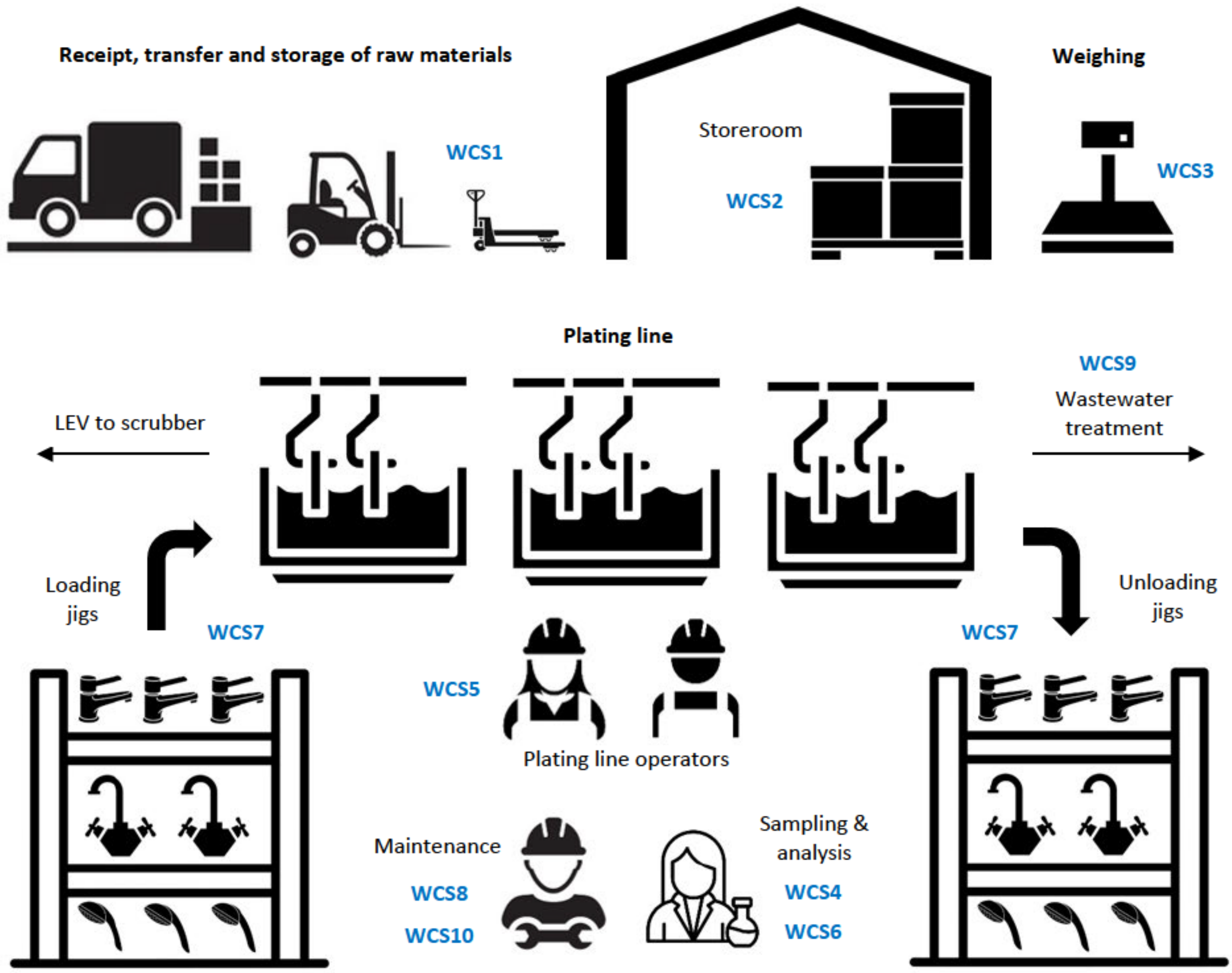


Figure 4*: Overview of the electroplating process, with references to the relevant WCS*

The following sections provide a brief description of the process steps involved. Cross-references are made as appropriate to the relevant Worker Contributing Scenarios (WCS) in the CSR, namely:

- WCS1: Receipt of raw materials
- WCS2: Storage of raw materials
- WCS3: Weighing of chromium trioxide and replenishing of tank
- WCS4: Sampling of plating tanks
- WCS5: Operation of plating line
- WCS6: Laboratory analysis
- WCS7: Loading / unloading of brass parts
- WCS8: Maintenance
- WCS9: Treatment of wastewater and maintenance
- WCS10: Maintenance (cleaning of the filter press)

Appendix 1 provides further details of Perrin & Rowe's plating line (baths, volumes, chemistries, process flows, control limits and so on).

3.3.1. Pre-treatment

Receipt [WCS1]
Chromium trioxide is received as chrome flake (solid) which is delivered to the site in 25 kg containers on pallets. Deliveries are made to Good Inwards where they are checked against the delivery notes. Once the drums have been offloaded from the delivery vehicle, they are transported to the storeroom using a combination of forklift and pump truck by the Stores person and an authorised member of the plating team.

Storage [WCS2]
Access to the chemical store is restricted by way of keycode entry which is limited to six authorised persons: two Technicians, three Senior Operators and the Head of Maintenance. The chromium trioxide drum is stored in a bund which has been sealed with Robex paint. Only a maximum of two 25 kg drums of chromium trioxide flake will be stored in the bund at any one time.

Weighing [WCS3]
Weighing is conducted once a week by one (of two) Technicians. In the absence of a Technician, this activity will be conducted by a Senior Operator. The weighing takes place within the chemical store where a scoop/trowel is used to take chrome flake from the 25kg drum and decant it into a smaller container. The container is placed onto the weighing scales and flake is added/removed until 2 kg has been measured out. The activity is performed under local exhaust ventilation (LEV) with workers wearing respiratory protective equipment (RPE) and neoprene gloves. The container is then taken by hand to the plating line and added manually to the relevant bath. The distance between the chemical store and the plating line is approximately 7 metres.

Bath adjustment [WCS3]
Prior to making the addition of chromium trioxide to the tank, the line is shut down. Whilst the addition is being made to the bath, only one authorised person is on the chrome line platform conducting the bath addition. LEV will be in operation and the worker will wear RPE and neoprene gloves. The 2 kg of chrome flake is decanted from the container directly into the bath and a plastic mixer is used to stir in the flake.

Jigging / loading [WCS7]
The brassware is loaded onto jigs which are passed through an ultrasonic tank before entering the plating line. Jigs are supported on trolleys and then manually loaded on to the flight bar of the chrome plating line.

Pre-treatment [WCS5]
The parts first must be cleaned of any kind of dirt, both organic and inorganic contaminants. Removal of organic material from the surface of the substrate is achieved through alkaline cleaning processes, i.e. soak cleaning and electrolytic cleaning. These processes, in conjunction with intermediate rinsing, effectively remove the organic material from the parts and prepare the surface. Removal of oxidation from the surface of the parts is performed in an acidic activation process. Removal of the surface oxide film is required for appropriate adhesion of the subsequent plating layers.

3.3.2. Plating

The chrome plating line (Line 1) is approx. 60m in length and 4m in width. It is automated, with a total cycle process time of two hours (chrome plating itself takes less than 10 minutes). The plating line operation is supervised by two Technicians, who regularly walk the lines. The plating line is restricted to authorised personnel only. There is dedicated LEV for the chromium trioxide baths and other baths containing hazardous substances.

Nickel Plating [WCS5]
Nickel is applied by an electrolytic chemical deposition process (electroplating). Multiple nickel layers are needed prior to the final, chrome layer being applied, as the multi-layer combination is required to meet the required key appearance and performance requirements of the finished product. Such requirements include corrosion and chemical resistance, hardness, adhesion and surface appearance of the final product. The nickel is applied in a two-layer system. It combines a nickel strike layer and bright nickel layer.

Chrome Plating [WCS5]
The chrome layer is applied by electroplating, similar to the nickel, but utilising chromium compounds in the process bath instead of nickel compounds. The chrome plating solution contains dissolved chromium trioxide and additives (electrolytes). During the electroplating process, the hexavalent chrome, Cr(VI), is reduced to metallic chrome, Cr(0). The chrome plating layer forms a well-adhered coating on top of the nickel plating layers. This continues until the metallic chrome coating has reached the desired thickness level.

The thickness of the metallic chrome layer is typically on average equal to 0.25-0.60 µm and depends on the geometry of the substrate.

The bright chrome appearance of the product is not solely a result of the metallic chrome layer but also of the respective under plates. In contrast, the slightly bluish character of the metallic chrome coating is solely a result of applying a metallic chrome layer by chromium trioxide-based electroplating.

During the chrome electroplating process chain, numerous rinsing steps are carried out to prevent the drag-out of substances from one plating bath to the next. Rinsing is commonly performed by dipping the product in a bath filled with clean rinsing water. It usually occurs in several steps following the sequence technology. The most common technique is counter-current sequence rinsing, where the part is rinsed in a succession of rinsing baths that are dedicated to the plating bath.

The coating is applied quickly and due to the bath application technique, almost all kind of articles with all different geometries (flat, complex, with inner cavities, etc.) and size (independently if small or big) can be plated.

Rinsing / neutralisation [WCS5]
During the electroplating process chain, multiple rinsing steps are carried out to prevent the drag-out of materials from one plating bath to the next. Rinsing is conducted in a bath filled with clean rinsing water. It typically occurs in several steps following the various chemical process tanks. Counter-current rinsing is normally used, where the part is rinsed in a succession of rinsing baths. This both reduces water consumption as well as improving the rinsing effectiveness of the parts.

Following chrome plating, traces of chrome solution on the plated parts and racks will be neutralised by immersion into a tank containing chrome neutralising salts.

Sampling [WCS4] [WCS6]
To ensure electrolyte concentrations are kept within optimal parameters, the concentration of Cr(VI) must be regularly monitored. Bath analysis is conducted once per week internally and every three weeks by the external chemicals supplier. It involves using a flask to scoop out a small sample which is taken to the on-site laboratory where titration analysis is conducted according to a standard operating procedure (SOP). Surface tension sampling is also conducted by a third party every 2 weeks with results sent back to the on-site laboratory.

***Figure 5**: Perrin & Rowe chrome plating line (1)*

***Figure 6**: Perrin & Rowe chrome plating line (2)*

Maintenance [WCS8]
Weekly checks are conducted on the anodes, flight bars and flight bar contacts etc. Chrome baths will be emptied and refilled every 12 to 18 months depending on levels of contaminants, to avoid excess levels of contamination building up. A third-party contractor is used to perform this work under specific risk assessment and method statement. This process also allows for the anodes to be replaced if required.

3.3.3. Post-treatment

Rinsing and drying [WCS5]
The post plate operation involves various rinsing and drying steps. Multiple cold-water rinses, followed by a much higher purity deionized water rinse, are utilized to remove residue from both the internal and external surfaces of the parts. It is then followed by a forced air-drying step, where the water is then dried from the surfaces of the parts.

Unloading [WCS7]
The transporter returns the flight bars back to the loading area. The jigs are manually removed from the flight bar and placed on manual trolleys. The 'Unjigger' collects the trolleys and takes these through plating into the Unjigging Inspection Area. Careful visual inspection is performed on all individual parts to ensure stringent quality requirements are met.

3.3.4. Waste treatment

Wastewater and solids (sludge) [WCS9] [WCS10]
An on-site waste water treatment facility (see Figure 7 below) reduces Cr(VI) to trivalent chromium, Cr(III), in a highly effective manner, such that residual concentrations of Cr(VI) in effluent are very low and often non-detectable, and may be considered negligible. The process is automatic – probes send signals to a control panel and reagents are dosed automatically according to the readings on the panel. The treatment occurs through closed pipelines.

Once treated, the wastewater is sent via a series of tanks (pH and flocculation tanks) to a settlement tank where the sludge is allowed to settle before collection via a filter press and removal for disposal by a specialist waste handler. The wastewater is then discharged from the site.

Samples are taken from the final discharge point and analysed in the laboratory on site every 4 hours, 4 times a day by Technicians. The local water board, Severn Trent, also takes periodic samples for their analysis. Further information on waste treatment can be found in the CSR.

Air [WCS9]
The LEV has a scrubber which is cleaned periodically by a specialist third party under specific risk assessment and method statement. The LEV itself is subject to thorough examination and testing by a competent person, in line with the requirements of occupational health and safety legislation.

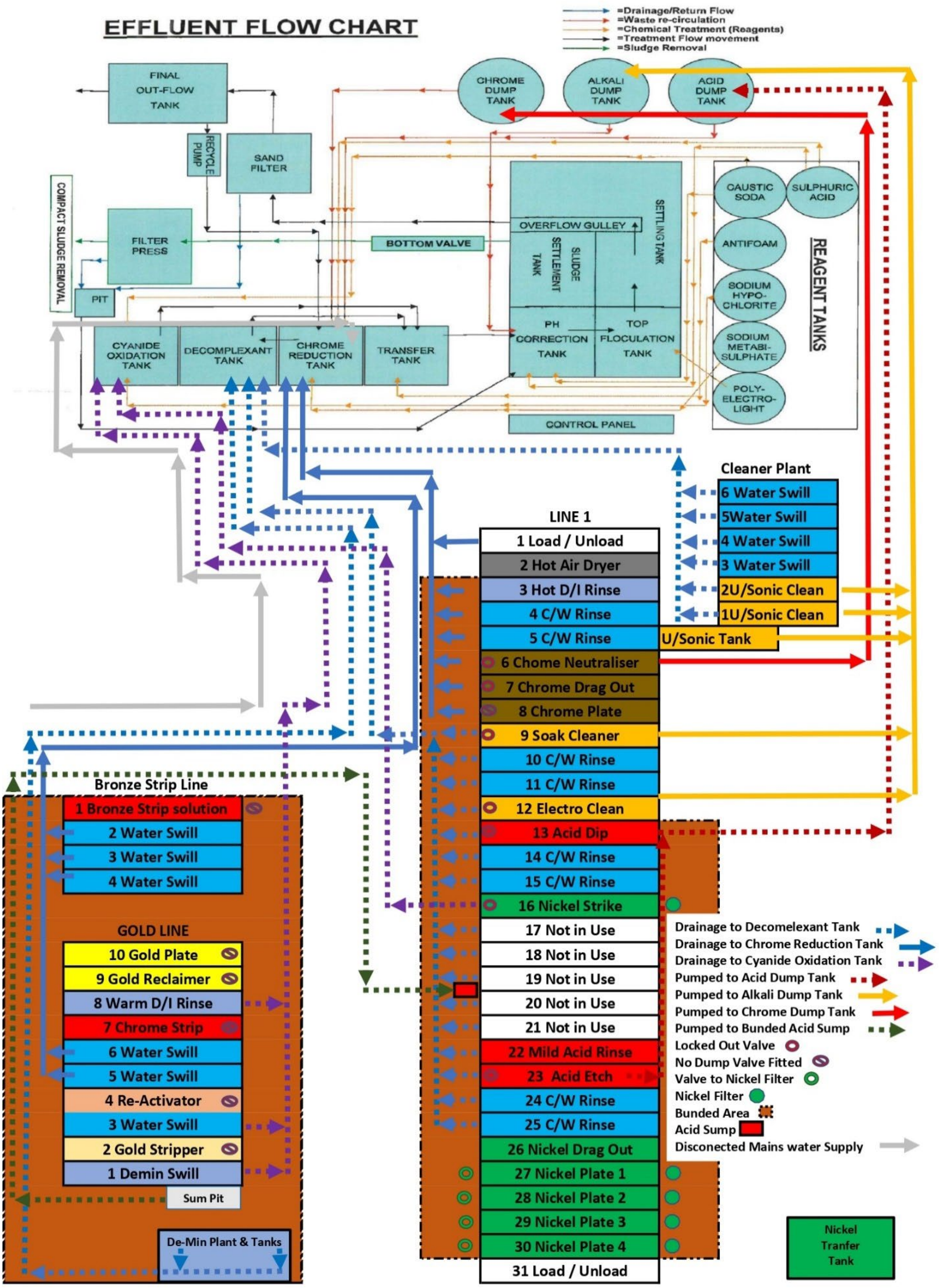


***Figure 7**: Effluent process flow schematic*

3.4. Performance standards

3.4.1. Overview of Perrin & Rowe performance standards

Perrin & Rowe undertakes functional plating with decorative character to apply a highly durable and aesthetically-pleasing surface to products for the sanitary sector, currently only using brass substrates. The metallic chromium layer is applied as a final coating on top of a multi-layer system, which combine to provide the key functionalities required. These functionalities are:

- Corrosion resistance
- Wear and abrasion resistance
- Adhesion
- Chemical resistance
- Colour and cosmetic surface appearance (aesthetics)
- Thickness
- Thermal cycle resistance
- Sunlight / UV resistance
- Longevity

All of the above-mentioned key functionalities are highly interconnected with each other and therefore it is essential that a potential alternative sufficiently fulfils every minimum requirement to achieve a high-quality surface under the conditions of use. This includes being able to provide a chromium-like appearance (where the alternative does not result in a chrome finish) even if all other functionalities are achieved, due to customer / consumer preferences and from the perspective of replacement of products/parts where replacements must colour-match other sanitary ware in the same area.

Table 8 below lists Perrin & Rowe's performance standards (test methods) and pass/fail criteria for the key functionalities concerned, which are based on Fortune Brands Water Innovations (FB WI) requirements. EU equivalent standards are provided where applicable. A more detailed description of the key functionalities is given in the following sections.

Key functionality	FB WI test method	EU equivalent	Performance criteria
Corrosion resistance	WI 10-020-0043	BS EN 248:2002 BS EN ISO 10289:2001	- Corrosion Resistance (Neutral Salt Spray): 200 hr - Corrosion Resistance (Neutral Salt Spray): 24 hr - Corrosion Resistance (Acetic Acid Salt spray): 24 hr - Corrosion Resistance (Copper Acetic Acid Salt Spray): 8 hr a) Parts shall not exhibit more than one surface defect per 650 mm² (1in²) of surface area. This criterion applies to any given square inch of significant surface area and is not an average over the entire surface of the part. b) Up to three surface defects may be permitted on a 25 mm (1in.) length of parting line. c) Surface defects shall not be more than 0.8mm (~1/32 in.) in any dimension.
Abrasion resistance	WI 10-020-0180	BS EN ISO 2819:2018, para. 4.8	- 350 cycles on the Taber Abraser - There shall not be any nickel or brass visible after 350 abrasion cycles have been completed. The test zone

Key functionality	FB WI test method	EU equivalent	Performance criteria
			is the characteristic "round" abraded area and is evaluated with the unaided eye.
Adhesion	WI 10-020-0182	BS EN ISO 2819:2018, para. 4.12	- ASTM B471 (File test), ASTM B471 (Grind-saw test), cross-hatch test - Flaking or peeling of the deposit is unacceptable.
Chemical resistance	WI 10-020-0175	-	- 16-hour droplet test / 30-day, extended immersion test - No changes in physical appearance including but not limited to, colour change, shrinkage, expansion (swelling) and cracking.
Colour and cosmetic surface appearance (aesthetics)	WI 02-005	-	- Components must match both visually and via colour meter to prevent noticeable difference.
Thickness	WI 10-020-0055	-	Chrome plating on copper base alloys - Copper (Min.): Optional - Nickel (Min.): 0.0003 inches (7.6 microns) - Chrome (Min.): 0.000010 inches (0.25 microns)
Thermal cycle resistance	WI 10-020-0190	BS EN 248:2002, para 5.2	- The test consists of 4 cycles in air. One cycle is defined as 1 hour at -40°C, 1 hour minimum at 20±5°C, 1 hour at 75°C, and 1 hour at 20±5°C. - The entire coated sample shall show no defects, which are visible to the unaided eye such as cracking, blistering, peeling, sink marks, or distortion.
Sunlight / UV resistance	WI 10-20-193	-	- 500 hrs exposure per ASTM G155 with a 340 nm Xenon Arc lamp and a window glass filter. - A ΔE* value greater than 4.5 at test completion is cause for rejection.
Longevity	Qualitative assessment	-	Qualitative assessment

***Table 8**: Perrin & Rowe performance standards for key functionalities*

<u>Corrosion resistance</u>

Corrosion resistance describes the ability to retard the degradation of an item due to the process of oxidation of a metallic material. This occurs because of chemical reactions with its environment. Water, increased humidity and increased temperatures often found in kitchen and bathroom areas can markedly increase the corrosion impact on the sanitary ware.

Corrosion resistance is one of the most important functionalities. Corrosion of the products can not only affect a product's aesthetics, but also its function and consumer safety. This means it is crucial that the sanitary ware resist the deleterious effects of corrosion for an extended period of time during use by the customer.

Corrosion resistance is tested by FB WI using three different tests based on the reference standard WI 10-020-0043 (Corrosion Testing). This standard includes the following ASTM test methods:

- ASTM B117-18 Standard Practice for Operating Salt Spray (Fog) Apparatus
- ASTM G85-19 Standard Practice for Modified Salt Spray (Fog) Testing

Abrasion resistance

The abrasion resistance of a coating is its ability to resist the gradual wearing caused by abrasion and friction. The wear resistance of a coating is tested through use of industry standard Taber Abrasion test equipment. The test consists of a specimen placed under abrading wheels equipped with a rubbing material, e.g. felt strip. A predetermined force is applied and the specimen is made to continuously rotate while in contact with the abrading wheels until the desired number of rotations is achieved. During the test, a rub-wear action takes place between the specimen and the abrading wheels. Abrasion resistance is tested by FB WI based on its reference standard WI 10-020-0180 (Resistance to Abrasion Evaluation test method).

Adhesion

Adhesion describes the ability of multiple materials, layers or surfaces to adhere to one another. The delamination of the different layers or the substrate is the result of poor adhesion. Sanitary products are exposed to a large variety of chemicals and reagents and mechanical stress through intensive use. For the required lifetime and aesthetic appearance of all coated parts, it is important that the coatings applied to the substrates can withstand these effects. Adhesion resistance is tested by FB WI using its reference standard WI 10-020-0182 (Adhesion Testing).

Chemical resistance

Chemical resistance is the ability of the coating materials to resist damage by chemical reactivity from cleaning agents. In general, a coating that is not adequately resistant against cleaning agents suffers degradation of the aesthetics as well as corrosion. This functionality is particularly important for those products that are likely to encounter cleaning chemicals on a frequent (daily) basis, e.g. products supplied to hotels and the wider hospitality sector. This procedure is based on testing products with cleaning agents normally used at home, using the FB WI reference standard WI 10-020-0175 (Chemical compatibility: drop and immersion testing).

Colour and cosmetic surface appearance (aesthetics)

For sanitary products, it is critical that the coating process ensures that the production of all parts, independent of production date or plating line, all result with the same appearance and colour. The required colour of a metallic chrome layer is typically brilliant silver with a hint of blue. Uniformity of colour is of particular importance, not only for the purposes of assembling different components to make the finished product, but also to ensure the colour of finished products is identical to other products likely to be used in the same kitchen or bathroom environment. In addition, colour matching is crucial over the lifetime of the products; the colour must remain stable under normal light and use conditions. This ensures colour-matched parts, products and add-ons are available for replacement, e.g. additional shower-head in an existing shower system, or a replacement diverter valve etc.

After finishing, all parts are subject to detailed inspection for surface defects, based on the extensive consumer-based standards. This is necessary to ensure that customers receive the best quality products possible to meet their expectations. This is one of the most important functionalities for Perrin & Rowe, given the positioning of its products at the luxury end of the market.

The product surface is classified according to the tolerance of defects, based on areas of various visibility by the customer. Defects in surfaces that are immediately noticeable to the customer, such as the top and front face of taps and mixers, require more stringent quality control than areas underneath that are much less visible. Colour and cosmetic attributes are evaluated through use of the FB WI test procedure WI 02-005 (Cosmetic Inspection Requirements).

Thickness
The thickness of the chromium layer has been determined, through extensive field use by customers, to be a critical attribute for longevity and customer satisfaction. This attribute is measured and evaluated through the use of the FB WI test procedure WI 10-020-0055.

Thermal cycle resistance
Thermal cycle resistance refers to a product's resistance to temperature changes and heat, which has to be high to withstand demanding conditions the products are exposed to in kitchen and bathroom environments. Thermal cycle resistance is evaluated through use of the FB WI test procedure WI 10-020-0190.

Sunlight / UV resistance
Ultraviolet (UV) resistance seeks to ensure that a product's coating is sufficiently robust to withstand natural (sunlight) and artificial UV radiation. Long-term sunlight / UV exposure can cause degradation resulting in cracks and blistering of the coating. UV resistance is evaluated through the FB WI test procedure WI 10-20-193.

Longevity
The customers of Perrin & Rowe's sanitary ware expect the product to maintain both its appearance and its performance for a considerable number of years of field use. P&R's sanitary ware is warranted for 10 years of residential use. If the chromium top layer has insufficient performance characteristics to maintain both the appearance and performance attributes expected by the customers, then this will result in detrimental effects on the brand and the business.

Whilst the measure of longevity is a qualitative rather than quantitative assessment, the measurement of longevity is essentially included in all of the above-mentioned key functionalities. Corrosion resistance, chemical resistance, adhesion, temperature and UV resistance, thickness and colour and cosmetic surface appearance are all aspects of longevity and are measured using the standards described above.

3.4.2. Regulatory requirements

In addition to the above, Perrin & Rowe must also meet regulatory requirements relevant to each of the markets which the business supplies. While this includes non-UK markets such as the EU, US, Canada and Australia, the following information focuses on UK requirements to illustrate just this part of the regulatory backdrop against which Perrin & Rowe operates.

The Water Fittings Regulations
The principal legislation relating to water supply installations in the UK is the Water Supply (Water Fittings) Regulations 1999 for England and Wales, the Water Supply (Water Fittings) (Scotland) Bylaws 2014 for Scotland, and the Water Supply (Water Fittings) Regulations (Northern Ireland) 2009 for Northern Ireland. Collectively, these are known as the Water Fittings Regulations.

The Regulations set requirements for the design, installation and maintenance of plumbing systems and water fittings in England and Wales. They are enforced by water companies in their respective areas of supply. The Regulations' objectives include contamination prevention and water conservation. Water systems and fittings in premises that are, or will be, connected to public water suppliers must comply with the Regulations. The legal duties are placed on all users, owners or occupiers of premises and anyone who installs plumbing systems or water fittings and water-using appliances in them. Water suppliers are responsible for the enforcement of the Regulations.

The Water Regulations Approval Scheme (WRAS) was established in support of the aims and objectives of the Water Fittings Regulations. WRAS is an independent UK certification body for plumbing products and materials, to help businesses and consumers choose compliant products that keep water safe. Its approval and listing scheme has become the byword for product approvals in the UK plumbing world. A WRAS-approved product helps demonstrate compliance with the Water Fittings Regulations (although the product must still be installed and operated correctly).

To enable a product to be certified to meet with the requirements of the Water Fittings Regulations, it must be mechanically tested to the relevant standards. UKAS-accredited mechanical test facilities in the UK include KIWA Ltd (Watertec Trading Division) and NSF International.

All materials used in applicable products must meet with the requirements of BS 6920 (Suitability of non-metallic materials and products for use in contact with water intended for human consumption, with regards to their effect on the quality of the water). In particular, all non-metallic materials which come into contact with water intended for domestic use must conform to the requirements of BS 6920. This includes several tests which assess the suitably of non-metallic materials to ensure they do not impart odour or flavour, cause a change in appearance (colour or turbidity), promote microbial growth or leach substances (including toxic metals) harmful to human health. Test facilities in the UK accredited to carry out BS 6920 testing include Intertek, The Water Quality Centre (WQC) and NSF International. Once fully tested the plumbing fittings can be certified in the UK by either WRAS or KIWA Watertec. The certificates of both organisations each state that the plumbing fitting complies with the requirements of the Water Supply (Water Fittings) Regulations.

All UK water suppliers will accept the installation of products certified by WRAS or KIWA Watertec. Perrin & Rowe have an extensive range of their UK products tested, certified and listed by KIWA Watertec.

The Water Quality Regulations

The quality of drinking water in the UK is governed by the Water Supply (Water Quality) Regulations 2016 in England, the Water Supply (Water Quality) Regulations (Wales) 2018 in Wales, the Public Water Supplies (Scotland) Regulations 2014 in Scotland, and the Water Supply (Water Quality) Regulations (Northern Ireland) 2017. These Regulations implemented the requirements of Council Directive 98/83/EC on the quality of water intended for human consumption, which forms part of retained EU law in the UK. The legislation is enforced by the Drinking Water Inspectorate (DWI) in England and Wales, the Drinking Water Quality Regulator (DWQR) in Scotland and the Drinking Water Inspectorate (DWI) in Northern Ireland.

The legislation aims to protect human health against harmful effects which could originate from contaminants in water designated for human consumption, and to ensure it is pure and suitable for consumption. It imposes a duty on water suppliers to supply “wholesome” water. ‘Wholesome’ water is water supplied for drinking, washing, cooking or food production that does not contain any element, organism or substance at a concentration that would be detrimental to public health (whether on its own or in conjunction with anything else), and which does not exceed any concentrations or values in excess of parameters listed in the Regulations themselves.

For Perrin & Rowe, this means that materials used in the manufacture of products that will be used in contact with drinking water must not negatively affect human health, or the smell and taste of drinking water, nor may they result in the release of substances into drinking water above acceptable concentrations or values. Given the manufacturing process, the chemical indicator parameters of highest interest are nickel and chrome. Under the Regulations, the concentration of nickel in drinking water (e.g. caused by Ni migration) must not exceed the threshold value of 20 µg/l and the total chromium concentration in drinking water (e.g. caused by chrome leaching) must not exceed 50 µg/l.

4. Identification of potential alternatives

4.1. Efforts made to identify potential alternatives

4.1.1. Research and development (R&D)

Perrin & Rowe, via FB WI, has already expended much effort in R&D of alternatives to electroplating with chromium trioxide and will continue to do so in the future. WI's Finishing Engineering team is actively engaged in developmental work on Cr(VI) alternatives. R&D resources include a well-equipped testing laboratory and six finishing engineers available for R&D activities in China, supplemented by five personnel and two laboratories in the US, used for finishing and product qualification. WI can undertake R&D activities across the breadth of surface finishing regimes, including but not limited to Cr(III) processes. At the present time, Cr(III) processes appear most promising and WI have a pilot plant for trivalent chromium processes (a manual plating line in China) currently being used for testing Cr(III) alternatives. WI undertakes R&D into other coating technologies, e.g. physical vapour deposition (PVD), using third party technology providers.

However, the unique functionalities of Cr(VI) make it ideal for its current usage and difficult to replace for sanitary applications where requirements such as corrosion and chemical resistance under demanding conditions, colour and appearance must be met. There is currently no single suitable alternative (substance or process) which provides the same multi-functionality of coatings generated from chromium trioxide.

4.1.2. Data searches

A number of sources of information (literature and websites) were screened in the development of this analysis of alternatives. In addition, Perrin & Rowe has also reviewed data presented as part of other similar applications for authorisation that have already been made under EU REACH. The AoA for these applications are made publicly available on the ECHA website and these documents were reviewed to ensure that all potential alternative processes to Cr(VI)-based electroplating were considered. The various sources of information used are presented in Table 9 below.

Type	Source
Literature	BAUA (Federal Institute for Occupational Safety and Health, Germany) '*Survey on technical and economic feasibility of the available alternatives for chromium trioxide on the market in hard/functional and decorative chrome plating*' (2020)
	TURI (Toxics Use Reduction Institute) '*Five Chemicals Alternatives Assessment Study*' (2006)
	DEFRA '*Environmental Risk Reduction Strategy and Analysis of Advantages and Drawbacks for Hexavalent Chromium*' (2005)
Websites	OECD Substitution and Alternatives Assessment Toolbox http://www.oecdsaatoolbox.org/
	BAUA SUBSPORTplus (Substitution Support Portal) https://www.subsportplus.eu/subsportplus/EN/Home/
Previous applications for authorisation	For example, CTACSub (EU REACH application ID 0032-03), Grohe (EU REACH application ID 0034-01), Hansgrohe (EU REACH application ID 0114-01), Schell (EU REACH application ID 0131-01), CP4C Consortium (EU REACH application ID 0212-02), Kesseboehmer (EU REACH application ID 0231-01), Gessi, San Marco (EU REACH application ID 0241-01) etc.

***Table 9**: Sources of information used to identify potential alternatives*

4.1.3. Consultations

Information has been gathered from technical experts from Perrin & Rowe and FB WI to gain an overview of potential alternatives and their experiences in relation to them, as well as the key functionalities and performance requirements required. Detailed information was provided on R&D activities conducted over recent years into potential alternative technologies. In addition, Perrin & Rowe and FB WI are working closely with their formulation partners and suppliers to gain further understanding of existing and emerging technologies that could provide possible alternatives to Cr(VI)-based processes.

In summary, the longlist of alternatives presented below represents the outcome of extensive reviews into available information and in-house consultation with technical experts.

4.2. Longlist of alternatives

Table 10 below presents the outcome of screening of all potential alternative coating technologies considered and assessed by Perrin & Rowe. These alternatives have been screened for technical limitations and economic considerations in order to achieve a realistic shortlist of alternatives. Based on this screening, the alternatives are categorised either as shortlisted alternatives that will be assessed in further detail in this report or as rejected alternatives which are not considered further as potential alternatives for electroplating of sanitary applications as they have fundamental limitations at the present time.

Alternative considered	Description	Decision
Trivalent chromium electroplating processes Chromium sulphate Chromium chloride	Similar to the hexavalent chromium plating process, trivalent chromium plating uses chromium sulphate or chromium chloride instead of chromium trioxide. Technical limitations of this process involve corrosion, colour consistency, chemical resistance and aesthetics. Economic considerations: - Higher processing time which will result in higher unit cost, and potentially necessitating construction and installation of a complete, dedicated plating line for Cr(III). - Potentially increased scrap rate. - Potential revenue and brand impact due to reduced corrosion resistance, and perceived lower quality and aesthetics. - Production and inventory changeover and transition costs. However, further R&D is justified. Cr(III) electroplating, though currently not capable of meeting key functionalities, is believed to have the highest likelihood of success. Full evaluation of both trivalent processes is underway. The goal is to select one of the two systems and apply additional, detailed R&D to that system, to address the manufacturing challenges and ultimately expand to full production operation.	Shortlisted
Trivalent chromium + lacquer	This alternative is similar to trivalent chromium electroplating processes but involves an additional process step involving the application of a lacquer coating on top of the Cr(III) coating. Technical limitations of this process involve corrosion, colour consistency, chemical resistance and aesthetics. Economic considerations:	Shortlisted

Alternative considered	Description	Decision
	- This alternative requires an additional process step to be added in the operation. - The added lacquer coating operation is different from the Cr(III) "wet" process and will require a completely separate coating operation. - It would require capital purchase and installation, and then additional operation expenses, which will result in higher unit cost. However, while unlikely to be successful, additional investigation into this alternative may be possible in the future.	
CVD coatings	A chemical vapour deposition (CVD) coating uses a vacuum-based chemical reactive deposition process. CVD coating can involve a range of deposition methods, typically under vacuum, where the substrate is exposed to one or more volatile precursors which react on the surface and produce the desired deposit. Coatings can be polysilicon, SiO_2, Si_3N_4, various metals, graphene and diamond. Technical limitations are associated with chemical resistance and aesthetics. In addition, other AfA (e.g. application ID 0131-01) report the process is not compatible with complex geometric parts and parts with small internal diameters. Economic considerations: - This alternative would require capital purchase and installation, for new coating process, with high investment in equipment - Additional operational expenses which would result in higher unit cost. The appearance of the CVD coating is not comparable with the blue-white colour and high lustre of chrome-coated products. As a result, this alternative would not meet customer appearance requirements. No further evaluation is justified.	Rejected
PVD coatings PVD chromium	Physical vapour deposition (PVD) refers to a variety of vacuum-based processes. The coating material will be in a solid (or rarely in a liquid) form and is placed in a vacuum or low-pressure plasma environment. The coating material is vaporised and deposited, atom by atom, onto the surface of the substrate in order to build up a thin film. PVD coating materials include titanium nitride, titanium-aluminium nitride, zirconium nitride, chromium nitride, chromium carbide, silicon carbide, titanium carbide, and tungsten carbide. For these purposes, PVD chromium is considered, which refers to a vacuum-based deposition of a metal chrome coating. Technical limitations are associated with corrosion and chemical resistance. Economic considerations: - This would require capital purchase and installation for new coating process, with high investment in equipment. - There would be additional operational expenses which would result in higher unit cost. This alternative requires a process with high equipment and operating costs and does not meet key functional requirements. However, while the process is unlikely to be successful, additional investigation into this alternative may be possible in the future.	Shortlisted

Alternative considered	Description	Decision
DLC coatings	Diamond-like carbon (DLC) coatings are PVD coatings (see above) of combined bond types of graphite and diamond. DLC forms an amorphous diamond-like carbon layer. This alternative does not yield a chromium-like colour (it is black) and as such does not meet a fundamental and basic requirement. No further evaluation is justified.	Rejected
Lacquer + PVD + Lacquer	This is a three-layer system with an initial lacquer coating applied to a substrate, a subsequent PVD layer and then another clear coat lacquer to form the top layer. Technical limitations are associated with corrosion, abrasion resistance, chemical resistance and aesthetics. Economic considerations: - This alternative requires three different processes. - This would require capital purchase and installation for three coating processes, with high investment in equipment. - Additional operational expenses would result in higher unit cost. This alternative requires multiple processes with high equipment and operating costs and does not meet requirements. In addition, a lacquer coating is an organic based coating which has different tactile and heat transmissive characteristics then metals (a 'no-metal' feeling). Current development is not sufficiently able to overcome this. There are no current plans for further development of this alternative.	Rejected
Lacquered Nickel	This process refers to electroplating nickel on to the substrate and then applying a lacquer layer as topcoat. Technical limitations are associated with corrosion, abrasion resistance, chemical resistance and aesthetics. Economic considerations: - This alternative would require an additional process step to be added in the operation. - The added lacquer coating operation is different from the nickel plating "wet" process and will require a completely separate coating operation. - The alternative would require capital purchase and installation, and then additional operational expenses, which would result in higher unit cost. The appearance of the lacquered nickel is not comparable with the blue-white colour and high lustre of chrome-coated products. As a result, this alternative would not meet customer appearance requirements. No further evaluation is justified.	Rejected
Stainless Steel	This involves using stainless steel as an alternative substrate to replace the whole electroplating process. Technical limitations are associated with corrosion, abrasion resistance, chemical resistance and aesthetics. Economic considerations: - This would require complete change of substrate material used for components. - It would also involve additional operational expenses which would result in a higher unit cost.	Rejected

Alternative considered	Description	Decision
	Aesthetically, stainless steel surfaces do not provide a comparable appearance to a coated surface by chromium electroplating. Although the general colour of stainless steel is silvery, it has a yellowish tinge and the surface is not of the same shine (even when polished) compared to a chrome coated surface. Colour matching would not be possible. As a result, this alternative would not meet customer appearance requirements. No further evaluation is justified.	
Anodised Aluminium	Anodising is an electrolytic process used to develop or enhance an aluminium oxide coating on the surface of an aluminium substrate. Technical limitations are associated with corrosion, abrasion resistance, chemical resistance and aesthetics. Economic considerations: - This alternative would require capital purchase and installation for a new coating process, with high investment in equipment. - It would also require complete change of substrate material used for components. - The alternative would create additional operational expenses which would result in higher unit cost. The appearance of the anodized aluminium is not comparable with the blue-white colour and high lustre of chrome-coated products. As a result, this alternative would not meet customer appearance requirements. No further evaluation is justified.	Rejected
Powder coating	Powder coating is a type of surface coating that is applied as a free-flowing, dry powder which is applied electrostatically and then cured under heat or UV light. The powder will be a thermoplastic or thermoset polymer. This alternative does not yield a metallic looking surface nor a chromium-like colour and as such it does not meet a fundamental and basic requirement. No further evaluation is justified.	Rejected
Wet lacquering / colour painting	This involves liquid coating materials applied either as clear or coloured lacquer. This alternative does not yield a chromium-like colour and as such it does not meet a fundamental and basic requirement. No further evaluation is justified.	Rejected

***Table 10**: Longlist of potential alternatives*

The alternatives outlined in Table 10 were evaluated on the basis of several criteria which would affect overall business financials as well as preserving equity of the brand. The primary considerations were technical feasibility to implement in a consistent, robust production process, the ability of the alternative to meet customer requirements, and relative production costs.

The alternatives were assessed based first on investigations available in the public domain, undertaken by others in the industry. Of the range of technical alternatives to chromium trioxide-based plating, electroplating based on trivalent chromium solutions are the most promising and will be considered in the most detail. Two other potential alternatives, PVD chromium and trivalent chromium with lacquer coating, may be investigated further in the future.

All of these alternatives currently fail on a technical basis because of critical performance weaknesses, particularly in the areas of corrosion resistance, chemical resistance and aesthetics. Any general attempt to offer products to the market using these alternatives without additional development would result in a critical loss of market share and sales, as consumers switch to more reliable and durable products, based on Cr(VI) imported from outside GB.

As a result, in addition to the alternatives outlined above, the following 'managerial' scenarios can be considered as alternatives to the continued use of chromium trioxide in Great Britain:

- Ceasing production of all products that require the use of chromium trioxide – in this scenario, Perrin & Rowe would cease to manufacture and supply all chrome-plated products but would attempt to continue to manufacture and supply products with other finishes in the UK.

- Outsourcing production of products that require the use of chromium trioxide – in this scenario, Perrin & Rowe would continue to supply chrome-plated products but the company would no longer electroplate the products itself in the UK; electroplating would be outsourced to a third-party provider based in a non-EEA country. (Additionally, given the costs of shipping and complexity of logistics, manufacturing of brass components in their entirety would likely be outsourced.)

- Relocation of production associated with the use of chromium trioxide – In this scenario, Perrin & Rowe would relocate its manufacturing operation (partly or completely) to a non-UK and non-EEA country. This would involve establishing the company in another territory and setting up a new production site.

4.3. Shortlist of alternatives

Table 11 below lists the potential alternatives shortlisted for further assessment in this report based on the initial screening undertaken when developing the longlist (above). In order to adopt a proportionate approach to the assessment of alternatives in this report, these potential alternatives have been categorised as follows:

- Category A alternatives – these show the most promise, with R&D activities currently ongoing, and will be carried forward for detailed, **quantitative** assessment in this report.

- Category B alternatives – these show less promise but additional R&D activity may be possible in the future. These are carried forward for **qualitative** assessment in this report.

- Category C alternatives – these reflect '**managerial**' options.

Cat.	Potential alternative	Type	Justification
A	Trivalent chrome (chromium sulphate) Trivalent chrome (chromium chloride)	Most promising; carried forward for **quantitative** assessment	Replaces a single process (Cr(VI) electroplating) with a similar single electroplating process (Cr(III) electroplating). Can utilize electroplating equipment and processes very similar to current operation. Least per unit cost impact.

Cat.	Potential alternative	Type	Justification
B	PVD chromium Trivalent chromium + lacquer	Less promising; carried forward for **qualitative** assessment	While unlikely to be successful, additional investigation into these alternatives may be possible in the future.
C	Ceasing production Outsourcing production Relocating production	Managerial options	All alternative processes / technologies to Cr(VI)-based electroplating currently fail on a technical basis because of critical performance weaknesses, particularly in the areas of corrosion resistance, chemical resistance and aesthetics. Any general attempt to offer products to the market using these alternatives would result in a critical loss of market share and sales, as consumers switch to more reliable and durable products, based on Cr(VI) imported from outside of Great Britain. Managerial options therefore consider either ceasing to supply Cr(VI)-based product or continuing to supply Cr(VI)-based product that has been produced outside the UK / EEA, i.e. in territories not subject to UK REACH or EU REACH where use of chromium trioxide is still permitted.

***Table 11**: Shortlist of potential alternatives*

The above short-listed potential alternatives have the potential to eliminate the use of chromium trioxide in GB, but there will be many unknown impacts to the products' performance, in addition to negative financial impacts on the products' cost. It is not feasible nor prudent to perform a complete technology switch from Cr(VI) to any of the potential alternatives at the present time given the current level of process development, as they are not capable of meeting the key functionalities required. Doing so now, without additional development, would cause serious harm to Perrin & Rowe's business and brand.

5. Analysis of alternatives

The aim of this AoA is to assess the feasibility of potential alternatives to the use of chromium trioxide for electroplating of kitchen and bathroom brass products with functional chrome plating of decorative character. The objective is to identify the most likely NUS for Perrin & Rowe in the event that its use of chromium trioxide must cease, to provide input for the SEA and SP.

Article 60(5) of REACH provides that when assessing the availability of suitable alternative substances or techniques, all relevant aspects must be taken into account, including:

a) whether the transfer to the alternative would result in reduced overall risks to human health and the environment (as compared to the Annex XIV substance) taking into account risk management measures; and
b) the technical and economic feasibility in Great Britain of alternatives for the applicant for replacement of the Annex XIV substance.

The alternative must also be available for the applicant, i.e. it can be accessed in sufficient quantity and quality for substitution.

In this section, the identified potential alternatives are therefore assessed in terms of their technical feasibility, economic feasibility, potential for risk reduction and availability.

Category A alternatives are assessed in detail using a quantitative approach and based on testing undertaken by FB WI's R&D department for Perrin & Rowe. Category B alternatives are assessed using a qualitative approach that focuses on technical feasibility in the first instance and, if found to have critical technical weaknesses which means some of the key functionalities are not fulfilled, economic feasibility and other considerations are not then assessed in detail. This is in line with the approach suggested in the ECHA guidance on authorisation[14] and aims to ensure a proportionate approach is taken to the AoA. As none of the potential alternatives are currently suitable, Category C alternatives are also assessed. These represent 'managerial options' which would permit the cessation of the use of Cr(VI) in GB by Perrin & Rowe.

A potential alternative process or technology **must fulfil all key functionalities** for sanitary applications to ensure quality, regulatory and customer needs before it can be considered a suitable alternative for chromium trioxide in functional chrome plating with decorative character.

5.1. Trivalent chromium electroplating

Based on Perrin & Rowe's research and data available for the alternatives to Cr(VI)-based plating, it was concluded that the first priority development will focus on trivalent chromium (Cr(III)) as the most viable solution to substitution of hexavalent chromium, despite many challenges to scale up the manufacturing of Cr(III)-based processes. Transitioning from hexavalent Cr(VI)-based electroplating to trivalent Cr(III)-based electroplating involves similar equipment and technology. However, this transition is not as simple as changing the chemistry in the electroplating tanks. The transition to this process would require considerable additional R&D efforts to better understand process parameters and interactions and determine ways in which they might be modified to create an alternative that would be able to meet customer requirements. This would entail several years of R&D effort and labour as well as a high number of process trials and considerable expense in parts and materials. If a suitable process could be developed, then additional project phases would be needed to industrialise the process and phase-out the use of chromium trioxide. This is explored further in the Substitution Plan.

This part of the report examines potential alternatives based on both chromium sulphate and chromium chloride processes together, because these alternatives are sufficiently related.

5.1.1. Substance identity, properties and process description

Electroplating with trivalent chromium electrolytes is similar to the hexavalent chromium process in that it will result in the deposition of a metallic chrome coating on the surface of the substrate. The substrate will be immersed in a Cr(III) plating solution (the electrolyte) containing dissolved Cr(III) salts, typically with additives such as ammonium salts as complexing agents and boric acid or borate salts as buffering agents. During electroplating, the dissolved Cr(III) cations are reduced to metallic chrome and the coating builds up on the substrate by electrodeposition.

The composition of the Cr(III) electrolyte can differ and the choice will depend on the surface treatment and application which is to be substituted. This section of the report considers two potential alternatives, namely [redacted], a chloride-based alternative, and [redacted], a sulphate-based alternative. It

[14] ECHA, 2021, p45 and p81

also considers post-plate passivation, an additional step required in Cr(III) plating processes. These types are more commonly used in functional plating with decorative character.

Table 12 below explores some of the main differences between trivalent and hexavalent chromium plating.

Difference	Cr(VI)	Cr(III), Chloride	Cr(III), Sulphate	Comment
Chromium Content	Cr(VI) 150 g/l	Cr(III) 20 g/l	Cr(III) 10 g/l	Trivalent chromium processes contain much lower concentrations of chromium in plating bath. Also, the chromium is present in its much safer +3 valence rather than the hazardous +6 valence.
Electrolyte composition	-	-	-	Hexavalent chromium electrolytes contain chromium trioxide in a sulphuric acid solution with additional components like surfactants and catalysts. The chromate anion is reduced in a complex multistep process at the cathode and deposited as chrome metal. Trivalent chromium electrolytes usually contain chromium salts (sulphate, chloride) as well as complexing agents, buffers, catalysts and surfactants to achieve the required performance for plating. The deposition of metallic chromium takes place from cationic chrome sulphate (or chloride) complexes.
Bath lines	Shorter	Longer	Longer	As trivalent chromium plating baths are very sensitive to impurities, additional technologies (an ion exchanger using a special resin) and a number of additional baths are needed to enable adequate rinsing processes to reduce impurities as much as possible. This is necessary for both the pre-treatment bath technology as well as the trivalent chromium plating step and post-plating passivation.
Ion exchangers	Not required	Required	Required	In order to avoid co-deposition, foreign metal cations have to be removed by use of ion exchangers.
Surface passivation	Not required	Required	Required	Passivation is a post-plating process that provides additional corrosion protection to a substrate. It results in an oxide layer that separates the chromium metal from the atmosphere, so that further oxidation by diffusion is impeded by this passivating layer. With Cr(VI) electrolytes, this passivation layer is generated by the oxidative chromic acid. However, Cr(III) electrolytes cannot produce this passivating layer. This means the passivation has to be generated in an additional process step using, for example, phosphates or polyphosphates or other kinds of organic substances. The formation of chromium phosphates on the surface can cause changes in colour.
Anodes	Lead	Graphite	Inert Metal Oxide	Trivalent chrome processes do not require lead anodes.
Temperature	35-43^{0}C	30-40^{0}C	50-60^{0}C	Trivalent chromium processes can be similar or higher operation temperature.
pH Value	<1	2.5-3.0	3.3-3.8	The pH (acidity level) is considerably higher in Cr(III) processes.

Difference	Cr(VI)	Cr(III), Chloride	Cr(III), Sulphate	Comment
PFAS	Used	Not used	Not used	Mist suppressants are added to minimize misting. Trivalent chromium processes have an advantage in that they do not use perfluorinated alkylated substances (PFAS) for surface tension adjustment. PFAS are persistent in the environment and may be subject to future restriction under REACH.
Process time	Faster	Slower	Slower	Chromium deposition is slower in trivalent chromium-based processes.
Bath maintenance	Less effort	More effort	More effort	Analytical efforts will be much higher for adequate control of bath composition in Cr(III)-based processes given all its additives. Analysis of layer thickness and colour has to be performed on a daily basis. Quality maintenance of a trivalent chromium bath will likely take about 14 hours per week, compared to 2 hours per week for the chromium trioxide bath.

***Table 12**: Differences between trivalent and hexavalent chromium plating*

A non-exhaustive overview of general information on substances used within Cr(III)-based electroplating alternatives as well as their hazards to human health and the environment is presented in the tables in Appendix 2.

Appendix 3 presents information on how the various substances presented in Appendix 2 are used in trivalent chromium electroplating.

5.1.2. Technical feasibility

Over recent years, Perrin & Rowe (through FB WI) has conducted a substantial amount R&D activity into a number of Cr(III) processes on various substrate types, including brass. Results of comparative physical testing on different substrates with a final chromium coating need to be considered side-by-side to evaluate the technical feasibility. Additionally, considerations of the colour and appearance of the trivalent chrome electroplating requires careful review prior to adopting this in place of hexavalent chrome electroplating

To evaluate whether the transition from hexavalent chrome to trivalent chrome-based processes can produce components that would be considered a viable alternative, numerous tests have been conducted to compare these electroplating systems. Table 13 below summarises the current findings of such testing as regards various key functionalities.

Functionality	Findings
Colour	The colour of Cr(III) is not bluish-white, as with Cr(VI), but a darker, more yellow/brown. The exact colour of the coating is a result of the electrolyte used: sulphate-based coatings for example are slightly lighter, while chloride-based coatings are slightly darker. The yellowish/brownish shade of the coating is caused by iron ions that are incorporated into the metallic chromium layer. The sulphate-based coatings, while capable of producing a lighter, less yellow deposit, have also demonstrated high variability in final colour and lustre. Cr(III) baths are more sensitive to metallic impurities and the composition of the bath than conventional Cr(VI) plating baths. Even small deviations in process conditions can strongly influence the deposition process, the quality of the deposition layer and the final appearance. Such variations in colour and appearance would not

Functionality	Findings
	be acceptable to the customer, especially if such variation occurred on parts within an assembly built with components produced over various points in time. The surface of Cr(III) deposits are not as fully stable as Cr(VI) deposits and have proven to have poor colour stability over time.
Corrosion resistance	The corrosion resistance was tested using the various accelerated corrosion test procedures utilised in current performance testing of hexavalent sanitary ware products. The various corrosion tests are listed elsewhere in this report. Test results show that Cr(III) coatings have significantly reduced corrosion resistance when compared to Cr(VI) coatings. Testing also demonstrates that the Cr(III) coatings fail in their ability to resist the corrosive effects typically encountered in use by customers.
Chemical resistance	The chemical resistance of Cr(III) coatings have been tested by both droplet testing and immersion testing, utilizing chemicals typical of household cleaning agents used by consumers and owners of sanitary ware. This testing has shown that Cr(III)-based coatings have failed to meet chemical resistance requirements.
Abrasion resistance	Cr(III) coatings were tested as per WI internal test protocols utilizing typical sanitary ware industry rotary Taber abrasion test equipment. Results have shown that Cr(III) coatings do not have the same level of abrasion resistance as do Cr(VI) coatings. This attribute is critical to customer satisfaction due to the very frequent cleaning performed on sanitary ware with mildly abrasive household cleaners. This issue is even more problematic in hospitality applications, as the frequency of cleaning and harshness of cleaners used are both much higher than residential customers.
Longevity	The typical lifetime for a WI sanitary ware product is often longer than 10 years, which means that long-term quality is a key customer expectation and a core feature of the P&R brand. Testing and CTAC references have indicated that Cr(III) plated parts have reduced colour stability over time, which is not the case with Cr(VI). Chloride-based Cr(III) performs slightly better than sulphate based Cr(III), but has an initial colour that is darker and more yellow, and less desirable. Combining colour issues with corrosion and chemical resistance issues, indicates that the quality of Cr(III) sanitary ware cannot be guaranteed for the long-term.

***Table 13**: Summary of findings of testing on Cr(III)-based coatings*

Perrin & Rowe cannot market products which exhibit significantly inferior levels of performance without a significant reduction in the prices it is able to sell at and the markets it is able to sell into. For instance, commercial customers (such as hotels) in the luxury end of the market require durability and guaranteed long-life and would not accept reduced levels of performance even if at a significant price discount.

The following section of the report presents the results of testing by FB WI on brass substrates plated using Cr(III)-based processes. The following tests have been conducted on three types of chrome-plated parts:

- parts made using hexavalent (Cr(VI)) chrome;
- parts made with Chloride trivalent (Cr(III)) chrome (processes with and without sealer chemistry were tested); and
- parts made with Sulphate trivalent (Cr(III)) chrome (again, processes with and without sealer chemistry were tested).

<u>Corrosion resistance</u>

Corrosion resistance was tested by FB WI on its products made with hexavalent chrome and two types of trivalent chrome plating. The method followed is outlined in Table 14 below.

Test Method:	WI 10-020-0043
Number of spraying cycles	2
Sprayed Solution	Sodium Chloride 53 g/l in deionized water (conductivity <5 uS)
Absolute Spray Pressure	126 kPa
Chamber Temperature	35°C
Humidifier Temperature during spraying	48°C
Spray Time per cycle	100 hr
Stop time after 1st cycle	48 hr
Overall duration of the test	248 hr
pH of the collection solution	6.85 (+/- 3.5)
Rainfall constant	1.2 ml/hour
Method used for cleaning samples pre-test	Isopropanol
Total number of samples	7
Base substrate material	Brass and Zinc
Coatings	Electrolytic Nickel and chromium (hexavalent and trivalent)

***Table 14**: Test method details for corrosion resistance testing*

The results obtained in the corrosion tests shown below demonstrate how the articles made with the alternative trivalent chromium (Cr(III)) process show corrosion of the base material when compared to the hexavalent (Cr(VI)) parts.

Cr(VI) test results and images

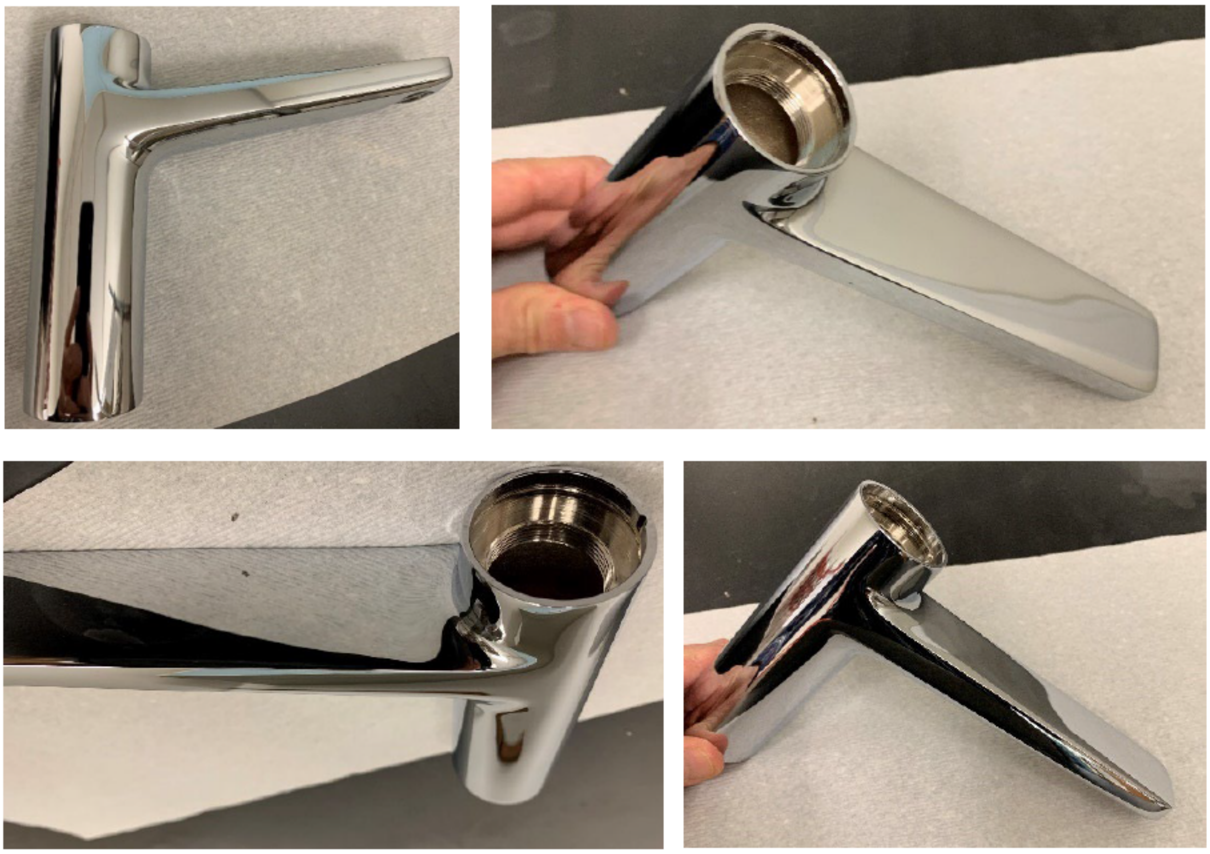


***Figure 8**: Results of corrosion test on Fortune Brands products made with Cr(VI) - No staining or corrosion spots observed in any of the salt spray tests*

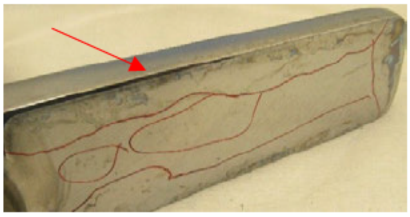
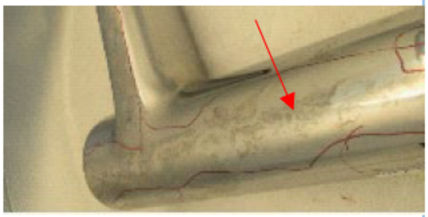
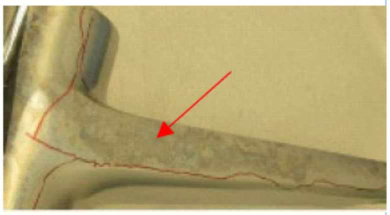
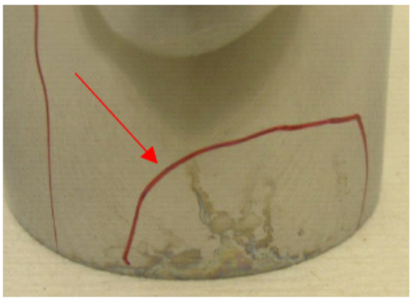
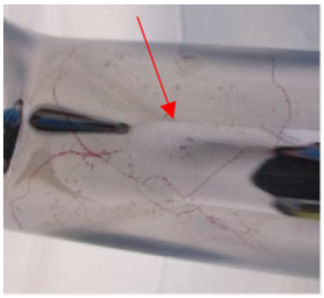
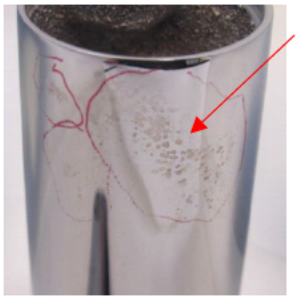
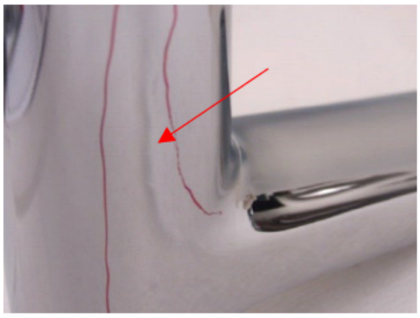
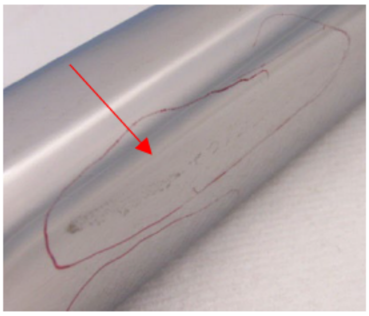
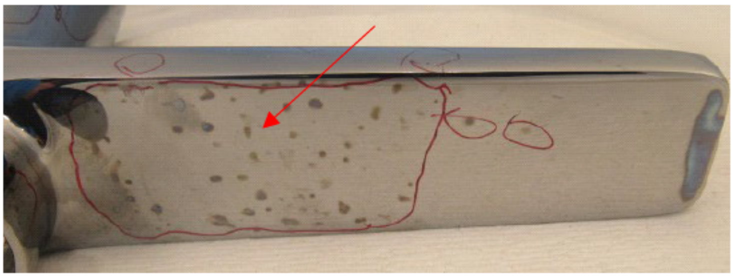
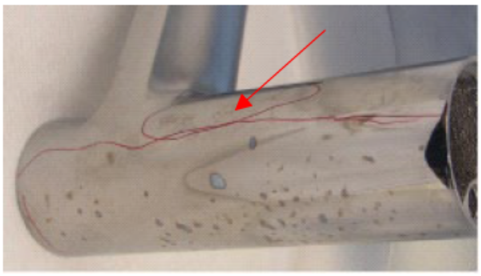
Cr(III) test results and images		
200hr neutral salt spray. Corrosion stains evident.		
		
24hr neutral salt spray. Corrosion stains evident.		
		
Acetic acid salt spray. Corrosion stains evident.		
		
Copper acetic acid salt spray. Corrosion stains evident.		
		

***Figure 9**: Results of 4 corrosion tests on Fortune Brands parts made with Chloride Cr(III) (Unsealed Process)*

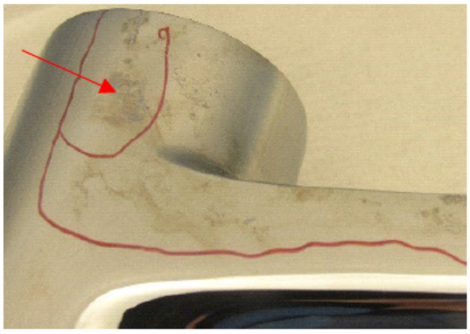
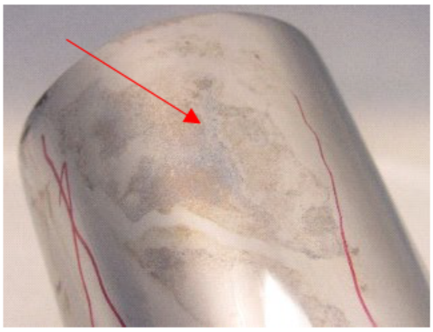
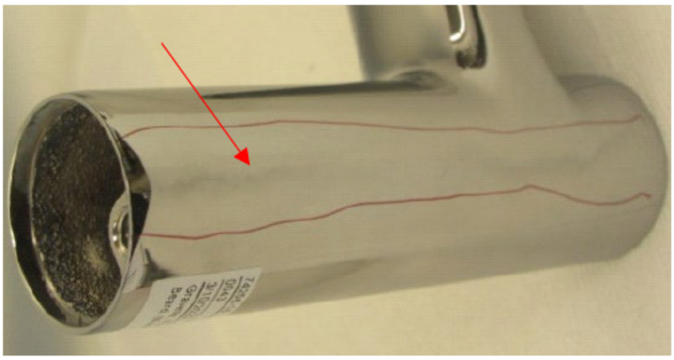
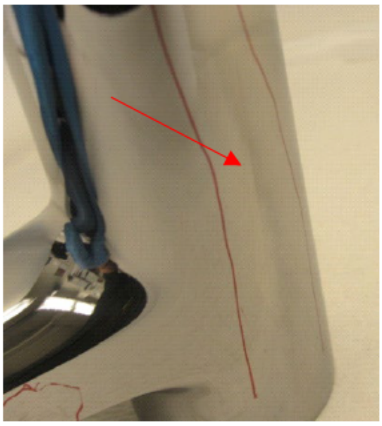
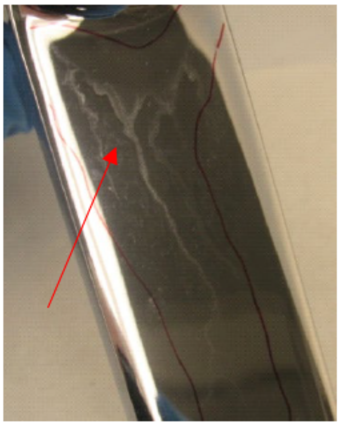
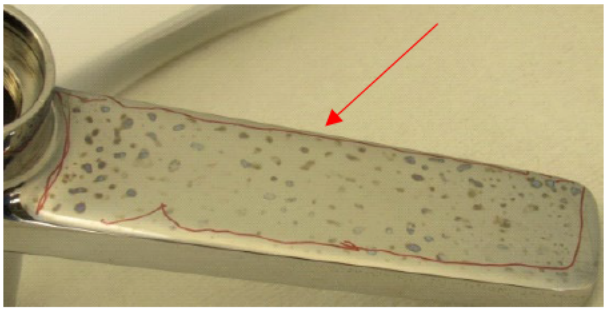
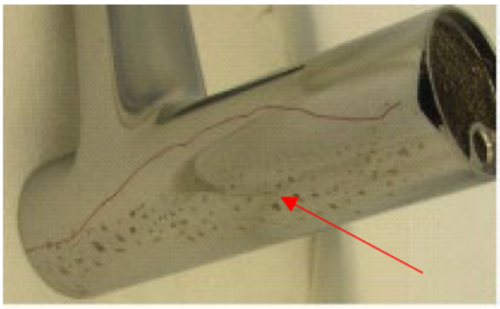
Cr(III) test results and images		
200hr neutral salt spray. Corrosion stains evident.		
		
24hr neutral salt spray. Corrosion stains evident.		
		
Acetic acid salt spray. Corrosion stains evident.		
		
Copper acetic acid salt spray. Corrosion stains evident.		
		

***Figure 10**: Results of 4 corrosion tests on Fortune Brands parts made with Chloride Cr(III) (Sealed Process)*

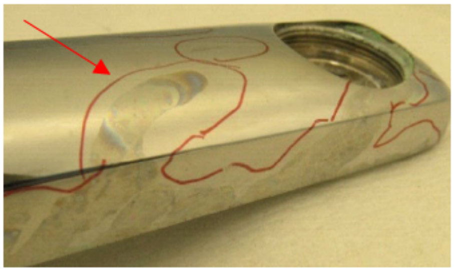
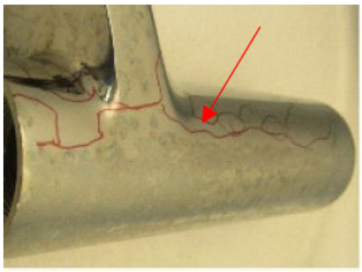
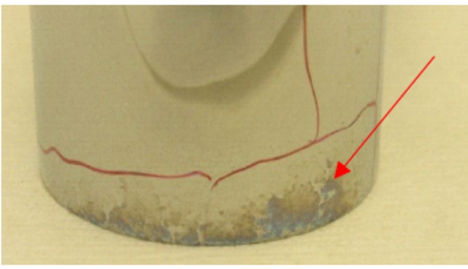
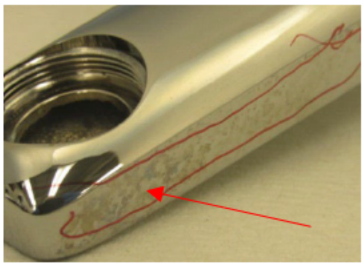
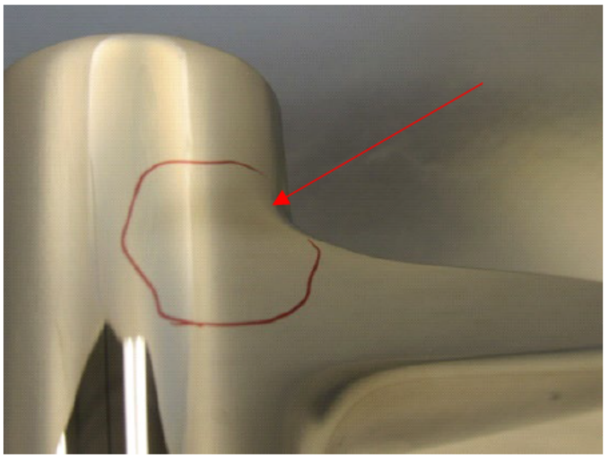
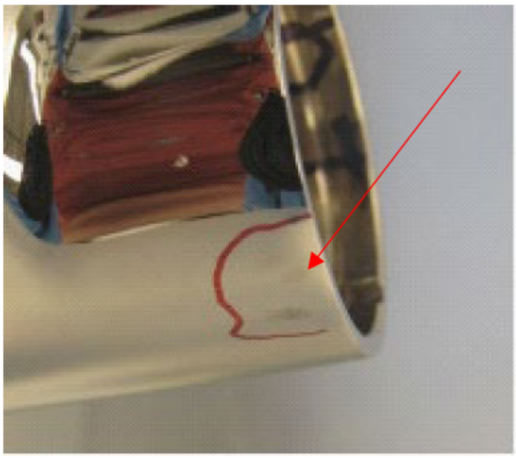
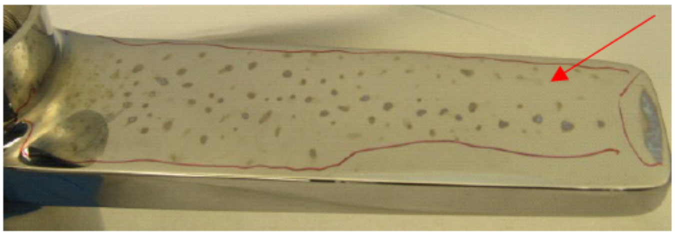
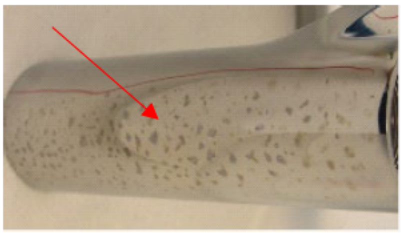
Cr(III) test results and images		
200hr neutral salt spray. Corrosion stains evident.		
		
24hr neutral salt spray. Corrosion stains evident.		
		
Acetic acid salt spray. Minor corrosion stains evident.		
		
Copper acetic acid salt spray. Corrosion stains evident.		
		

***Figure 11**: Results of 4 corrosion tests on Fortune Brands parts made with Sulphate Cr(III) (Unsealed Process)*

<table>
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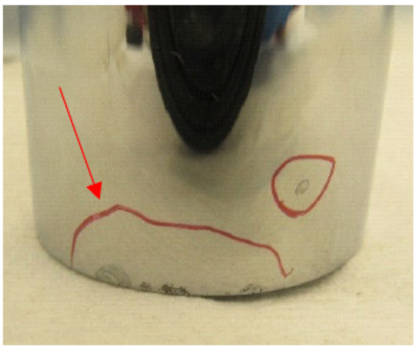
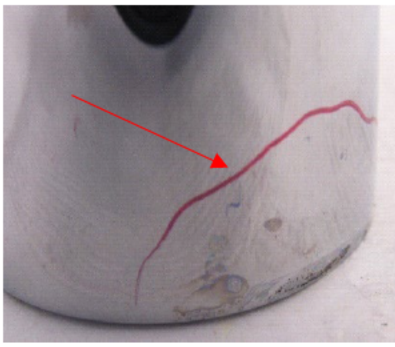
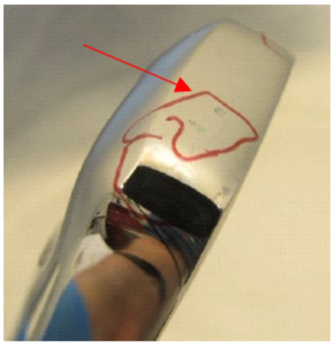
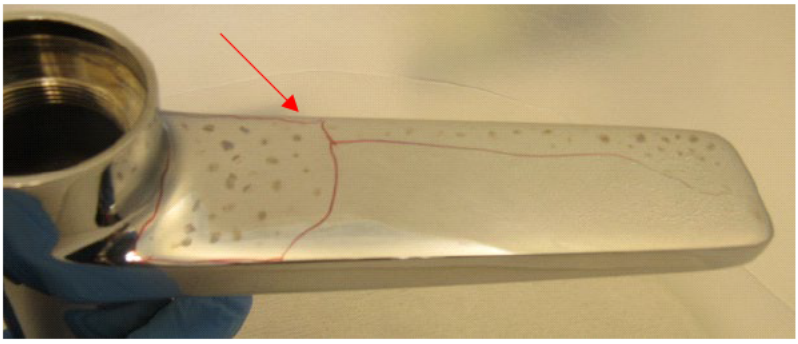
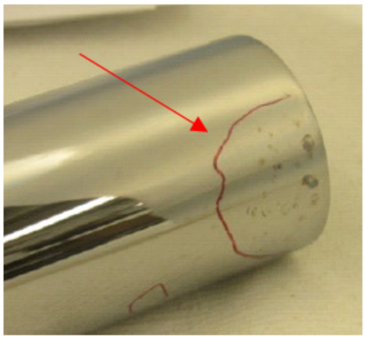
<tr><td colspan="6">200hr neutral salt spray. Minor corrosion stains evident.</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="6">Copper acetic acid salt spray. Corrosion stains evident.</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td colspan="6">Note: Acetic acid salt spray and 24hr neutral salt spray tests showed no corrosion spots or stains</td></tr>
</table>

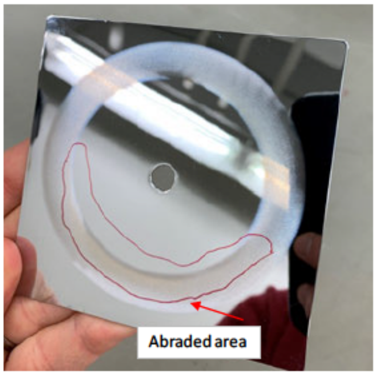
***Figure 12**: Results of 4 corrosion tests on Fortune Brands parts made with Sulphate Cr(III) (Sealed Process)*

In summary, the corrosion resistance of the two tested coatings using the alternative, trivalent chromium electroplating process clearly failed the corrosion resistance requirements.

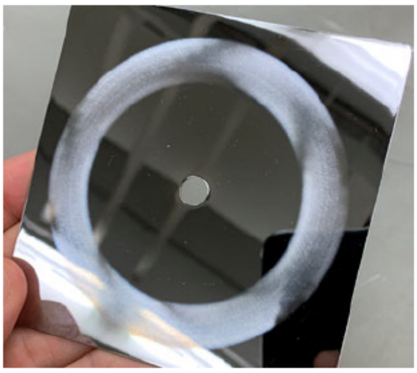
<u>Abrasion resistance</u>

The abrasion resistance was tested by Fortune Brands on its products made with hexavalent (Cr(VI)) processes and two types of trivalent chromium (Cr(III)) plating. The results are presented below.

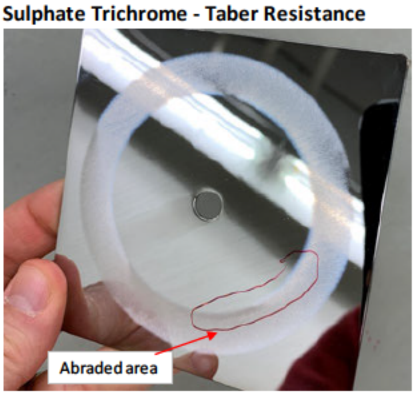
Hexavalent Chrome - Taber Resistance



Chloride Trichrome - Taber Resistance



Sulphate Trichrome - Taber Resistance



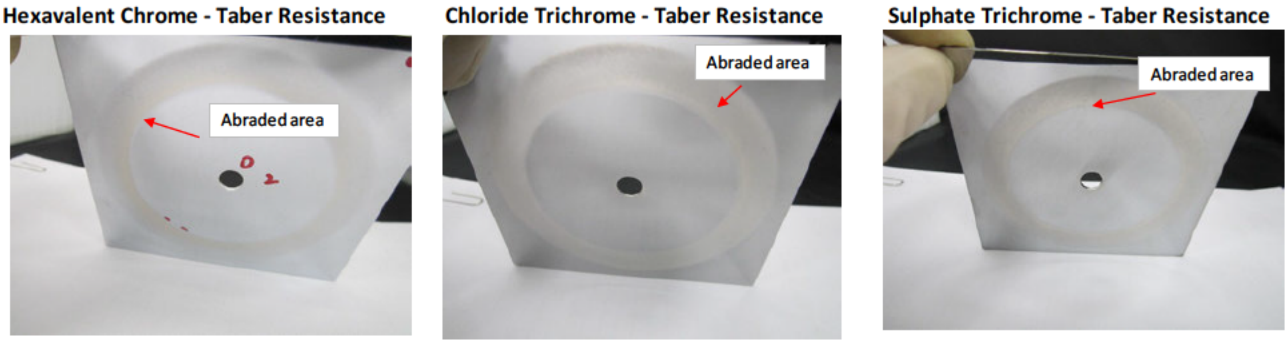


***Figure 13**: Results of abrasion tests on Fortune Brands parts made with hexavalent and trivalent chromium processes*

(Note: the arrows pointing to areas on the photographs represent areas where the chrome finish has been abraded to reveal the nickel plating layer underneath.)

The abrasion corrosion resistance of the two tested coatings using the alternative, trivalent chromium electroplating process compared to hexavalent chrome are inconclusive at this stage of development – further studies are underway to determine the overall impact to the finish quality.

<u>Adhesion</u>

The electroplating adhesion was tested by Fortune Brands on its products made with hexavalent (Cr(VI)) processes and two types of trivalent chromium (Cr(III)) plating. The results are presented below.

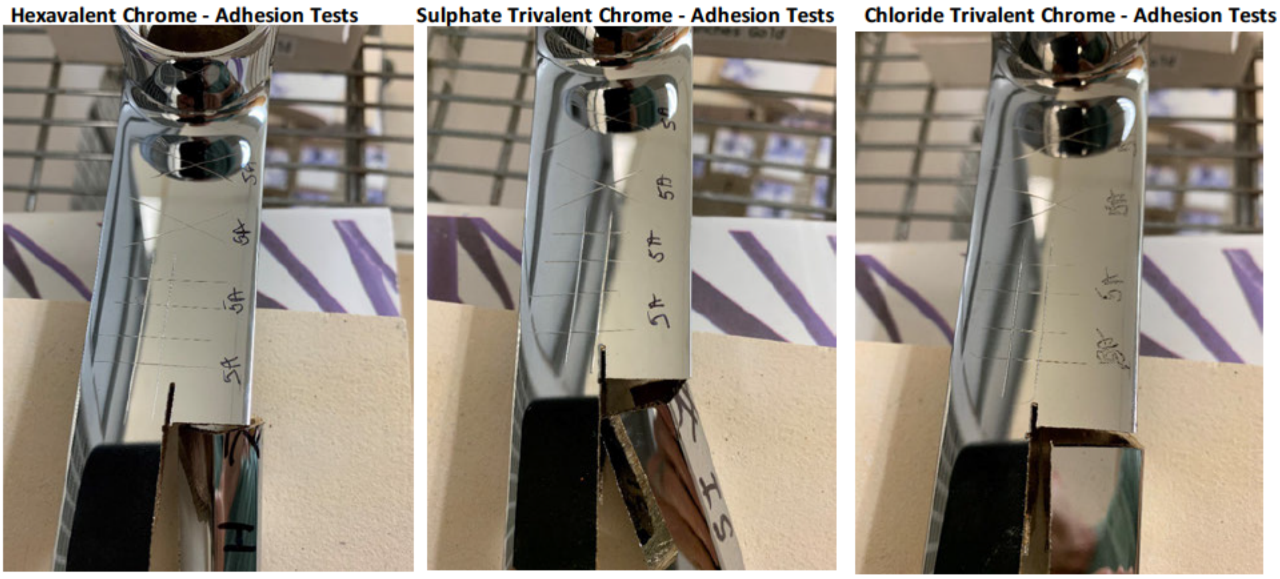


***Figure 14**: Results of adhesion tests on Fortune Brands parts made with hexavalent and trivalent chromium processes*

The adhesion of the electroplating showed that the trivalent chromium electroplating process passed the required performance requirements.

Chemical resistance

The chemical resistance was tested by Fortune Brands on its products made with hexavalent (Cr(VI)) processes and two types of trivalent chromium (Cr(III)) plating. Tests were conducted both on overnight spot-testing and long-term (30 day) immersion in typical household cleaning agents. The testing duplicates a wide variety of cleaners commonly used by consumers. For all tested parts, Fortune Brands uses specific criteria, as shown in the following table, for evaluating visible surfaces for changes in physical appearance including but not limited to, colour change, shrinkage, expansion (swelling) and cracking.

Criteria	Evaluation
1	Serious degradation of material
2	Moderate degradation of material
3	Mild degradation of material
4	No visible degradation of material

***Table 15**: Rating scale used for overnight chemical spot resistance testing*

The overnight spot chemical test results are as follows (note: highlighted cleaners and chemicals were chosen that demonstrated major differences between hexavalent and trivalent chromium plating variations):

Hexavalent Chrome			
Test Site	**Solution #**	**Rating**	**Comments**
1	Lysol Toilet Bowl cleaner	2	Moderate degradation
11	Scrubbing Bubbles	3	very mild degradation
12	Drano Max Clog Remover	3	mild degradation
13	Clorox Clean Up	3	mild degradation
14	Sodium Hydroxide 1.0M (pH=14)	3	mild degradation
15	Sodium Hydroxide 6.0M	3	moderate degradation
16	citric acid 1.0 M	3	very mild degradation
25	FeCl3 (Ferric Chloride) (1.0 M)	1	serious degradation
34	Tilex Soap Scum Remover	3	very mild degradation
Chloride Trichrome Cr(III) Sealed			
Test Site	**Solution #**	**Rating**	**Comments**
1	Lysol Toilet Bowl cleaner	1	serious degradation
12	Drano Max Clog Remover	3	mild degradation
13	Clorox Clean Up	2	moderate degradation
17	HCl (Hydrochloric Acid) (0.1 M)	1	serious degradation.
22	CH3COCH3 (Acetone) (Neat)	3	mild degradation
23	NaOCl (Sodium Hypochlorite) (6%)	3	mild degradation
25	FeCl3 (Ferric Chloride) (1.0 M)	1	serious degradation

Chloride Trichrome Cr(III) Unsealed

Test Site	Solution #	Rating	Comments
1	Lysol Toilet Bowl cleaner	2	serious degradation
5	Clean Shower	3	mild degradation
12	Drano Max Clog Remover	3	mild degradation
13	Clorox Clean Up	3	very mild degradation
17	HCl (Hydrochloric Acid) (0.1 M)	1	serious degradation.
18	H_3PO_4 (Phosphoric Acid) (0.1 M)	3	very mild degradation
19	NH_4OH (Ammonium Hydroxide) (0.1 M)	3	very mild degradation
20	$NaHCO_3$ (Sodium Bicarbonate) (0.2 M)	3	very mild degradation
30	Olive oil	3	mild degradation
25	FeCl3 (Ferric Chloride) (1.0 M)	1	serious degradation

Sulphate Trichrome Cr(III) Unsealed

Test Site	Solution #	Rating	Comments
1	Lysol Toilet Bowl cleaner	1	serious degradation
11	Scrubbing Bubbles	3	very mild degradation
12	Drano Max Clog Remover	3	very mild degradation
13	Clorox Clean Up	3	mild degradation
14	Sodium Hydroxide 1.0M (pH=14)	3	very mild degradation
15	Sodium Hydroxide 6.0M	3	very mild degradation
16	citric acid 1.0 M	3	very mild degradation
17	HCl (Hydrochloric Acid) (0.1 M)	2	moderate degradation
20	$NaHCO_3$ (Sodium Bicarbonate) (0.2 M)	3	very mild degradation
23	NaOCl (Sodium Hypochlorite) (6%)	1	serious degradation
24	$CH_3CH(OH)CH_3$ (Isopropyl Alcohol) (70%)	3	very mild degradation
25	FeCl3 (Ferric Chloride) (1.0 M)	1	serious degradation
27	Triton 100X 100%	3	very mild degradation
34	Tilex Soap Scum Remover	3	mild degradation

Sulphate Trichrome Cr(III) Sealed

Test Site	Solution #	Rating	Comments
1	Lysol Toilet Bowl cleaner	1	serious degradation
3	Ecolab Oasis 297(32oz/gal)	3	very mild degradation
12	Drano Max Clog Remover	3	mild degradation
13	Clorox Clean Up	2	moderate degradation
15	Sodium Hydroxide 6.0M	3	very mild degradation
17	HCl (Hydrochloric Acid) (0.1 M)	1	serious degradation
23	NaOCl (Sodium Hypochlorite) (6%)	3	mild degradation
25	FeCl3 (Ferric Chloride) (1.0 M)	1	serious degradation
34	Tilex Soap Scum Remover	3	very mild degradation

***Figure 15**: Summary results tables for the 16hr chemical resistance test – hexavalent and trivalent chromium variations*

Photographic results of the chemical drop testing for hexavalent and trivalent chrome processes are presented below.

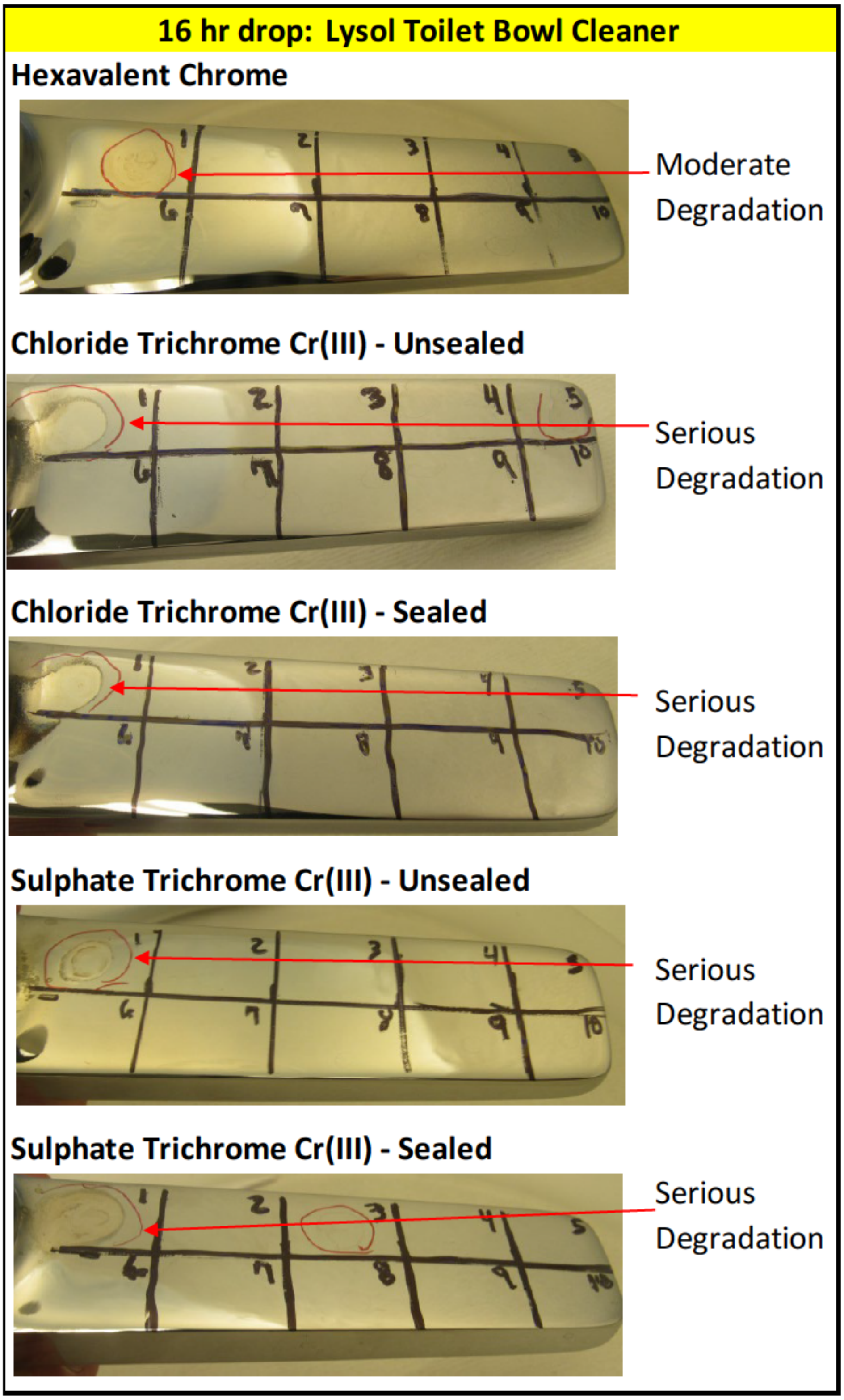


***Figure 16**: Results of the 16hr chemical drop test with Lysol Toilet Bowl Cleaner on hexavalent and trivalent chrome versions*

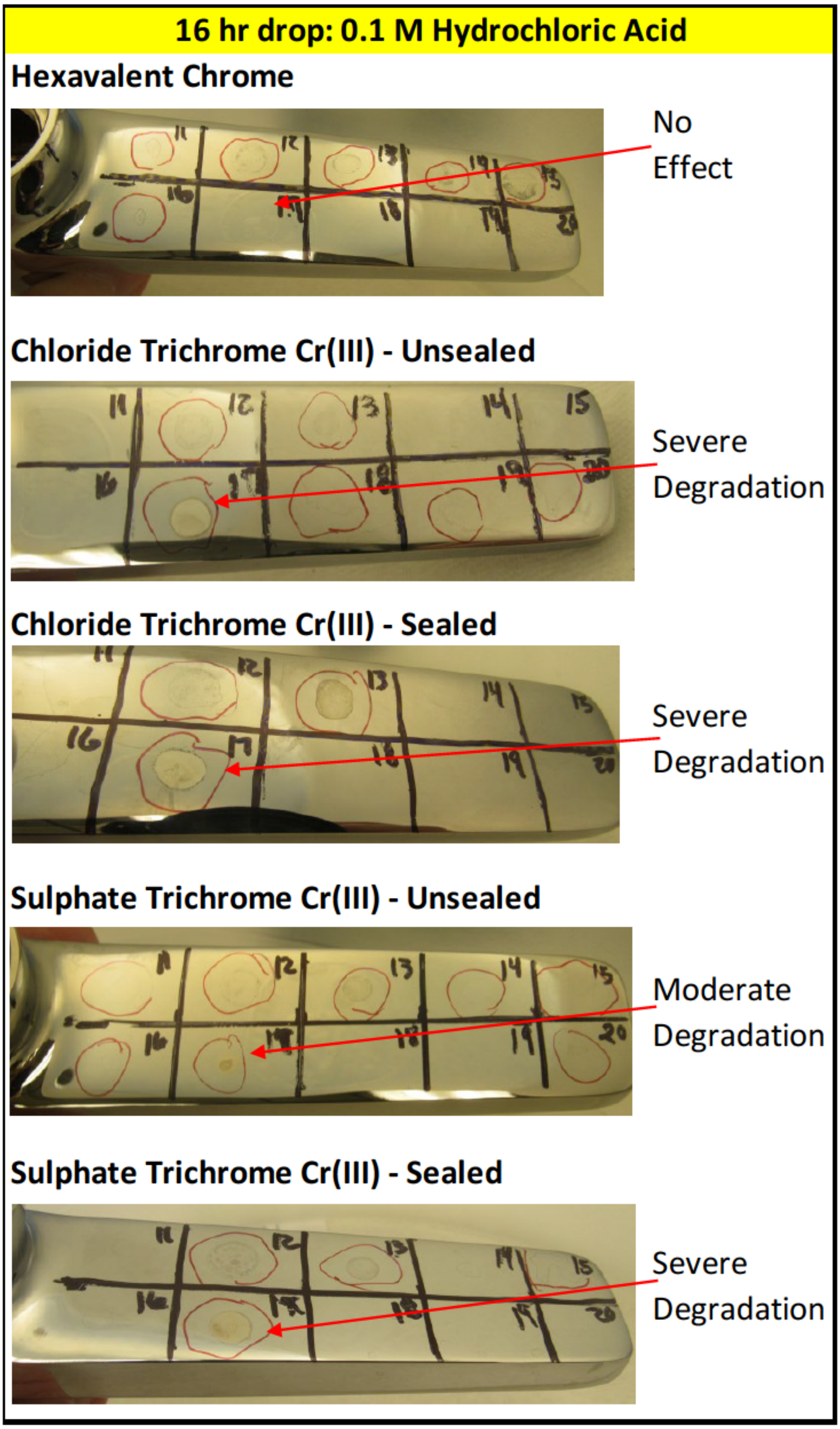
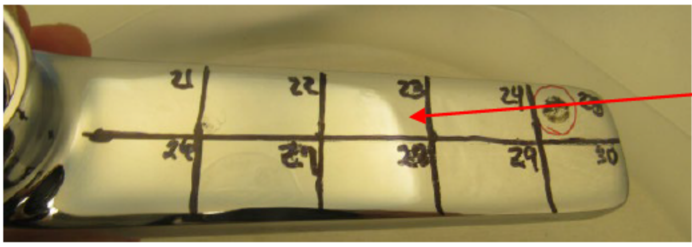


***Figure 17**: Results of the 16hr chemical drop test with Hydrochloric Acid (0.1M) on hexavalent and trivalent chrome versions*

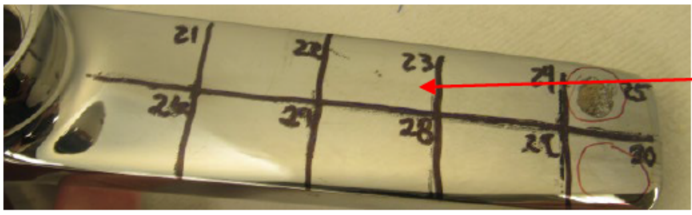
16 hr drop Sodium Hypochlorite (6%) Bleach:

Hexavalent Chrome



No Effect

Chloride Trichrome Cr(III) - Unsealed

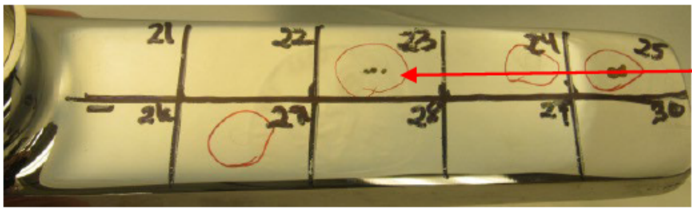


No Effect

Chloride Trichrome Cr(III) - Sealed

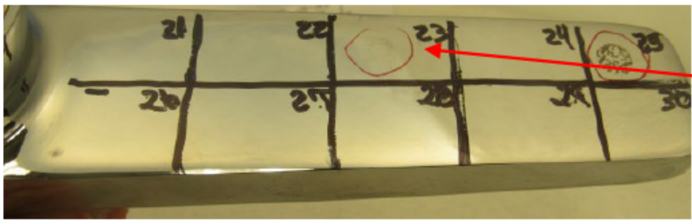
Mild Degradation

Sulphate Trichrome Cr(III) - Unsealed



Serious Degradation

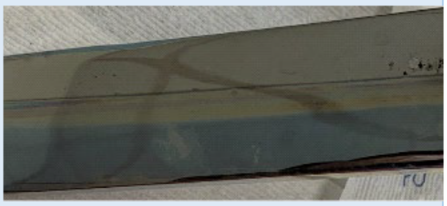
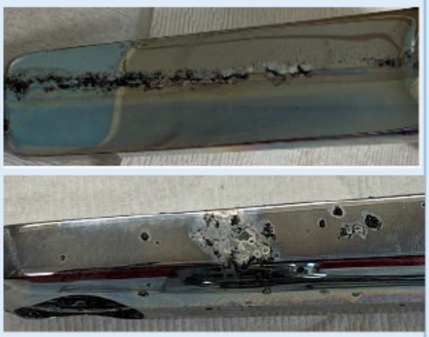
Sulphate Trichrome Cr(III) - Sealed



Mild Degradation

***Figure 18**: Results of the 16hr chemical drop test with Sodium Hypochlorite (6%) Bleach on hexavalent and trivalent chrome versions*

In terms of the long-term (30 day) chemical immersion testing, the results indicate that trivalent chromium-based samples are significantly more susceptible to plating deterioration when tested with Chlorox's Cleanup and Ecolab's Oasis products and more susceptible to staining when used with a Drano product.

Results for brass spouts with hexavalent Cr(VI) chrome plating (controls)		
		
Cr(VI) 30 day exposure to Ecolab No effect	**Cr(VI) 30 day exposure to Chlorox Cleanup** Minor plating deterioration	**Cr(VI) 30 day exposure to Drano** Minor staining
Results for brass spouts with sulphate trivalent Cr(III) variations (sealed and unsealed)		
		
Sulphate (sealed) Cr(III) 30 day exposure to Ecolab Significant plating deterioration	**Sulphate (sealed) Cr(III) 30 day exposure to Chlorox Cleanup** Significant plating deterioration	**Sulphate (sealed) Cr(III) 30 day exposure to Drano** Minor staining
		
Sulphate (unsealed) Cr(III) 30 day exposure to Ecolab Significant plating deterioration	**Sulphate (unsealed) Cr(III) 30 day exposure to Chlorox Cleanup** Significant plating deterioration	**Sulphate (unsealed) Cr(III) 30 day exposure to Drano** Significant plating deterioration
Results for brass spouts with chloride trivalent Cr(III) variations (sealed and unsealed)		
		
Chloride (sealed) Cr(III) 30 day exposure to Ecolab Significant plating deterioration	**Chloride (sealed) Cr(III) 30 day exposure to Chlorox Cleanup** Significant plating deterioration	**Chloride (sealed) Cr(III) 30 day exposure to Drano** Significant staining

		
Chloride (unsealed) Cr(III) 30 day exposure to Ecolab Minor plating deterioration	**Chloride (unsealed) Cr(III) 30 day exposure to Chlorox Cleanup** Significant plating deterioration	**Chloride (unsealed) Cr(III) 30 day exposure to Drano** Significant staining

Figure 19: *Results of 30-day chemical immersion tests with Ecolab, Chlorox Cleanup and Drano cleaners*

In summary, the chemical resistance of the two tested coatings using alternative (trivalent) processes clearly failed the chemical resistance requirements, at the current stage of development.

<u>Thermal cycle resistance</u>

Thermal cycle resistance was tested by Fortune Brands on its products made with hexavalent (Cr(VI)) processes and two types of trivalent chromium (Cr(III)) plating. This test consists of subjecting the samples to a series of thermal shock cycles, following the procedure described in the following table:

Test Method:	WI 10-020-0190
Temperature to Reach	-40 (+/- 5) degrees C
Cooling Period	60 minutes
Return to Room Temperature	15 minutes
Warming period at Room Temperature	45 minutes
Warming Temperature	+75 (+/-5) degrees C
Warming Period	60 minutes
Return to Room Temperature	60 minutes
Number of cycles	4

Table 16: *Test Details for thermal cycle test*

When evaluating the test parts, no cracking, crazing or other defects appeared to the naked eye. Further evaluation was completed using a 100x microscope to examine the parts to look for any micro-cracking of the chrome plating layer. Photomicrographs are presented below showing the results.

Hexavalent Chrome **Sulphate Trichrome Cr(III)**

Figure 20*: Thermal cycle test results – Micrograph photo comparing hexavalent and sulphate trivalent chrome processes – no cracks observed*

Chloride Trichrome Cr(III) ---- Thermal cycle test (100X)

BEFORE TEST AFTER TEST

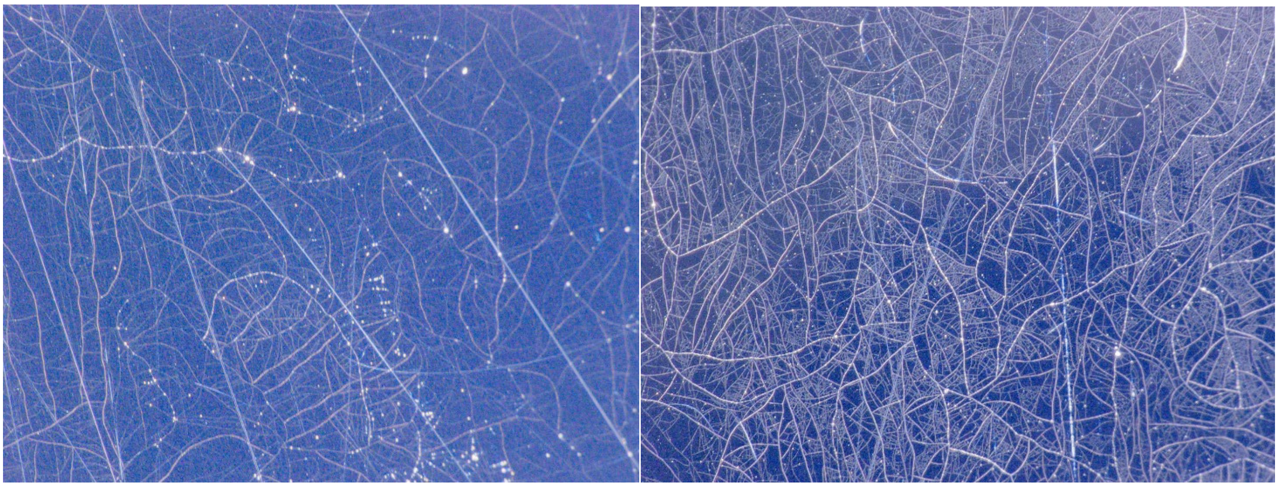


Figure 21*: Thermal cycle test results – Micrograph photo of chloride trivalent chrome processes – cracking observed*

For Figure 21 (showing the results of the testing on the chloride trivalent alternative), the "Before Test" photo shows a micro-cracking pattern demonstrated by the chloride trivalent chromium plating system. The "After Test" photo shows a similar pattern, but with more extensive cracking. Additional investigation into the plating structure of the chloride trivalent chromium system is on-going to determine if there is a relationship between the inherent micro-cracking in this system and the corrosion failures that were reported in earlier sections of this report.

In summary, the thermal cycle resistance of the two tested coatings using alternative, trivalent chrome electroplating was inconclusive, but showed a tendency on the part of one of the trivalent chromium systems (chloride) to be weaker in this testing.

<u>Colour appearance</u>

Fortune Brands has conducted an analysis of colour appearance to describe the differences between products realised with Cr(VI) with respect to products realised with Cr(III). The colour analysis was performed using a "X-Rite Ci62" spectrophotometer. The measurement was performed on three samples to have an average of the measured parameters. The results are expressed as different parameters of the CIELAB colour space where:

- L* describes the brightness, between 0 (black) and 100 (white); and
- b* describes the hue of the colour that varies between yellow (for positive values) and blue (for negative values).

COLOUR COMPARISON - SPECTROPHOTOMETER ANALYSIS (L* vs b*)

Name	L*	b*
CONTROL - Hexavalent Chrome (CrVI)	83.37	0.56
Trivalent Sulphate (CrIII) Trial colour	81.52	3.26
Trivalent Chloride (CrIII) Trial colour	77.07	2.77

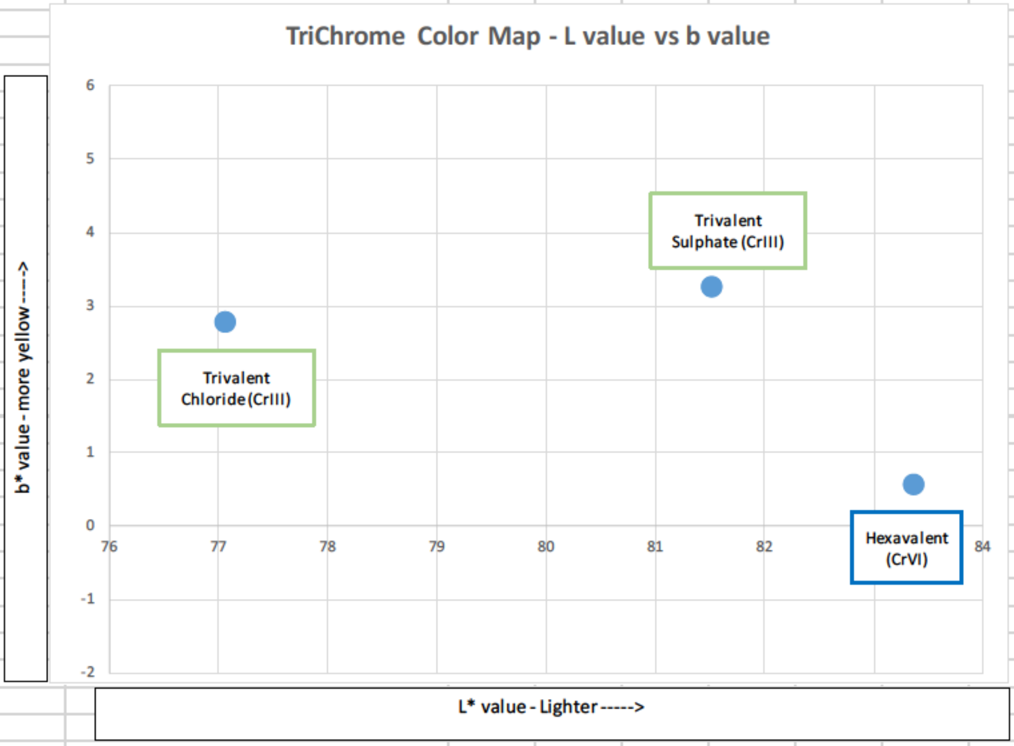


***Figure 22**: Colour comparison test data – colour positions*

The colours of the trivalent chromium samples (for both chemistry types, sulphate and chloride) are significantly different from the hexavalent chrome controls. Significant departures from the control in both the Dark/Light (L*) values and Yellow/Blue (b*) values is readily apparent on the chart and is consistent with visual analysis of the parts when compared in a standardized light booth using both Daylight and Cool White settings.

Conclusions

Significant efforts have been made, and are still on-going, to determine if trivalent chrome (Cr(III)) electroplating is a viable alternative to hexavalent chrome electroplating. Major deficiencies observed in the physical test performance of the trivalent chrome parts demonstrate that it is not currently a suitable alternative to hexavalent chrome electroplating. Furthermore, the significant differences in colour and appearance reinforce the belief that simply switching the electroplating to trivalent chrome processes is not viable at this point in time for sanitary ware. Despite the similarities in terms of the manufacturing process, trivalent chromium plating processes do not currently represent a 'drop-in' alternative to hexavalent chromium plating processes in terms of their technical feasibility.

Table 18 below summarises the results of the testing on the comparison samples against the key functionalities required, using the numerical evaluation criteria set out in Table 17. This shows that products made with hexavalent chromium have a much higher level of technical performance than those made with trivalent chromium and this is also reflected in the longevity of the products.

Number / colour	Explanation
1	Not sufficient – the parameters / assessment criteria do not fulfil the requirements
2	The parameters/assessment criteria fulfilment not yet clear - the process still not defined - further experimental investigations need to be performed
3	Sufficient - the parameters/assessment criteria do fulfil the requirements
4	Same performance/impact/high performance level of the product
5	No data available / not assessed

***Table 17**: Colour-coding approach to summarise the feasibility assessment of alternatives*

Process	Technical key functionalities					
	Corrosion resistance	Abrasion resistance	Adhesion	Chemical resistance	Thermal cycle resistance	Colour and appearance
Hexavalent chromium electroplating	4	3	4	3	4	4
Sulphate trivalent chromium electroplating	1	2	4	1	4	1
Chloride trivalent chromium electroplating	1	2	4	1	3	1

***Table 18**: Results of assessment on technical key functionalities of Fortune Brands WI products made with hexavalent Cr(VI) electroplating process versus the parts made with trivalent chromium Cr(III) electroplating*

The production of sanitary ware using Cr(III)-based electroplating can be achieved but would produce products with significant quality deficiencies compared with Perrin & Rowe's current products based on Cr(VI) technology.

5.1.3. Economic feasibility

A switch to Cr(III)-based electroplating would have significant impacts in terms of capital (development and upgrade) costs and ongoing manufacturing (operating) costs. These costs are considered further in this section. However, due to the significant reduction in quality associated with Cr(III)-based products, Perrin & Rowe would expect the major costs of switching to this alternative to be associated with lower sales revenues and market share.

Despite the technical feasibility issues, there are some potential benefits associated with Cr(III)-based processes compared to Cr(VI)-based processes[15]. The throwing power of Cr(III) plating is generally better, meaning that more parts can be placed on jigs simultaneously increasing throughput on that task by up to 15%. With regard to worker and environmental protection, Cr(III) processes result in fewer air emissions, due to higher cathodic efficiency, which also means that a PFAS mist suppressant is unlikely to be required. In addition, as a typical Cr(III) plating bath has a lower chromium concentration, there is likely to be less total chromium in the wastewater stream and, since the wastewater will contain Cr(III) cations, no reduction step from Cr(VI) to Cr(III) is necessary. This will result in reduced costs for handling and disposal of hazardous waste.

Conversely, as Cr(III) processes involve organic complexing agents and stabilisers, these substances are likely to pose additional complications for wastewater treatment and could prompt additional wastewater treatment measures, such as oxidative destruction of the organic components. In addition, despite the increased throwing power, the benefits of higher throughput are cancelled out entirely by the longer plating duration required for Cr(III) processes. Air emission reduction advantages are desirable but will have little added value in practice because Perrin & Rowe already has worker protection and pollution control measures in place, such as local exhaust ventilation (LEV) and a scrubber.

Capital costs have been estimated at approximately £2 million (excluding development costs). These would be associated not only with wastewater treatment upgrades but also the installation of an entirely new plating line and building extension. Currently there is not enough physical space at Perrin & Rowe's Wolverhampton site to upgrade the existing plating line to accommodate the additional baths required for Cr(III) plating, post-plating passivation and the additional rinsing required. In any event, a new line would be required so that it could operate in parallel with the existing Cr(VI) line to ensure continuous production and allow for a phased transition between Cr(VI) and Cr(III) processes. As there is no other available location to install a new plating line at the Wolverhampton facility, a building extension will be required to create the room to house it.

Table 19 below provides an overview of the upgrades that are likely to be required to the plating line and other equipment to accommodate a change to Cr(III)-based electroplating.

[15] NEWMOA, 2003, p7-9.

Equipment changes	Comments
Cr(III) plating tank	Preventing any influx of Cr(VI) material into the Cr(III) chemistry is necessary for proper operation. This necessitates the use of a completely separate processing tank for the Cr(III) plating process. Also, whereas Cr(VI) plating is rather simplistic in operation, Cr(III) process is considerably more complex and requires considerably more equipment and control in operation. This includes: - Continuous solution agitation and filtration. Filtration requires continuous carbon treatment in addition to particulate removal. This will require technicians to frequently change out both particle filter material and removal and replacement of the activated carbon. This material will need to be disposed of as hazardous waste. - Continuous metallic contaminant removal through an ion exchange system. This system requires technicians to regenerate the IX resins regularly, to remove the metallic contaminants pulled from the process chemistry. The regeneration chemistry will need to be processed through the waste treatment system. - Specialty inert anodes - Rectification.
Dedicated rinse tanks (Cr(III))	Cr(III) will require additional, dedicated rinse tanks.
Post plate passivation	Cr(III) will require the addition of a post-plate electrolytic seal tank. This tank will also require solution agitation, filtration and rectification.
Dedicated rinse tanks (passivation)	Passivation will require additional, dedicated rinse tanks.
Reduction tank	A reduction process tank will be needed to neutralise the residue from the electrolytic passivation process.
Dedicated rinse tanks	Reduction will require additional, dedicated rinse tanks.
Wastewater treatment	Cr(III) may require additional waste water treatment processes to remove organic additives
New dedicated Cr(III) plating line	The current Cr(VI) plating line does not contain enough empty tank space to allow introduction of the above process tanks. This precludes modification of the current Cr(VI) plating line to allow conversion to Cr(III) plating. Instead, a completely new Cr(III) dedicated plating line will need to be constructed and installed. This will also require the requisite production floor space to house this new line, which will require an extension to the existing building at the Wolverhampton site.

***Table 19**: Equipment upgrades required for Cr(III)-based electroplating*

In terms of ongoing costs, research conducted by the CTACSub estimated that the operating costs associated with a Cr(III) process would be up to 30% higher than chromium trioxide electroplating. The cost of the chemicals used for Cr(III)-based processes are higher than for Cr(VI)-based processes. Anodes required for sulphate-based Cr(III) electroplating (inert metal oxide) have a much higher cost than anodes used for Cr(VI)-based electroplating and anodes for chloride-based Cr(III) electroplating (graphite) have reduced usage life and are more fragile, likely requiring more frequent replacement. Substantially more analytical effort must go into maintaining the quality of the electrolyte and minimise quality loss caused by impurities in the bath. Research conducted by the CTACSub suggested that a chromium trioxide electrolyte requires 2 hours analytical control per *week*, while Cr(III) plating baths requires 2 hours analytical control per *day*. There may also be higher costs associated with an increased 'scrap rate' (rejection of parts that fail to meet stringent quality requirements).

Table 20 below provides an estimate of the total investment and recurrent costs associated with transferring to Cr(III)-based electroplating.

Area	Cost item	Estimates
Development costs	R&D pilot plating line	£30,000
	R&D team members, lab technicians, labour cost	Finishing Engineers (4 x FTE) [redacted]
		Lab Technician (1 x FTE) [redacted]
		Finishing Manager (1 x FTE) [redacted]
	Trial component cost (blanks)	£78,400
	Chemistry cost	£18,400
	Processing equipment costs (racks, IX resin, hull cells etc)	£15,300
	Extended field trial cost	£56,720
Cr(III) plating line upgrade costs	New plating line cost	Approx. £961,000
	Building extension cost (to accommodate new plating line)	Approx. £650,000
	Chemistry cost	Approx. £100,000
	Anode cost	Approx. £60,000
	Waste treatment upgrade cost	Approx. £250,000
Ongoing costs	Piece cost increase	Increased operating costs, reported up to 30% with Cr(III), is likely to lead to increased component costs
	Ongoing production labour cost	Broadly similar to existing labour costs
	Waste treatment	No Cr(VI) reduction step needed, reduced sludge generation, however, anticipated issues with organic components
	Analytical	Analysis frequency reported to have increased from 2 hrs per week to 2 hrs per day to maintain proper chemistry control
	Bath maintenance	Filter changes and IX resin regen labour
	Anode replacement	Cr(III) replacement est. 2-3 yrs vs Cr(VI) of around 20 yrs
	Increased chemical makeup / replenishment cost	Cr(III) is around twice that of Cr(VI)
	Part rack density	Approx. 15% increase in part density may be possible
	Plating rate	Cr(III) is around a third of Cr(VI) (the process takes approx. 3 times longer)
	Scrap cost	Scrap rates have been reported as both higher and lower for Cr(III) than Cr(VI). Actual scrap rate analysis will need to be performed during future internal Cr(III) trials for determination.

Area	Cost item	Estimates
	Overheads	These include higher business rates and buildings insurance triggered by the building extension.

***Table 20**: Estimates of the investment and recurrent costs associated with transferring to Cr(III)-based electroplating*

Perrin & Rowe manufactures products with a range of different finishes, including chrome. A range of surface finishes are an important part of the market proposition. Demand for other finishes does exist but chrome is by far the dominant colour. When it comes to chrome finishes, Perrin & Rowe does not currently produce or supply Cr(III)-based products due to the demonstrable quality issues outlined above. Cr(VI)-based products offer better performance and a higher quality aesthetic and which also ensures availability of spares and colour-matching of replacements in a kitchen or bathroom environment. As a result, if Perrin & Rowe were to switch to Cr(III)-based product, it would not expect product sales and market share comparable to its current position. Even if sales volumes could be kept at the same levels, the price Perrin & Rowe could command per product would fall substantially and would be too low to cover production costs. These production costs are heavily associated with traditional, time-served manufacturing processes with an emphasis on hand-made and finely crafted products, aimed at the luxury sector of the market.

As has been demonstrated earlier in this report, the most likely outcome would be that customers would switch either to alternative suppliers in the EU who hold an authorisation for the use of chromium trioxide (or whose application for authorisation has been made but a decision is still pending) or to non-EU suppliers. This would result in an almost total loss of market share to competing Cr(VI)-based imports.

5.1.4. Risk reduction

The alternative Cr(III)-based processes under consideration involve chromium hydroxide sulphate (chromium (III) sulphate) and chromium trichloride (chromium (III) chloride). With reference to Appendix 2, both these substances have workplace exposure limits (WELs) under the Control of Substances Hazardous to Health Regulations 2002 (COSHH) and both are classified as hazardous under CLP although for far fewer hazards. In particular, neither substance is classified for carcinogenicity and mutagenicity. In this way, the move from chromium trioxide to chromium (III) sulphate and chromium (III) chloride can be seen as a move to less hazardous substances.

In addition, a move to trivalent chromium-based processes would likely avoid the use of a PFAS for surface tension adjustment, a further benefit in terms of risk reduction. PFAS are currently being considered for restriction under EU REACH[16] and a regulatory management options analysis (RMOA) is being conducted under UK REACH[17].

Conversely, chromium (III) chloride is classified for skin sensitisation category 1 by EU REACH registrants of the substance. A substance evaluation recently published on the ECHA website for chromium (III) oxide[18] noted that a group assessment is currently under development by the evaluating Member State Competent Authorities under EU REACH for chromium (III) compounds more generally, due to concerns for skin

[16] In particular, the Netherlands and Germany, with support from Norway, Denmark and Sweden are preparing a broad restriction proposal likely to cover many thousands of PFAS and a wide range of uses. They are expected to submit the proposal to ECHA in January 2023.

[17] The UK, Welsh and Scottish Governments have asked HSE and the Environment Agency to prepare a RMOA for PFAS. This RMOA will investigate the risks posed by PFAS and recommend the best approach to protect human health and the environment from any identified risks. This could result in proposals for restriction or other forms of regulatory control in the future.

[18] See https://echa.europa.eu/documents/10162/08bcc9ff-13bc-d854-31ac-ad132898500e

sensitisation. The substance evaluation also identified a data gap for reproductive toxicity and suggested this can be addressed in a grouping approach, recommending that ECHA request further testing (an extended one-generation reproductive toxicity study and a developmental toxicity study). At the time of writing, it is not clear how ECHA might respond to this substance evaluation. It is possible that chromium (III) sulphate and chromium (III) chloride have the potential to meet the criteria of 'equivalent level of concern' under Article 57(f) of REACH due to skin sensitisation although currently no regulatory action is proposed in relation to them.

Recent research has indicated that there is the potential for Cr(VI) generation during the Cr(III) plating process[19]. This is because trivalent chromium may be oxidized by hydrogen peroxide (generated by oxygen reduction or deliberately added to the coating environment), forming hexavalent chromium. The fluorides present in the bath (usually added to accelerate film growth and native oxide dissolution) are thought to be responsible for promoting hydrogen peroxide formation, subsequently oxidizing Cr(III) to Cr(VI).

The manufacturing process for chromium (III) salts most commonly originates from chromite. To obtain the chromium from this mineral, the most widely used method involves an alkaline process which transforms the Cr(III) into water-soluble Cr(VI) in alkaline solution which is then separated[20]. Cr(III) salts can then be prepared by the reduction of sodium dichromate with sulphur dioxide. For chromium (III) sulphate, this reaction can be represented as follows:

$$Na_2Cr_2O_7 + 3\ SO_2 + H_2O \rightarrow Cr_2(SO_4)_3 + 2\ NaOH$$

Here, sodium dichromate would be used as an intermediate and so would not be subject to authorisation under REACH, with the increased focus on risk management measures this gives rise to (although it is possible that it might be handled under strictly controlled conditions if registered as an intermediate). This means that an increased demand for Cr(III) alternatives might result in risk reduction for the users (such as Perrin & Rowe) but would result in increased health risks elsewhere in the supply chain, although it is acknowledged that this might occur outside the UK. Alternative processes for manufacturing Cr(III) salts are available but not feasible for Perrin & Rowe's applications due to the presence of Fe ions in the electrolyte and the unacceptable effects this would have on colour variations in the finished product.

Use of Cr(III)-based processes would also involve use of boric acid at significant concentrations as part of the bath chemistry (see Appendix 3 for further details). Boric acid is classified under CLP as toxic to reproduction category 1B and is itself a substance of very high concern (SVHC) under both UK REACH and EU REACH. It was recommended for inclusion in Annex XIV of EU REACH in the sixth recommendation round. It does not currently appear on the list of substances recommended for inclusion in Annex XIV of UK REACH although in light of its status as a SVHC and the previous recommendation for authorisation made at a time where the UK was part of the EU, this substance cannot be ruled out for future regulatory action under UK REACH.

Whether the use of boric acid for Cr(III)-based electroplating 'adds' to the risks is a matter of some debate, in that boric acid is already used for Cr(VI)-based electroplating. This is not as part of achieving the chromium finish, but as part of earlier processing steps during nickel electroplating (as outlined earlier in this report and with further details given in Appendix 1). However, it is true to say that Cr(III)-based electroplating would increase the quantity of boric acid to be used and, on this basis, would not contribute to overall risk reduction.

[19] Gharbi et al, 2018

[20] Zang et al, 2016.

The passivation step required with Cr(III)-based electroplating requires the use of potassium permanganate. This substance does not currently meet the criteria under Article 57 of REACH to be designated a SVHC but nevertheless is classified for reproductive toxicity (category 2) and environmental toxicity (classified for both acute aquatic toxicity and chronic aquatic toxicity, category 1). A recent assessment of regulatory needs (ARN) by ECHA concluded that there is a need for further EU regulatory risk management[21], suggesting a combination of restriction and authorisation following a potential redesignation of the substance's classification as toxic to reproduction 1B.

Finally, the various additives and complexing agents present in the Cr(III) electrolyte may affect how the wastewater treatment functions and reduce the efficiency of the water treatment. This aspect is not fully understood yet but would require additional investigation prior to the use of these electrolytes.

In summary, while it would appear at present that substitution of Cr(VI)-based electroplating processes with Cr(III)-based electroplating processes would, on balance, lead to an overall reduction in risk, the reduction is not as significant as may be first thought. In addition, it is based on existing knowledge and further investigation through substance evaluation may identify additional concerns surrounding reproductive toxicity and skin sensitisation. Additionally, if substitution were to reduce risks in one part of the supply chain, it would drive them up in another, which does not lead to an overall reduced risk across the supply chain (even if it does for that part of it that is regulated by UK REACH authorisation requirements).

5.1.5. Availability

Cr(III) electroplating technology (in terms of the chemicals and equipment required) is available on the market and, as such, Cr(III) alternatives can be regarded as available.

5.1.6. Conclusions

Significant efforts have been made and are still on-going to determine if trivalent chrome Cr(III) electroplating is a viable alternative to hexavalent chrome Cr(VI) electroplating.

Major deficiencies that have been observed in the physical test performance of the trivalent chrome parts demonstrate that it is not currently a suitable alternative to hexavalent chrome electroplating. Furthermore, the significant differences in colour and appearance reinforce the belief that simply switching the electroplating to a trivalent chrome process is not viable today in the sanitary ware sector and cannot be regarded as a 'drop-in' alternative.

This is important to understand but perhaps not so readily understandable to the layperson; after all, both Cr(VI) and Cr(III) processes result in the deposition of chrome onto a substrate, so it is reasonable to ask what is giving rise to the differences. This is because Cr(VI) and Cr(III) electroplating processes not only utilise different plating chemistries but the metallic layers deposited from each process are different in composition.

Cr(VI) solutions deposit a very consistent metallic layer. The bulk composition of the layer is approximately 90% chromium, with the balance being oxygen. The surface of the chromium naturally converts very quickly to chromium oxide. This creates a very stable coating layer (see Figure 23).

[21] ECHA Assessment of regulatory needs (7 December 2021), available at https://echa.europa.eu/documents/10162/630768d3-fdcd-fe11-7e76-9c2ce137318b

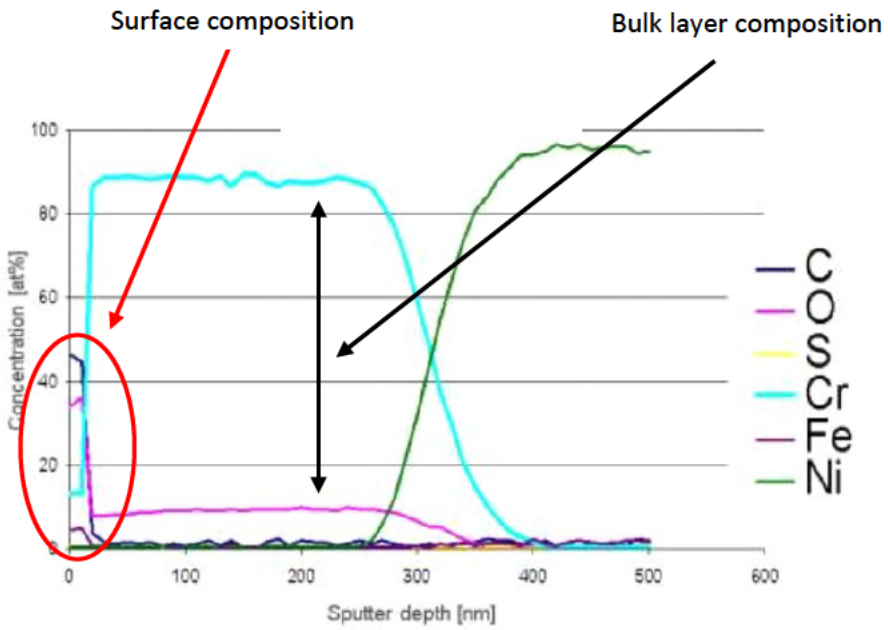


Figure 23*: Hexavalent Chromium Composition*

Cr(III) solutions deposit a metallic alloy rather than simply metallic chromium. The bulk composition of the layer is no longer 90% chromium but is reduced to around 80-83%. Other materials are incorporated into the layer, such as iron, carbon and sulphur. These other components lead to a reduction in the brightness of the metal layer (reduced L* value) and an increase in the yellowness (increased b* value). These components also affect the corrosion resistance and stability of the coating. Unlike Cr(VI), the surface of the metal deposited by Cr(III) does not naturally form a stable oxide film. Figure 24 below shows the mixed alloy composition of both the bulk and the surface. There is a lack of oxygen, and its replacement with Fe, C and S at the surface can lead to potential colour shifts and reduced corrosion resistance.

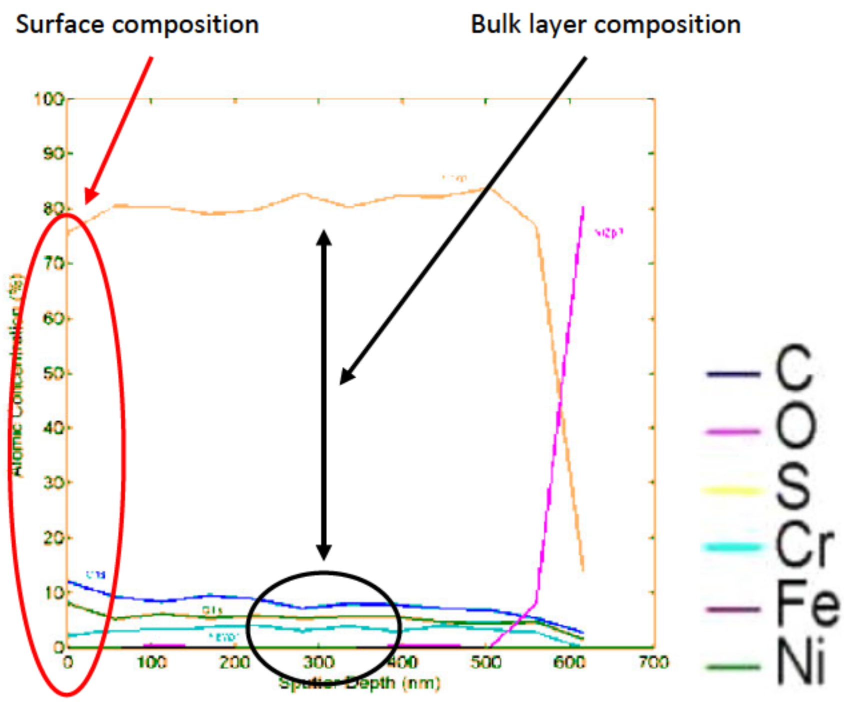


Figure 24*: Trivalent Chromium Composition*

Table 21 below provides information on the resulting chrome layer composition using Cr(VI) and Cr(III) electroplating processes.

Process	Cr	Fe	C	O	S
Cr(VI)	90	-	-	10	-
Cr(III), sulphate based	83	-	6	10	1
Cr(III), chloride based	80	5	9	6	-

Table 21*: Chrome layer composition (average %)*

Based on extensive testing, Perrin & Rowe does not consider trivalent chrome electroplating to be a technically feasible alternative to its current use of chromium trioxide in the production of high-quality sanitary ware. In particular, the corrosion resistance, chemical resistance and colour / appearance of Cr(III) plated parts is not sufficient. A switch to Cr(III) production would entail high costs in terms of capital (development and upgrade) costs, of around £2.3 million (undiscounted) and ongoing manufacturing (operating) costs. Due to the significant reduction in quality associated with Cr(III)-based products, Perrin & Rowe would expect even higher impacts to be associated with lower sales revenues and market share. In addition, there are competing factors in terms of whether there is an overall benefit in terms of risk reduction.

Despite the current failings of Cr(III)-based electroplating, Perrin & Rowe will continue to devote time and resources to further R&D into this potential alternative in an attempt to address the current performance weaknesses. It is hoped that the issues with trivalent chromium-based alternatives can be resolved in the future although at this point in time this is far from clear and not guaranteed.

5.2. Trivalent chromium + lacquer

5.2.1. Substance identity, properties and process description

This alternative involves electroplating with trivalent chromium electrolytes as described in the section above, but with a subsequent additional process step involving the application of a lacquer coating on top of the Cr(III)-based coating. This alternative is being considered to understand whether it would provide a solution to the problems associated with corrosion and chemical resistance identified by the testing undertaken in relation to trivalent chrome electroplating.

The lacquer coating would provide a clear topcoat so as to interfere as little as possible with the colour of the finished product. There are potentially a large number of lacquer coatings that could be selected for these purposes which could involve powder, wet or UV application. Perrin & Rowe has not tested this potential alternative yet nor is aware of any other manufacturers in the sanitary ware sector that uses a trivalent chromium + lacquer solution as proposed, so considerable additional R&D effort would be required to identify, select and test suitable lacquer coating technologies.

For these purposes, a wet lacquer application is considered. This would be applied by spraying the lacquer onto chrome-coated products in a spraybooth, i.e. the operation would be undertaken in a dedicated facility that did not form part of the electroplating line. Ideally an automated process would be selected although it is recognised that this may need to be undertaken manually.

5.2.2. Technical feasibility

From an aesthetic point of view, the application of a lacquer coating on top of the Cr(III) coating is visually less appealing to the customer. Customers have stated that a lacquer coating on top of chromium imparts a "plastic-coated" appearance which they consider to be of lower quality, simply from the changed appearance. This would seriously impact customer acceptance of this alternative. Adjusting the thickness or gloss levels of the coating can have minor improvements but cannot correct the negative appearance. In addition, applying a clear coating as the final coating can greatly reduce the tactile metallic feel of the product. Customers typically perceive this lack of metallic feel with lower quality products, which would be detrimental to a high-end brand.

The corrosion resistance of the Cr(III) could be enhanced by a lacquer top coating. The characteristics of the top coating would need to be closely matched to the Cr(III) coating to be successfully applied.

In the CTAC consultation, test results of lacquer coatings (though in relation to PVD coatings rather than Cr(III)-based coatings) were not consistent. Some of the tested coatings clearly failed the continuous immersion test in household cleaning agents, while other results showed that both continuous immersion tests as well as cleaning agent spray tests with household cleaning agents were passed. In general, the final lacquer defines the functionality of the overall coating and is the reason for the varying test results. No final overall conclusion can be made at this stage, but inconsistent performance is clearly not sufficient and processes with consistent and reproducible performance need to be developed.

The major problem with all lacquer-PVD-lacquer coating systems is that the final lacquer layers are generally not as hard as metallic chrome coatings obtained from chromium trioxide electroplating, and the lower hardness is the reason for the overall failure of the abrasion resistance tests. A lack of abrasion resistance is particularly problematic in the hotel and wider hospitality sector.

The typical lifetime for a FB WI sanitary ware product is often longer than 10 years, which means that long-term quality is a key customer expectation and a core feature of the Perrin & Rowe brand. Combining appearance and tactile issues with reduced abrasion resistance issues indicates that the quality of lacquer coated Cr(III) sanitary ware cannot be guaranteed for the long-term.

The above means that trivalent chromium + lacquer coatings are not sufficiently able to provide all the required functionalities and therefore do not currently represent a technically feasible alternative. However, additional investigation into these alternatives may be warranted in the future.

5.2.3. Economic feasibility

This potential alternative involves applying a lacquer top-coat onto a trivalent chromium-based coating. This means that all the economic feasibility considerations concerning capital expenditure and operational costs outlined in the section above on trivalent chromium-based alternatives also apply to this alternative.

In addition, applying a lacquer top-coat would involve an additional process step after plating. A new spraying line would need to be installed independent of the electroplating line. Perrin & Rowe has not explored the cost of the equipment that would be required with any potential suppliers, although it is estimated that the likely capital cost of installing the lacquer coating technology would be in excess of £400,000, taking into account the need for a coating booth, dryer, positive charge room, extraction system etc. Perrin & Rowe also estimates that it would result in an additional 10-15% increase in component costs.

5.2.4. Risk reduction

As this alternative involves the use of trivalent chrome electroplating before applying a lacquer top-coat, the same considerations as to risk reduction that have already been explored in the context of Cr(III)-based alternatives above also apply here.

In addition, the risks associated with the lacquer technology would need to be considered. There are a wide range of lacquers potentially available and so, at this stage, it is not possible to provide details of any specific types in order to explore the associated hazards and risks. However, lacquers that offer the best performance as regards corrosion, chemical and scratch resistance are likely to contain hazardous substances, including volatile organic compounds.

In particular, two-pack (or "2K") systems that involve the use of a lacquer and a hardener will likely contain isocyanates, which are potent respiratory sensitisers. Isocyanates have been said to be the leading cause of occupational asthma in the western world[22] and it is well-documented that spraying coatings containing isocyanates puts workers undertaking such activities at up to 80 times greater risk of developing asthma[23]. Isocyanates have recently become subject to restriction under UK REACH and, given their classification as respiratory sensitisers, they have the potential to meet the criteria of 'equivalent level of concern' under Article 57(f) of REACH. If the lacquer top-coat needed to be applied manually, this would increase exposure although Perrin & Rowe would try to automate wherever possible to reduce exposure.

5.2.5. Availability

Use of a trivalent chromium + lacquer solution would require substantial R&D effort and does not represent an 'off-the-shelf' technology. A bespoke system would have to be developed. This alternative cannot yet be considered as available.

5.2.6. Conclusions

At this point in time, trivalent chromium + lacquer does not represent a technically or economically feasible alternative. It also does not guarantee risk reduction unless a lacquer can be found that does not involve substances such as isocyanates, which is not guaranteed given that the top-coat would need to exhibit high levels of corrosion and chemical resistance and be hard-wearing. The technology also cannot be considered as being available and significant R&D effort would be required to develop this potential solution further.

5.3. PVD Chromium

5.3.1. Substance identity, properties and process description

Physical vapour deposition (PVD) refers to a variety of vacuum-based processes. The coating material will be in a solid (or rarely in a liquid) form and is placed in a vacuum or low-pressure plasma environment. The coating material is vaporised by an electric arc or electron beam and deposited onto the surface of the substrate in order to build up a thin film. Nitrogen, oxygen or methane are used as gases while argon is used for the formation of the plasma phase[24].

[22] HSE, 2001, p43.
[23] HSE, 2009, p16.
[24] TURI, 2006

Vaporizing of the coating material may be conducted by one of the following methods:

- *Ion-assisted deposition/ion plating*: This is a combined method as a film is deposited on the substrate while ion plating bombards the deposited film with energetic particles. The energetic particles may be the same material as the deposited film, or may be a different inert (argon) or reactive (nitrogen) gas. Ion beam assisted deposition (IBAD) describes a process in a vacuum environment where the ions originate from an ion gun;

- *Sputtering*: This process is a non-thermal vaporization where the surface atoms on the source material are physically ejected from the solid surface by the transfer of momentum from bombarding particles. Typically, the particle is a gaseous ion accelerated from low pressure plasma or from an ion gun;

- *Low temperature arc vapour deposition (LTAVD)*: This is a low temperature PVD-based technique applying metal coatings at ambient temperatures. The parts to be coated are placed in the vacuum chamber and spun around the metallic source of the coating (the cathode). By applying a vacuum to the chamber, a low-voltage arc is created on the metallic source and the metal is evaporated from the arc at temperatures of around 100°C.

Figure 25*: Example of a decorative batch PVD coater utilising the LTAVD process (source: westcoastpvd.com)*

The conditions for PVD coatings are process-specific and dependent on the substrate and applied coating. PVD coating temperatures are typically in the range between 180°C to 450°C, but processes with lower (for example LTAVD) and even higher temperatures are also available. The coating time depends on a number of factors, such as coating thickness, spinning time of the part in the vacuum chamber, and the geometry of the part to be coated. The PVD coating time for metal substrates is typically in the range between 1.5 to 2 hours. In general, the throughput of parts depends on the size of the vacuum chamber and the geometry of the parts.

PVD coatings, which are directly applied on the substrate, require an atomically clean surface because they are highly sensitive to contaminants (e.g. water, oils and paints) on the surface to be coated. Inadequate or non-uniform ion bombardment leads to weak and porous coatings and is the most common failure in PVD coating. In most cases, ion bombardment during coating is responsible for a high internal stress. This stress accelerates with increasing coating thickness and can lead to delamination of the coating. As a consequence, PVD layers are optimally applied with a thickness of about 1-3 µm (in rare cases about 15 µm).

PVD coating materials include titanium nitride, titanium-aluminium nitride, zirconium nitride, chromium nitride, chromium carbide, silicon carbide, titanium carbide, and tungsten carbide.

For these purposes, PVD coating using chromium nitride (CrN) is considered, as this yields a similar colour to that obtained by Cr(VI)-based electroplating. Other coating materials are not considered because these would not yield the same colour as Cr(VI)-based coatings.

5.3.2. Technical feasibility

From an aesthetics perspective, the colour and brightness levels of PVD Chromium is closely compatible to Cr(VI).

PVD coatings, by nature of the physics of the deposition mechanism, have columnar structures. This results in microporosity through the coating layer, which can allow electrolytic corrosive action to proceed below the PVD layer. To prevent this, PVD processes currently in use in the sanitary ware sector utilise a Cr(VI) electroplated layer underneath the PVD layer. The Cr(VI) layer provides the necessary corrosion and chemical resistance for the total coating system.

PVD metal coatings are currently not a stand-alone coating technique and, for the key functionalities such as corrosion resistance and chemical resistance, large technical efforts will be necessary to develop a PVD coating or a coating system potentially able to meet the requirements for high-end sanitary ware which does not rely on a combination of Cr(VI) and PVD. Concerns regarding corrosion resistance are reported in various publications[25] and other similar applications for authorisation under EU REACH, including consultations reported by the CTACSub, where PVD-based processes have been assessed for their potential to act as an alternative for conventional chromium trioxide electroplating. According to the CTAC consultation, coatings tested with different methods have shown that the chemical resistance of PVD-based coatings is highly dependent on the kind of coating and the coating system (including the supporting layer). Currently only a Cr(VI)-based supporting layer can provide this kind of resistance.

The CTACSub also found issues with the abrasion resistance of PVD metal coatings. While the low hardness of the PVD coating is considered not to be the reason for abrasion problems, it is potentially the high layer thickness of the coating that increases internal stress. Comparative tests on PVD chrome with coatings from chromium trioxide (Cr(VI) electroplating showed that PVD chrome with a 0.5µm coating has a strong tendency to damage at the edges under mechanical stress, although the tendency was reported to be much smaller for PVD chrome with a 0.25µm coating.

At the current stage of development, PVD-based metal coatings are not sufficiently able to provide all the required functionalities and therefore do not represent a technically feasible alternative. They are a more promising potential alternative and so additional investigation into these alternatives may be possible in the future.

[25] Müller et al., 2020, p39

5.3.3. Economic feasibility

Given the technical limitations of PVD-based processes, no detailed quantitative analysis of economic feasibility has been conducted. However, indications from the CTACSub consultation stated that the operational costs for PVD-metal coatings (as an additional coating on top of a chromium trioxide electroplated metallic chrome coating) are up to 50% higher compared to electroplating using chromium trioxide. Further factors are that, at the current stage, full automation is not possible and due to the complexity of PVD based systems, maintenance costs would be very high.

In any event, the capital (development and upgrade) costs associated with setting up a PVD-based production line at Perrin & Rowe of an adequate size to guarantee sufficient throughput would be very high and likely prohibitive. Compared to a traditional electroplating line, at least two PVD coating lines would be necessary to realize the same throughput of parts. The CTACSub consultation found that the cost for the installation of one PVD coating line is estimated to be about 1 million Euros (approximately £833,000), resulting in investment costs (only for the PVD coating) of at least 2 million Euros (approximately £1,666,000).

In addition to investment costs, the PVD vacuum chamber must have a sufficient size for the respective parts and accommodate the complexity of the parts. In general, the need of a vacuum chamber limits the size and the type of parts that can be coated. PVD operates on a 'line-of-sight' basis and so is not suitable for complex geometries and larger parts. The complexity and size of the parts to be coated with PVD has to be taken into account when planning the vacuum-based process.

On top of the capital and operating costs, there are the additional costs that would be associated with the expected loss of sales and market share arising from a switch to a product that did not meet all the key technical functionalities and so would be regarded as inferior. As described in relation to Cr(III)-based electroplating alternatives, the availability of Cr(VI) plated products on the market that have been manufactured outside Great Britain means that any reduction in the quality of Perrin & Rowe's products would be met with a switch by customers to imported products. Perrin & Rowe could not attempt to lower its price point to be competitive because of the higher costs associated with running PVD-based processes.

In conclusion, PVD-based metal coating does not represent an economically feasible alternative for Perrin & Rowe at the present time.

5.3.4. Risk reduction

Based on notifications to the classification and labelling inventory under EU CLP, chromium nitride (EC no. 246-016-3) is not regarded as hazardous. In addition, PVD is mainly a closed-system process, reducing the potential for exposure, although exposure to chromium nitride and other chemicals would remain possible during the degreasing phase and during maintenance. This means that moving from chromium trioxide to PVD chromium coating can be seen as a move to less hazardous substances.

However, as has been demonstrated above in relation to Cr(III)-based electroplating alternatives, increased use of CrN would result in higher risks elsewhere in the supply chain. CrN is commonly manufactured via a route using sodium dichromate which again would be used as an intermediate and not subject to authorisation under REACH. As such, the use of CrN does not exclude the use of Cr(VI) compounds in the supply chain and therefore is unlikely to result in an overall reduction in risk within that supply chain, although it is acknowledged that the entire supply chain may not be subject to UK REACH.

5.3.5. Availability

It is not yet clear whether PVD chromium alternatives are sufficiently available. R&D is still ongoing, as PVD-based alternatives do represent a potential alternative to chromium trioxide electroplating at the current stage of development, albeit not as promising as Cr(III)-based electroplating.

In cases where PVD is used in the sanitary ware sector, it is combined with a Cr(VI)-based sub-layer because PVD coatings are not currently capable of being used as a stand-alone technique. In general, the availability of sufficient PVD equipment in the short-term to cover Perrin & Rowe's coating capacity is not guaranteed, as it may be the case that a number of requests would be made at the same time by others in a similar position. In addition, the PVD coating technique is generally limited to smaller parts (dependent on the size of the vacuum chamber) and limited geometries (avoiding complex shapes).

5.3.6. Conclusions

At the current stage of development, PVD chromium does not represent a technically feasible nor economically feasible alternative. While the risks to the user are likely to be reduced by this technology, the risks in the overall supply chain are unlikely to be reduced, and availability of the technology is not yet clear. Significant R&D effort would be required to develop this potential solution further and this is not regarded as a current priority over Cr(III)-based electroplating alternatives.

5.4. 'Managerial' options

The alternatives assessed in this section describe various scenarios that would result in Perrin & Rowe ceasing the use of chromium trioxide in GB by the end of the transition period under UK REACH, but without replacing current electroplating processes with an alternative process / technology.

5.4.1. Description of scenarios

There is currently no suitable 'drop-in' alternative process or technology for chromium trioxide electroplating. Faced with the prospect of having to cease use of chromium trioxide by the end of June 2022, Perrin & Rowe has therefore explored the following alternative options:

- *Option 1: Ending the production of all products that require the use of chromium trioxide*. In this scenario, Perrin & Rowe would cease to manufacture and supply chrome-plated products but would attempt to continue to manufacture and supply products in GB with other finishes.

- *Option 2: Outsourcing production of products that require the use of chromium trioxide*. In this scenario, Perrin & Rowe would continue to supply chrome-plated products, but the company would no longer electroplate the products itself in GB. Instead, electroplating would be outsourced to a third-party based outside the UK and the EEA, given that chromium trioxide is also subject to authorisation under EU REACH. In developing this option, Perrin & Rowe has considered the two following sub-scenarios:

    - *Option 2a*: Manufacture brass components in GB, then send the components to the third party for Cr(VI)-based electroplating, then send back the plated products to be assembled and finished in GB. This is a highly unlikely scenario given the high shipping costs and complexities with logistics, meaning that Option 2b is far more realistic.

- *Option 2b*: Manufacturing and electroplating of brass components is undertaken entirely by the third party and the plated products are sent to Perrin & Rowe to be assembled and finished in GB.

In Options 2a and 2b, it is possible that a range of third parties might be required, depending on the components to be plated and the capacity and capabilities of the third parties involved.

- *Option 3: Relocation of production to enable continued use of chromium trioxide*. In this scenario, Perrin & Rowe would relocate its manufacturing operation (partly or completely) to a non-UK and non-EEA country. This would involve establishing the company in another territory and setting up a new production site.

These options are considered in further detail in the socio-economic analysis (see section 6.3.2).

5.4.2. Technical feasibility

All three options described above are technically feasible, in that there are no specific technical issues that would prevent them from being achieved, although they would be challenging. The activities to be undertaken would involve, depending on the option selected, redundancy of employees, disposal of saleable assets (plant and equipment, inventory and ultimately the site itself), demolition of plant and buildings, disposal of waste, site remediation, new site acquisition and set up. Perrin & Rowe would ensure these steps are taken observing relevant employment and environmental law.

5.4.3. Economic feasibility

Perrin & Rowe has considered and prepared outline plans for each of the three options identified above. However, Perrin & Rowe does not currently outsource production, nor is it established in any country other than the UK. This means there is no simple option to switch production to another facility; it would require many months, if not years, to outsource or relocate chromium plating activities.

The market for sanitary ware is highly diversified and competitive and Perrin & Rowe has limited ability to influence trends for brassware in kitchens and bathrooms. Perrin & Rowe does not expect to be able to offset the loss in chrome-plated products and revenue by continued production of products with different types of finishes. It is therefore expected that Perrin & Rowe would suffer a substantial downturn in turnover and profit relating to loss of production and sales of chrome-plated parts until such time the activity could be fully outsourced. Job losses would be inevitable with any of the scenarios.

In addition, were manufacturing to be outsourced or production moved outside the UK, this would effectively destroy the company's current unique selling proposition. The Perrin & Rowe brand is 'Perrin & Rowe, Mayfair, London' and the Perrin & Rowe promise includes 'a commitment to UK manufacturing'. The brand is strongly associated with being 'Crafted' or 'Made in Britain' and 'Made to last, with quality and integrity'. Perrin & Rowe is recognised as a luxury consumer brand in the US and Australia and recognised as a luxury trade brand in the UK with all marketing efforts internally focused on emerging as a luxury consumer brand. While the value of Perrin & Rowe's market identity as 'the height of British craftmanship' is difficult to measure, it contributes strongly to market appeal in countries such as the US and Australia. It is reasonable to expect that moving manufacturing away from the UK would have a significant negative impact on the brand that would adversely affect future sales and revenue.

Outsourcing or moving production would also create a need to ship a large volume of products back to the UK for sale. Current shipping times mean that products are likely to be in transit for up to 16 weeks, i.e. revenue and profit is effectively tied up over this period, and costs associated with shipping and customs duties would be incurred. Other costs would potentially be associated with damage in transit, quality management issues and warehousing.

For the above reasons, none of the three options would be considered as being a suitable alternative for Perrin & Rowe. Economic feasibility is considered further in the socio-economic analysis (SEA) below, in terms of discussion of the non-use scenario (NUS).

5.4.4. Risk reduction

All of the options above would result in ceasing the use of chromium trioxide in GB with no replacement by alternative processes or technologies. In this sense, these potential alternatives would certainly reduce risks (to zero).

However, if Options 2 or 3 were followed, then this would simply transfer the risk elsewhere. Admittedly this would be to a non-GB location not covered by UK REACH and so therefore not of direct concern to any UK regulatory authority. However, the UK's performance on health and safety ranks favourably across the EU[26] and the EU itself compares favourably to safety standards across the rest of the world[27]. This means that switching production to a non-UK and non-EEA country may well result in poorer standards of worker protection and consequently higher exposure to chromium trioxide by workers and non-workers in the vicinity of the production site, with higher levels of ill-health that could be expected as a result.

5.4.5. Availability

There is no restriction on Perrin & Rowe's ability to cease its use of chromium trioxide after June 2022 in pursuit of one of the above three options and so, in this sense, these alternatives can be considered as available. However, options associated with outsourcing or relocating could not be achieved immediately and there would be a delay of many months, likely years, before supply could recommence.

5.4.6. Conclusions

The managerial options under discussion do not present attractive alternatives to Perrin & Rowe. However, given the lack of any suitable 'drop-in' alternative processes / technologies at the present time, Perrin & Rowe will need to consider one of these options as its chosen alternative for the purposes of the NUS should authorisation not be granted. This is explored further in the SEA.

5.5. Conclusions on shortlisted alternatives

From a technical perspective, none of the alternative technologies or processes can be implemented in the short-term. Any potential alternative must sufficiently fulfil every key functionality to achieve a high-quality surface which is suitable for the conditions of use. These alternatives would also entail high capital and operating costs and so are not currently considered economically feasible. Not all alternatives can be

[26] HSE, 2021.

[27] United Nations Global Compact, 2021, p5.

considered to be available and, for those that are, there is an argument that they might lead to risk reduction in some respects but the arguments are balanced against risks being transferred elsewhere in the supply chain or the introduction of new risks associated with alternatives.

Trivalent chrome-based electroplating is considered to be the most promising alternative but will take many years to develop further. The investigation and testing by Perrin & Rowe / FB WI has shown that Cr(III)-coated products are not currently a technically viable alternative to Cr(VI) electroplating for several reasons. In particular, the appearance of articles produced with Cr(III) present aesthetic problems due to a darker, yellowish / brownish hue of the coating. This can be caused both by iron ions incorporated into the metallic chrome deposition from bath constituents, as well as other impurities entering the Cr(III) process chemistry. This darker, yellower appearance does not meet the high aesthetic standards required by customers. Cr(III) also presents critical problems with regards to corrosion and chemical resistance. The testing did not meet the necessary requirements, showing a generally significantly lower chemical and corrosion resistance than coatings derived from Cr(VI) based electroplating technology. This means that Cr(III) coated parts for sanitary ware do not meet longevity expectations which would be especially problematic with long-term, high-quality, high-use applications, for example in hotels or other hospitality settings.

6. Socio-economic analysis

6.1. Continued use scenario

6.1.1. Summary of substitution activities

If authorisation is granted, Perrin & Rowe will continue existing efforts in searching for a suitable alternative to Cr(VI)-based electroplating. These activities are described in detail in the substitution plan, along with associated timescales, complexities and uncertainties.

6.1.2. Conclusion on suitability of available alternatives in general

Following the judgment of the General Court in the lead chromates pigments case[28], businesses applying for authorisation for the continued use of a substance where there is a suitable alternative generally available (SAGA) are expected to submit a substitution plan. Despite the UK having since left the European Union (EU), the European Union (Withdrawal) Act 2018 provides that relevant cases of the Court of Justice of the European Union (CJEU) form part of retained EU law in the UK. This means that UK courts and tribunals should still refer to pre-exit CJEU case law, unless the senior courts decide to depart from pre-Exit CJEU case law or retained EU law is modified.

Based on Perrin & Rowe's analysis, the current Cr(III) technology is not a SAGA, i.e. not just for the applicant but for all other applicants. This, and all other alternative technologies and processes considered in the AoA, currently fail because they are not technically and economically feasible. Cr(III) plating technology does exist and in one sense could be adopted by any manufacturer – in this sense, it is 'generally available'. However, very few electroplaters do actually use it due to its clear economic and technical deficiencies compared with established customer requirements. In particular, Perrin & Rowe is not aware of any other

[28] EU General Court judgment of 7 March 2019 in Case T-837/16, *Sweden v. Commission*, upheld on appeal in the EU European Court of Justice judgment of 25 February 2021 in Case C-389/19 P, *Commission v. Sweden*

producers of sanitary ware for the luxury end of the market that use Cr(III)-based processes, where customers will more readily notice and move away from inferior alternatives.

The mere existence of an alternative on the market which anyone could use does not indicate that the alternative meets the definition of 'generally available'. There must be some evidence that the alternative is in some sense in general use. This interpretation is supported in law. The concept of SAGA originates from judgement T837-16 of the General Court in 2019 (the lead pigments case). Paragraph 73 of that judgement states, "*As may be inferred from the phrase 'economically and technically viable', the meaning of the word 'suitable' is not limited to the existence of an alternative in abstracto or in laboratory conditions or under conditions which are only of an exceptional nature. The word 'suitable' relates to the 'availability' of alternative substances and technologies which are technically and economically feasible in the European Union*." In other words, for it to be demonstrated that an alternative is technically and economically feasible in GB, it must be in use in GB, and that use must not be exceptional, i.e. it must be reasonably common or widespread. This interpretation is also consistent with the latest ECHA template for compiling an AoA, SEA and SP, where the instructions state that alternatives which are generally available in the EU must be 'used by competitors'.

6.1.3. Substitution plan / R&D plan

As there is currently no SAGA for Cr(VI) in the chrome-plating of sanitary ware in GB (or indeed, across the EU) a substitution plan is not legally required. Nevertheless, Perrin & Rowe has developed a substitution plan because it remains the intention to substitute the use of chromium trioxide with a suitable alternative if possible. Perrin & Rowe will therefore continue to commit time and resources to research and development (R&D) into alternatives. These efforts currently centre on trivalent chromium processes initially, in an attempt to address their current performance weaknesses. It is hoped that the issues with trivalent chromium-based alternatives can be resolved in the future although at this point in time this is far from clear and not guaranteed.

The substitution plan contains details of the R&D and other activities foreseen and their associated timescales, challenges and uncertainties. This plan forms a separate report to this combined AoA-SEA.

6.2. Risks associated with continued use

Chromium trioxide has been identified as a substance of very high concern (SVHC) under Article 57(a) and (b) of REACH and included on Annex XIV of REACH due to its carcinogenicity and mutagenicity. For this reason, the risk associated with continuous use of chromium trioxide focuses on human health. The risk to the environment is not required for the authorisation of chromium trioxide, although releases to and fate in the environment are relevant for the assessment of human exposure via the environment.

The SEA assesses the health impacts attributable to the ongoing use of chromium trioxide in line with the scope of the applied for authorisation (i.e. considering the applied for use and review period). Such impacts are compared to the situation in the non-use scenario (NUS). Impacts beyond the UK are not strictly within the scope of this assessment, though the implications are considered where relevant for context and completeness.

6.2.1. Impacts on humans

The potential health impacts relevant for this application for authorisation are lung cancer and gastrointestinal cancer associated with exposure to chromium trioxide via inhalation and ingestion respectively. The ECHA Risk Assessment Committee (RAC) has discussed these risks in detail and defined the dose-response relationship to be used for the purpose of authorisation in a paper[29] published in 2013. The risk associated with chromium trioxide relates to the hexavalent chromium ion, and the assessment of risk to human health is therefore based on exposure to the hexavalent chromium ion. This document refers to chromium trioxide, hexavalent chromium and chromium (VI). The molecular weight of chromium trioxide is 100g/mol and the molecular weight of the hexavalent chromium ion is 52g/mol.

The assessment considers both workers that could be directly exposed to chromium trioxide in the course of their activities at Perrin & Rowe and the general population, specifically residents and workers in the neighbourhood of the site that, hypothetically, could be indirectly exposed to releases from the site to the local environment.

The number of potentially exposed workers and members of the general population considered for the assessment are summarised in the table below. The number of workers is based on information from Perrin & Rowe. The number of different workers that may be in the scope of this assessment should not be confused with the full time equivalent (FTE) of the number of workers that carry out specific tasks (tasks may be shared between equally trained individuals). Workers that are not directly exposed to trivalent chromium in the course of their activities are considered as part of the local general population for this assessment. The number of potentially indirectly exposed persons is based on default assumptions (discussed below).

Group	Number
Workers at the Wolverhampton site (total)	82
Workers with one or more duties directly involving the plating line at the Wolverhampton site	14
Potentially indirectly exposed local workers and residents (within a 1km radius of the site) (default)	10,000

***Table 22**: Numbers of persons potentially exposed*

For the risk assessment of workers directly exposed, the exposure route of concern is inhalation of dusts and mists or aerosols. Taking a conservative approach in line with the ECHA RAC paper (RAC/27/2013/06 Rev.1), in this assessment all particles inhaled are assumed to be respirable as a worst-case assumption for the risk assessment. Direct ingestion of chromium trioxide is not expected to occur considering workplace hygiene standards in place at the site. Therefore, the assessment of the health impact to workers directly exposed focuses on the risk of lung cancer associated with inhaling chromium (VI) in the course of work activities.

The assessment of health impacts in the general population considers both the risk of lung cancer relating to inhalation of chromium trioxide and the risk of intestinal cancer relating to the ingestion of chromium trioxide that may be released from the facility to the environment. The assessment considers release of chromium trioxide from the site to air and water and associated potential for exposure.

[29] ECHA paper RAC/27/2013/06 Rev.1 *Application for Authorisation: Establishing a Reference Dose Response Relationship for Carcinogenicity of Hexavalent Chromium* (4 December 2013, agreed at RAC -27), available at https://echa.europa.eu/documents/10162/13579/rac_carcinogenicity_dose_response_crvi_en.pdf/facc881f-cf3e-40ac-8339-c9d9c1832c32.

The relevant pathways for this assessment are summarised below:

Group	Inhalation	Ingestion
Workers (directly exposed)	✓	
General population (indirectly exposed)	✓	✓

***Table 23**: Summary of relevant exposure pathways*

The health impact assessment evaluates the risk of developing cancer based on a detailed characterisation of exposure to chromium (VI) and the reference dose-response relationship for the chromium (VI) ion published by RAC (RAC/27/2013/06 Rev.1). The projected health impacts relating to these exposures are then characterised and valued in financial terms based on available guidance and data.

<u>Impacts on workers</u>

Worker exposure in the case of continued use can be derived from data provided in the Chemical Safety Report (CSR). The CSR presents the estimated average exposures, based on measured and/or modelled data that is representative of the various activities (worker contributing scenarios) involving the continued use of chromium trioxide according to the operating conditions and risk management measures described in the exposure scenarios.

The estimated exposure for the worker contributing scenarios (WCS) set out in the CSR is summarised in Table 24. The average exposures presented for each activity are time-weighted over a typical 8-hour period. They account for both duration and frequency of tasks that contribute to exposure in a representative working day. They also take account of respiratory protective equipment consistent with the WCS.

WCS	Activity	Estimated exposure [1] µg/m³	Number of workers exposed [2]
1	Delivery of raw material	7.66E-5	1
2	Storage of raw material	5.94E-04	2
3	Decanting/weighing of raw material to replenish bath	1.06E-03	2
3	Replenishing liquid in bath	1.66E-07	2
4	Sampling of chromium solution in plating tank	7.5E-04	1
5	Operation of plating line	1.00E-01	2
6	Laboratory analysis of samples from plating tank	2.5E-05	1
7	Loading of jigs	1.82E-02	3
7	Unloading of jigs	8.6E-01	2
8	Maintenance	1.5E-02	2
9	Treatment of wastewater	1.6E-04	2
10	Maintenance: cleaning of filter press	2.50E-05	1

Notes:

[1] Estimated exposure as 8 hour-TWA and adjusted for frequency of task and RPE.

[2] Number of workers carrying out this activity on a daily basis.

***Table 24**: Estimated worker exposure for the worker contributing scenarios (WCS)*

As discussed above, the ECHA RAC derived a linear reference dose response relationship which describes the additional (excess) risk, up to the age of 89, of workers dying from lung cancer due to exposure to the chromium (VI) ion in the workplace. This states the excess lifetime lung cancer mortality risk for workers for the purpose of an application for authorisation is 4×10^{-3} per µg Cr(VI)/m^3. According to this model, there is no minimum threshold for effects. It assumes exposure occurs over a 40-year working life (8 hours a day, 5 days a week).

This excess lifetime lung cancer mortality risk for workers value has to be adapted for use in the application for authorisation by factoring for the duration of the requested authorisation (assumed to be 10 years from mid-2022 to mid-2032 inclusive)[30] as opposed to 40 years. The number of working days per year is also adjusted from 5 days per week over 52 weeks (260 days) to the number of working days, as appropriate, for each activity or WCS. The additional risk of a fatal lung cancer for each activity is calculated as the product of this adjusted unit risk value and the exposure per worker carrying out the activity. The additional risk of a fatal lung cancer across the workforce is the sum of these risks across all workers, considering all relevant activities for each worker.

The RAC dose response relationship relates to cancer mortality risk. It does not explicitly consider the excess risk of developing and surviving lung cancer due to exposure to chromium trioxide over the duration of the authorisation. This risk is separately determined considering the excess lifetime lung cancer mortality risk and data on cancer survival from the Office for National Statistics[31]. This indicates the age-standardised five-year and ten-year survival rates for lung cancer in the UK (all people) are 14.7% and 9.5% respectively, meaning the UK fatality rate for lung cancer is 90.5% over 10 years and an additional 0.105 (=9.5/90.5) non-fatal cancer cases typically occur for every fatal cancer case in the UK.

Total worker excess cancer risk	Lifetime	Per year
Additional fatal lung cancer risk	2.01E-03	2.0E-04
Additional non-fatal lung cancer risk	2.11E-04	2.1E-05
Total	**2.2E-03**	**2.2E-04**

Table 25: *Total worker excess cancer risk for review period from mid-2022 to mid-2032*

The valuation of these potential additional fatal and non-fatal cancer cases has been calculated based on values of a statistical life (VSL) and for morbidity due to cancer (VCM) published by ECHA[32] and adjusted from 2012 to the base year (2022) with reference to gross domestic product (GDP) deflator indexes[33] and the current exchange rate[34] for Euro and UK £.

[30] The period used for calculating risk to human health is mid-2022 to mid-2032 whereas the period used for economic impacts is assumed to start from the beginning of 2024.

[31] ONS, 2019.

[32] ECHA, 2016a.

[33] HM Treasury, 2022.

[34] OANDA, accessed 19 May 2022, available from https://www.oanda.com/currency-converter/en

Value	Lower bound EUR 2012	Lower bound [1] EUR 2022	Lower bound [2] UK £ 2022	Upper bound EUR 2012	Upper bound [1] EUR 2022	Upper bound [2] UK £ 2022
Value of statistical life (VSL)	3,500,000	4,165,000	3,540,250	5,000,000	5,950,000	5,057,500
Value of cancer morbidity (VCM)	410,000	487,900	414,715	410,000	487,900	414,715
[1] The 2012 value adjusted by 1.19 based on the UK GDP deflator of 2022 compared to 2012. [2] Exchange rate EUR : GBP 0.85						

***Table 26**: Valuation of potential additional fatal and non-fatal cancer cases*

Lung cancer has a latency period of around 10 years. To account for this, the values (VCL and VCM) are discounted (at a rate of 4% in accordance with ECHA guidance) over a 10-year period[35]. Based on these adjusted values, the value of (avoiding) a fatal cancer is £2.67M to £3.70M and the value of (avoiding) a non-fatal cancer is £0.28M. Applying a lower discount rate of 2% to account for an increased value on health and safety in accordance with improved living standards in the UK since 2012 suggests an upper value of (avoiding) a fatal cancer is £4.49M and an upper range value of (avoiding) a non-fatal cancer of £0.34M.

The health impact cost of continued use (or benefit of a discontinued use) is calculated as the product of the total excess lifetime risk, based on exposure across all workers and activities over the duration of the requested review period, and the adjusted value of one additional lung cancer case, considering both fatality and survival outcomes and rates. Thus, the starting point for the valuation for lung cancer is lung cancer fatality. This is adjusted to include for the associated cost of non-fatal lung cancer based on UK survival rates.

The monetised health impacts for workers potentially exposed to chromium trioxide are summarised in Table 27.

	Lower bound * UK £	Upper bound ** UK £
Lung cancer [fatal and non-fatal] between mid-2022 and mid-2032 (10 years)	5,4245	9,086
Notes: * 4% discount rate ** 2% discount rate		

***Table 27**: Summary of monetised health impacts for potentially exposed workers*

<u>Impacts on the general population</u>

Releases of chromium trioxide to the environment from the Wolverhampton facility are limited. Wastewater is treated by reduction of hexavalent chromium to trivalent form prior to release to the public sewer, from where the treated wastewater is transferred to the municipal wastewater (sewage) treatment works (STP) operated by Severn Trent Water. Colorimetric testing of the treated wastewater on site indicates complete reduction of hexavalent chromium via the on-site chemical wastewater treatment process. The wastewater finally released to the environment from the STP is substantially diluted. Discharges of hexavalent chromium to surface waters are therefore, at worst, negligible.

[35] ECHA, 2016a, at p41.

Surfactants are used to minimise release of aerosol from the plating tank. Air immediately above the chromium plating bath is extracted and discharged via a roof stack. Measurements of hexavalent chromium in the air discharged from the stack have been used to predict environmental concentrations (e.g. concentrations in air 100m from the site and in the food chain) and are presented in the Chemical Safety Report.

Environmental parameter	Predicted concentration
Predicted concentration in air 100m from the stack	1.39E-09 mg/m^3
Predicted concentration in surface water	0.00 mg/l
Predicted concentration in regional air	0.00 mg/m^3
Predicted concentration in regional water	0.00 mg/l
Predicted uptake man via the environment	1.24E-08 mg/kg.bw/day

***Table 28**: Summary of predicted environmental concentrations relating to releases from the site*

Based on treated wastewater measurements at the site, chromium (VI) concentrations in sludge from the STP can be considered negligible.

The risk assessment considers exposure of people living and working locally, in the vicinity of the Wolverhampton site. The default number of local people in the vicinity of any site that may be exposed on a local scale of 10,000 (based on ECHA guidance[36]) is used, given that the site is in an urban area with mixed residential and commercial use.

This local population is assumed to be exposed to the local predicted concentration in air (i.e. the concentration 100m from the point source), calculated as a yearly average in accordance with ECHA guidance[37]. This is a worst-case assumption. Furthermore, due to the location of the site, the potential for chromium (VI) discharged to the air to be deposited on farmland or other land used for food is limited.

Changes in the regional concentration of chromium (VI) in air from releases at the site are not considered in this assessment. Several published reports including the EU risk assessment report (RAR) for chromium trioxide[38] identify chromium (VI) will normally be reduced to trivalent form under environmental conditions and conclude the risk relating to exposure on regional scale is negligible.

As discussed, RAC derived linear reference dose response relationships describe the additional (excess) risk of the general population of fatal lung cancer and of developing intestinal cancer due to exposure to chromium (VI). According to the RAC document, the excess lifetime lung cancer mortality risk for the general population is 2.9×10^{-2} per µg Cr(VI)/m^3 and the excess lifetime intestine cancer risk for the general population is 8×10^{-4} per µg Cr(VI)/kg.bw/day. These values are used in the risk assessment. The dose-response relationships for the general population assumes exposure occurs over a 70-year period (24 hours a day, 7 days a week) and assumes there is no minimum threshold for these health effects.

These excess lifetime risk values are adapted for use in the application for authorisation by factoring for the duration of the review period requested (until mid-2032) as opposed to 70 years. The assessment considers everyone in the general population to be a resident as a worst case, as reliable information regarding the

36 ECHA, 2016b.

37 As above.

38 European Chemicals Bureau, 2005.

number of workers or residents in the neighbourhood is not readily available. As the dose response relationship relates to mortality for lung cancer and incidence for intestinal cancer, the detailed methods for the cost calculations for lung cancer and intestinal cancer differ accordingly.

The approach to calculating fatal and non-fatal lung cancer cases and associated costs is consistent with the approach described for workers.

The age-standardised five-year survival rates for small intestinal cancer in the UK (average of men and women) is 36% meaning the UK fatality rate for intestinal cancer is 64% over 5 years[39] and the latency period is 26 years[40].

The additional risk of developing intestinal cancer is the product of the adjusted unit risk value and the average exposure across the population.

The health impact cost of continued use (or benefit of a non-authorisation) for intestinal cancer is calculated as the product of the total excess lifetime risk, based on exposure across the local population over the duration of the requested review period, and the adjusted value of one additional intestinal cancer case, considering both fatality and survival outcomes and rates.

The valuation of avoided intestinal cancer is thus the sum of the VCM and the fatality rate multiplied by VSL.

The monetised health impacts for the general population in the vicinity of the Wolverhampton site are summarised in tables 29 and 30.

	Lower bound UK £	Upper bound UK £
Lung cancer [fatal & non-fatal]	155	260
Intestinal cancer [fatal & non-fatal]	11	25
Total for 10 years	167	285

***Table 29**: Summary of monetised health impacts for general population over 10 years to mid-2032*

	Lower bound UK £	Upper bound UK £
Lung cancer [fatal & non-fatal]	16	26
Intestinal cancer [fatal & non-fatal]	1	2.5
Total per year	17	28.5

***Table 30**: Summary of monetised health impacts for general population per annum*

[39] Cancer Research UK, based on a 2000 to 2007 dataset, available at https://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/small-intestine-cancer/survival

[40] Nadler, D.L. and Zurbenko, I.G., 2014.

6.2.2. Compilation of human health and environmental impacts

This section calculates the risk to human health relating to continued use at the Wolverhampton facility. The table below summarises the findings of the assessment of the impact to human health of continued use of chromium trioxide at the facility for 10 years, from the point of submission of the application for authorisation to mid-2032.

	Excess lifetime cancer risk[1]	Number of exposed people	Est. statistical cancer cases ([per year[4]] [over 10 years])[5]	Value per statistical cancer case (2022) GB £	Monetised excess risk ([per year[4]] [over 10 years])[5] GB £
Workers					
Directly exposed workers [2]	2.5E-08 - 8.60E-04	14 [6]	2.2E-04/year 2.2E-03 total	2.70M-4.52M	5,424 - 9,086
Indirectly exposed workers [3]	See below	See below	See below	See below	See below
General population					
Local	5.76E-09 lung 1.46E-09 intestinal	10,000 including indirectly exposed workers	5.76E-05 lung 1.46E-05 intestinal	2.70M - 4.52M lung 0.77M - 1.71M intestinal	166 - 285
Regional	0	0	0	-	0
Total					**5,591 - 9,372**

Notes:

Latency of lung cancer is 10 years and of intestinal cancer is 26 years.

1. Excess risk is estimated over a typical lifetime working exposure (40 years) and via the environment over a typical lifetime exposure (70 years). As excess risks differ depending on the task, the overall minimum and maximum excess risk among of all the tasks carried out by the workers is reported.
2. Directly exposed workers perform tasks described in the worker contributing scenarios, typically characterised by an 8-hour Time Weighted Average (TWA) exposure of a representative worker.
3. Indirectly exposed workers (bystanders) do not use the substance. They have been assessed as part of the general population.
4. Per average year during the time horizon used in the analysis.
5. Derived from the lifetime risk of 40 or 70 years.
6. Total number of workers carrying out one or more tasks on the plating line.

***Table 31**: Summary of additional statistical cancer cases for human health*

	Per year	Over 10 years
Total releases/emissions (in kg per period)	Water: 0kg/year Air: 0.0114kg/year	Water: 0kg Air: 0.1197kg

***Table 32**: Summary of remaining releases to the environment*

The range of values presented predominantly reflects uncertainty in the VSL and the discount rate applied during the assessment.

The impact assessment likely over-estimates exposure considering, for example, the assessment assumes 10,000 people are exposed to calculated chromium (VI) concentrations 100m from the stack. In practice, concentrations will diminish with distance so the average concentration will be far lower. Also, the ECHA dose response relationship assumes no threshold for effects. However, the ETeSS study[41] on which it was based states that "*…the lower the exposure (certainly below 1µg/m^3), the more likely it is that the linear [dose-response] relationship overestimates the cancer risk*". The study further states that "*the risk estimates for … exposures lower than 1 µg Cr(VI)/m^3 might well greatly overestimate the real cancer risks. It is also considered that at progressively lower Cr(VI) air concentrations (from about 0.1 µg/m^3 downwards), cancer risks may be negligible*". The calculated air concentration 100m from the point source is 1.39E-06 µg/m^3 and thus more than 7000 times lower than the concentration at which cancer risks may be negligible. Similarly, the majority of worker exposures are lower than 0.1 µg/m^3.

Finally, it is relevant and important to note that in the event of a refused authorisation, other manufacturers will quickly meet the demand relating to the removal of Perrin & Rowe products from the market based on their own chromium trioxide based plating processes. Therefore, the outcome of a refused authorisation will be the transfer of production and associated risk to one or more competitor facilities, within or beyond the UK.

6.3. Non-use scenario

The non-use scenario (NUS) is defined as what Perrin & Rowe will do, and what will happen more generally, if an authorisation is refused and Perrin & Rowe must stop using chromium trioxide.

6.3.1. Summary of the consequences of non-use

This section aims to summarise what would happen if an authorisation were not granted.

In case the authorisation is not granted, the impacts for Perrin & Rowe will be substantial. Social impacts local to the Wolverhampton site will also be notable, with knock-on impacts expected at Perrin & Rowe's facility in Rainham, Essex. Broadly, impacts to customers might be judged short-term and of limited severity; due to an established and diverse supply base of chrome plated brassware for bathrooms and kitchens, it will be possible to obtain brassware of some description. However, it will result in significant inconvenience to existing Perrin & Rowe customers who will no longer be able to source spares. This will be an issue, for example, in the hospitality sector, especially when Perrin & Rowe products have been selected for use across facilities. As architect and designer luxury aspirations are not easily met and the direct competition to Perrin & Rowe is limited, alternatives from beyond the UK or EU are unlikely to be available. Existing Perrin & Rowe inventory that can no longer be supported with aftercare will need to be repurposed. The impact for the Australia market is particularly significant. Several UK OEMs will need to find alternative suppliers of fittings, likely beyond the UK.

Various competitors to Perrin & Rowe have already secured or are in the process of securing authorisations to continue to use chromium trioxide to produce chrome plated brassware or are not subject to REACH authorisation because chromium plating is carried out outside the UK and EU. Such suppliers will be ready and delighted to rapidly move into any gap in the luxury market for taps and mixers left by Perrin & Rowe.

[41] ETeSS, 2013.

Separately, there will be an impact of a non-authorisation decision on the UK manufacturing and surface plating industry which should not be overlooked.

Impacts at Perrin & Rowe

If the authorisation is refused, chromium plating at the Wolverhampton site will need to stop at the date of the decision (estimated to be the end of 2023). Perrin & Rowe will not be able to produce products plated with chromium trioxide from the Wolverhampton site and has no other facility to produce these parts. Alternative technologies, as they are currently available, would result in unacceptable denigration of product quality and a loss of performance that would not be acceptable to the existing market considering the continued availability of existing competitive products (see section 2.2.5). Switching to an alternative technology at this time would result in a complete loss in market share and likely irreversible damage to the Perrin & Rowe brand. For this reason, substitution with an alternative to chromium trioxide is not a short-term option.

Furthermore, simply ceasing to market chrome products is not a realistic option. Considering the market is highly diversified and competitive, that chrome plated products will continue to be available (discussed below and elsewhere), and that Perrin & Rowe has very limited ability to influence trends for brassware in kitchens and bathrooms, it is not expected that Perrin & Rowe will be able to shift production to different types of finish to offset the loss in chrome products sales or revenue. A much narrower product portfolio than competitors is expected to result in loss of standing and share in the market.

For this reason, Perrin & Rowe would seek to continue to provide chrome plated product until such time acceptable alternatives were available. However, as Perrin & Rowe does not currently operate plating beyond the UK or outsource production, either within or beyond the UK, there is no simple option to transfer production to another facility; it would require many months to identify and implement an alternative arrangement. For example, it is expected to take at least 12 to 16 months to find a suitable supplier and considerably further time to onboard and qualify such a supplier. Even if such planning started in mid-2023, it is expected it would not be possible to start to outsource chromium plating activities before the end of 2025.

It is therefore expected, in this scenario, that Perrin & Rowe would suffer a substantial downturn in turnover and profit relating to loss of production and sales of chrome plated parts from the time of a negative authorisation decision (estimated to be 31 December 2023) until such time the activity could be fully outsourced. The inability to manufacture chromium product in house will directly impact the ability to innovate, launch new products and react to market trends; slower and more expensive time to market means less effective new product launches.

Market share would plummet. Perrin & Rowe would need to pull out of certain markets where the lower volume sales immediately mean costs are not covered. Substantial job losses to stem costs would be inevitable. As such, inevitably ceasing plating will not only impact plating processes but will influence FBHS's strategy for overall operations. Potentially all manufacturing would be moved from the UK, except services related functions.

The financial feasibility of a larger part of the Perrin & Rowe operations in the UK would likely be at risk following a refused authorisation. Chromium trioxide plated brassware accounts for [redacted] (public range 25-50%) of revenue and [redacted] (public range 25-50%) of gross margin (profit) at Perrin & Rowe. [redacted] (public range 50-70%) of Perrin & Rowe's revenue and profit from finished products currently depends directly on chrome plating. There are also a number of ancillary products such as 'roughs' (the internal wall fixtures required for installation) attached to chrome products which would result in additional lost sales. The business may not be able to bear the loss of this income alone over several months. Loss of further sales in the short term due to the reduced product range on offer and additional costs associated with mitigating the situation (e.g. outsourcing) would further exacerbate the situation in the short term. A reduction in sales at this scale in the longer term would almost certainly be unsustainable.

In summary, closure of the chrome plating line at Wolverhampton would be a substantial event for the business and one that cannot be easily mitigated. As a minimum there will be a hiatus while the business assesses options and shifts to adapt, and then a further period to introduce new operating model, if such a model is feasible at all. It is highly improbable that without a means of providing chrome plated parts the operation would be sustainable. It can by no means be ruled out that more substantial impacts, such as closure of the facility, would follow a refused authorisation.

<u>Impacts in the Community</u>
82 people are employed at Perrin & Rowe's Wolverhampton site, 19 of whom have responsibilities directly related to chrome plating activities.

Activities at the Perrin & Rowe facility in Rainham, Essex include design, prototyping, tool making, machining, assembly, logistics and support functions such as sales, customer service, HR, IT and Accounts. 65 people are employed at the Perrin & Rowe facility in Rainham, Essex, 49 of whom work directly with chrome plated products from Wolverhampton as part of their day-to-day activities. A third Perrin & Rowe site at Tamworth produces sanitary ware (ceramics) only and so is not expected to be substantially affected by a non-authorisation decision, although profits relating to brassware sales will be impacted.

In a best-case scenario, Perrin & Rowe estimates redundancies could be limited to 57 out of 147 employees across the Wolverhampton and Rainham sites in the event of a refused authorisation. The likelihood is, as noted elsewhere, that such limited impact at Perrin & Rowe is unsustainable and the entire Wolverhampton site closes, resulting in up to 82 redundancies.

Perrin & Rowe takes on and trains apprentices in brassware manufacture every year. In a best case, fewer such apprentice opportunities would be available. In a worst case, the scheme would stop.

<u>Impacts at Suppliers</u>
Perrin & Rowe purchases brass bar/billet, chemicals and precious metals to support the plating process as well as dedicated components from suppliers across the world. UK suppliers account for 35% of supplies by value. It is expected that a refused authorisation would impact the extended supplier base. Global suppliers will be able to tolerate the loss of Perrin & Rowe as a customer. However, business would be significantly impacted for several small local suppliers for whom Perrin & Rowe represents a significant percentage of turnover.

<u>Impacts at the Customer</u>
Perrin & Rowe supplies to domestic, hospitality and OEM markets. Perrin & Rowe is positioned in the upper end of the luxury segment of the market. It has an estimated 2% share of this luxury market segment in the UK and 1% share in the EU and the rest of the world. It exports approximately [redacted] (public range 50-70%) of its overall production to over 50 countries worldwide.

Perrin & Rowe's competitors in the luxury price segment of the market are in countries including Germany, the Netherlands, Italy and the UK. Many of these competitors in the EU either have their own REACH authorisations (Hansgrohe and Grohe) or applications for authorisation pending (e.g. Dornbracht and Gessi) for the use of chromium trioxide under EU REACH. Other competitors have manufacturing bases outside the UK and EU; their plating activities are not subject to REACH authorisation meaning they can continue to manufacture chromium plated brassware and export to the UK, European and global market in the long term without regulatory impediment. In short, there is a substantial, mature supply base for chromium plated brassware in the UK and global markets.

In case Perrin & Rowe stops manufacturing chromium-plated brassware, the availability of chrome plated parts to the UK market will fundamentally undermine attempts to introduce alternatives with lower technical performance and/or price points. It is expected that existing competitors, most likely with an established manufacturing bases outside the UK (since it must be expected other UK manufacturers would be similarly affected by a refused authorisation), would quickly seek to take over the position left by Perrin & Rowe in this highly desirable and valuable niche market.

The Perrin & Rowe promise includes 'a commitment to UK manufacturing'. The Perrin & Rowe brand is in fact 'Perrin & Rowe, Mayfair, London'. The Perrin & Rowe brand is strongly associated with being 'Crafted' or 'Made in Britain' and 'Made to last, with quality and integrity'. Perrin & Rowe is recognised as a luxury consumer brand in the US and Australia and recognised as a luxury trade brand in the UK with all marketing efforts internally focused on emerging as a luxury consumer brand. While the value of Perrin & Rowe's market identity as 'the height of British craftmanship' is difficult to measure, Perrin & Rowe believes it contributes strongly to market appeal in countries such as the US and Australia. Moving manufacture from the UK would thus have a significant material impact on the brand that would affect revenue. A sharp and significant impact on sales would be expected to accompany a loss in connection to UK manufacturing. It is expected that even on completion of outsourcing of manufacture of chromium products, the Australian market will not be recoverable and at least 20% (internal estimate) sales across all other geographies will be permanently lost.

Perrin & Rowe also supplies to certain OEMs such as [redacted] who market products under their own brand. These OEMs will need to identify alternative suppliers within or beyond the UK.

<u>Impacts for UK Manufacturing Industry</u>
Perrin & Rowe is one of the largest brassware manufacturers of kitchen and bathroom products in the UK, operating from its three UK manufacturing facilities (Wolverhampton, Rainham and Tamworth). Other kitchen and bathroom brassware manufacturers in the UK include Samuel Heath, Pegler, Vado and Bristan. A decision not to support chromium plating in the UK in the sanitary sector may have a substantial impact for UK manufacturing. Indeed, it is the UK Government's ambition to promote and achieve a competitive advantage on the global stage in UK-made, high-end products[42].

Perrin & Rowe is internationally accredited to BS EN ISO 9001, WRAS, National Sanitation Foundation (NSF), International Association of Plumbing & Mechanical Officials (IAPMO), Canadian Standards Association (CSA), Public Utilities Board (PUB), California Department of Health Services (DHS) and Water Quality Association (WQA) Gold Seal. The standards are important in terms of effectively communication information about Perrin & Rowe brand commitment quality to customers.

Perrin & Rowe has invested substantially in the last 3 years to stay at the forefront of engineering relating to domestic and commercial water supply and sanitation, investing £1.3M in new equipment. The business has invested in environmental improvements, including an upgraded effluent management facility (£250K), driving significant reductions in power and water consumption and waste generation.

Perrin & Rowe is committed to maintaining skills and training to ensure that product produced in years to come is as good if not better than the product that is being built today. Some roles that would be impacted by a refused authorisation are very skilled (e.g. polishers) and in demand. Loss of plating for any period would result in a loss of skills from Perrin & Rowe that would be difficult to reverse. Training of individuals with a similar level of skills can take upwards of 2 years.

[42] HM Government, 2022, at p58.

6.3.2. Identification of plausible non-use scenarios

Considering the likely impacts and associated market responses, the most likely non-use scenarios (NUS) are as follows:

A. Ceasing production of chrome plated parts.
B. Outsourcing of chrome plating (or all plating) to third parties.
C. Outsourcing of production of chrome plated parts to third parties.
D. Relocation of Perrin & Rowe manufacturing operations (partly or completely) to outside the UK.

These NUS are explored further below.

A. Ceasing production of chrome plated parts -Shutdown (partly or complete)

In this 'do nothing' scenario, Perrin & Rowe would cease to produce and market chrome plated products immediately. This would result in a substantial loss of revenue and profit considering [redacted] (public range 50-70%) of Perrin & Rowe's revenue and profit from finished products currently depends directly on chrome plating. This may under-estimate the impact. For example, there is one major distributor in Australia and one major distributor in New Zealand. Both customers are expected to cease buying Perrin & Rowe completely if it could not offer complete product ranges.

It might be possible to focus on increasing sales on other product lines slightly in the short term, but Perrin & Rowe will not buck market trends and compensate for the loss in chrome plated product sales. As demonstrated in the Analysis of Alternatives, it will not be possible to replace the chrome plated products with a similar finish and quality for at least 10 years from 2022.

Total fixed costs would have to be spread across a lower volume of non-chrome related parts, resulting in higher product prices that may not be accepted. It is possible that the remaining business would not be viable in this situation, considering not only the loss of revenue and profit but the substantially diminished and compromised product portfolio compared to others in the market. Perrin & Rowe estimates that the fixed cost allocation issue would lead to unit cost increases of approximately [redacted] (public range 10-25%) on remaining products (exacerbating inflationary issues that industry is currently experiencing in raw materials) and which could not be passed on to customers without sacrificing price competitiveness, and thus market share.

Perrin & Rowe will be unable to supply colour matched spares or legacy parts to existing clients going forward.

The Wolverhampton and Rainham facilities would have at least substantially reduced activity once production of chrome plated parts ceased. The partial or complete closure of operations would result in foregone profits due to loss of production and a series of redundancies.

In the long term, not before 2033, assuming Perrin & Rowe can sustain operations and R&D activities and that such ongoing R&D efforts are maintained and successful in the intervening period, it may be possible to introduce a replacement for chrome plate.

B. Outsourcing chrome plating (or all plating) to third parties

In this NUS, Perrin & Rowe would establish external contracts with one or more third parties to carry out chrome plating. This NUS assumes parts to be plated would be shipped to a low cost third party for chrome plating and then shipped back to the UK for finishing, assembly, and distribution. Preliminary assessment indicates that the additional costs associated with shipping the parts to and from the third-party plater are in the region of [redacted] (public range £0.5M to £1M) per annum. The diverse range of products and low batch quantities to be plated mean plating costs would increase, even if the cost base is lower. This would be further to a range of associated costs relating to qualification and accreditation of outsourced processes. Increased supply chain risks also suggest outsourcing chrome plating is a much riskier strategy. Noting the discussion above, the increase in unit cost would not be tolerated by the market. Implications for branding the finished goods as made in the UK will need to be re-evaluated.

Thus, this NUS is not considered further.

C. Outsourcing production of chrome plated parts to third parties

In this NUS, Perrin & Rowe would establish external contracts with one or more third parties to produce and plate chrome plated parts. The chrome plated parts would then be shipped to the UK for finishing, assembly, and distribution. This NUS starts with the assumption that non-plating activities and non-chrome finished product would continue to be manufactured at the existing Perrin & Rowe facility in the UK. However, the detail of the scenario would need to be clarified during detailed planning.

Several significant challenges in this NUS need to be successfully addressed, as discussed below.

Qualified, willing, low-cost suppliers must be identified. Perrin & Rowe has no existing relationship with third party platers so will need to start the process from the beginning. A third-party supplier in Asia might be most cost competitive and avoid concerns regarding future continuity of supply related to REACH authorisation. However, this also presents risks and challenges for supply chain and quality control that need to be managed.

Supplier selection is not straightforward. The large number of SKUs (8,000-9,000) in Perrin & Rowe's portfolio, the range and complexity of the products, the relatively small lot sizes, and the high expectations on quality on all components may affect supplier interest. Selected third-party suppliers must be able to deliver Perrin & Rowe's exacting quality standards, including the various formal management systems and accreditations (e.g. BS EN ISO 9001, WRAS, NSF, IAPMO, CSA, PUB, California DHS and WQA Gold Seal) currently operated by Perrin & Rowe. Further efforts are needed to understand how to deliver high standards of quality assurance. Additional effort will be needed to ensure suppliers maintain compliance, especially given the multiple brass types for different regions, and the increasing amount of regulation being seen within the industry, all of which impacts on the cost, complexity and timescales associated with bringing compliant products to market.

Based on previous experience within FBHS, the cost of outsourced parts is expected to be at least the same as those produced in-house (at a COGS level). All manufacturers are subject to the same commodity price inputs, and whilst labour costs may be lower in some countries they represent a relatively small proportion of the overall product cost and are likely to be offset by increased shipping and compliance costs, and the supplier's own margin.

Clearly there will be substantial additional financial and environmental costs associated with out-sourcing plating. They include:

- Minimum Order Quantities (MOQs) could make the option economically unviable.
- The complexity of Perrin & Rowe's products, relatively small lot sizes and high expectations on performance across a wide range (8,000-9,000) of components may affect minimum unit costs.
- New tools and components will be required. Qualification costs for tools and components are expected to be in the order of [redacted] (public range £1,000-£3,000) per component/tool.
- Additional costs relating to transportation, damage in transit, import duties and customs complications (e.g., clearance, duties).
- Additional costs relating to packaging and logistics.

- Additional warehousing to facilitate extra stock movements and mitigate supply risks. MOQ impact on inventory would require Perrin & Rowe to store parts externally to maintain supply to the market.
- Restructuring of the UK business, including job losses.
- Additional efforts relating to rebranding and marketing.
- Additional environmental impacts, including resource use and wastage (additional packaging, energy required to transport materials to and from plating operation) and, it can be assumed in the near term, CO_2 emissions (transportation).

There will be a significant period of non-operation associated with the NUS because:

- It will take time to identify and contract a supplier.
- It is likely to take several months [redacted] to qualify each component and tooling in accordance with relevant worldwide certification requirements, with 8,000-9,000 components in total. Perrin & Rowe has no prior experience in such an exercise, so it is not clear how it could be expedited. It would need to survey all affected components, determine which international standards applied to each component, and then determine whether a change in the nature of the plating process triggers a requirement to recertify, whether fully or partially, and in which markets. Then Perrin & Rowe would need to establish a well-resourced project team to undertake the recertification(s) in association with one (or more) external agencies.
- Increasing production prior to end of 2023 to build up a stock to bridge a period of non-production in 2024 and 2025 is not possible. Perrin & Rowe does not have the production capacity to build for stock, neither does it have the capacity to house increased inventory. Further, Perrin & Rowe's supplier would not be able to support with this short-lived demand. The bespoke nature of Perrin & Rowe's products means that any inventory is likely to be customer specific, and thus difficult to forecast, running the risk of high value stock write-offs in this scenario.

As noted above, in this NUS Perrin & Rowe will lose control on quality, supply and delivery. Outsourcing represents a major change in Perrin & Rowe's brand and operating model. Outsourcing a major part of the portfolio is particularly relevant given current geopolitical instability and pressure on global supply chains. In a best-case scenario, there will be substantially increased lead times associated with shipping to and from Asia (12 weeks) and work in progress at the supplier (24 weeks). Delays or issues at suppliers or during transit will introduce additional costs and may affect the Perrin & Rowe brand. Container availability is a major issue and container costs have increased 10-fold in the last two years. As noted above, forecasting is challenging in this complex market with multiple stakeholders, with best in class forecast accuracy around the 50% mark. An extended supply chain makes forecasting more complex, leading to increased inventory costs that would lead to increased product price and reduced service, neither of which are acceptable to customers in this market.

The NUS is not consistent with the 'Made in Britain' brand identity and positioning of Perrin & Rowe. Perrin & Rowe may need to re-work the narrative around the brand, and this will involve effort and significant cost. Nonetheless, overall, the response from the market is likely to be negative. Negative market reaction is expected to lead to reduction in customers and orders. This may be particularly significant in markets such as North America and Australia where the brand marketing strategy (Perrin & Rowe describes itself as "The English Tapware Company") is entirely based and predicated on its UK provenance.

The lack of plating volume remaining in the UK may force the decision to outsource plating of all remaining (non-chrome) product, which could affect the availability of lower volume (high margin) finishes such as bronze, aged and satin brass, gold, and satin gold. MOQs at a third-party supplier would likely be greater than required for the expected sales volumes in certain markets, causing a disconnect between input costs and the associated achievable revenues. For example, DZR (dezincified brass) may not be feasible due to MOQ issues even if brand positioning could be mitigated.

As noted approximately 50% to 60% of Perrin & Rowe's revenue and profit from plated products depends directly on the production of chrome parts, so outsourcing may not be a viable long-term option considering the additional costs and risks associated with maintaining business as usual in this scenario. However, this is currently considered the likely NUS in the context of this assessment because the other options are even less tenable.

D. Relocation of Perrin & Rowe manufacturing operations (partly or complete) to outside the UK

In this NUS, Perrin & Rowe would relocate its manufacturing operations beyond the UK and likely beyond the EU until such time an alternative to chromium plating acceptable to the market was available. Partly or wholly relocating operations would involve a substantial increase in capital and operating costs that would be prohibitive in both the short and longer financial perspective.

Relocation options would need to be assessed in detail and relocation planned carefully. Costs associated with relocation would include fitting out and hiring at the new sites, relocation of production assets relevant to both chrome and non-chrome plated parts (it is likely that some older assets would need to be replaced), establishment of required logistics and warehouses, contracting with suppliers, requalification with customers, employee training and quality control. To support sales levels and customer commitments, the duplication of equipment (plating line) would be the most likely outcome.

This NUS directly contradicts the 'Made in Britain' brand identity of Perrin & Rowe. Any option that challenges this key message that products are intrinsically linked to UK Craftmanship and production is likely to lead to significant reduction in customers and ability to operate in the luxury segment of the market.

Following partial relocation, the Wolverhampton and Rainham facilities would have at least substantially reduced activity. The closure of the site comes along with foregone profits due to loss of production and a series of job losses (social impacts).

Taking this together, relocation in / beyond Europe is not considered viable because the costs (expected £10million+) and timescales associated with relocation, including establishing a new facility, closing or partly closing the Wolverhampton facility, and obtaining new certifications and accreditation would be prohibitive. The implications in terms of cost are more severe than outsourcing production of chrome plated parts to third parties. Perhaps even more significantly, this scenario completely invalidates Perrin & Rowe's existing brand, placing the entire business premise at risk.

6.3.3. Conclusion on the most likely non-use scenario

A decision not to authorise the use of chromium trioxide would have direct and indirect impacts. In a worst case, such a refusal could mean Perrin & Rowe is uncompetitive and forced to exit the market entirely in the near or medium term. For the purpose of this application for authorisation, it is assumed that this is not the case, and that the temporary outsourcing of a substantial proportion of Perrin & Rowe's manufacturing process to a low-cost base will enable Perrin & Rowe to continue to operate until such time (estimated mid-2032) as a viable alternative to chrome plated product acceptable to the market can be implemented.

It is not possible for Perrin & Rowe to identify the specific course of action that would be taken in an attempt to mitigate the impact of such a decision or to precisely value these impacts (with or without such mitigating actions). The NUS has therefore been selected from all identified options by discounting those scenarios that are most clearly not feasible on economic grounds.

In summary, in the event of a refused authorisation, Perrin & Rowe would not be able to offer the range of products and performance demanded by the luxury market if it ceased to offer chrome plated products to the market. It would be uncompetitive while competitors from beyond the UK continue to provide chrome plated product of the quality demanded by the market, and market share would quickly collapse. For this reason, option A must be ruled out. The cost, timeframe and market challenges of relocating chrome plating alone (Option B) or of relocating the business entirely (Option D) are prohibitive. In the case of Option B, the substantial added costs associated with shipping parts to and from a third party with a low-cost base would render the business unprofitable and is not feasible. Similarly, relocating the entire business to a non-UK country would be extremely costly at the same time as obliterating the current business proposition and is not viable.

For this reason and for the purpose of this application for authorisation, the non-use scenario involving outsourcing production and plating of chrome parts to a third party with a low-cost base is considered the NUS that Perrin & Rowe would most likely seek to pursue, recognising that Perrin & Rowe has a low confidence that this option would allow the business to continue competitively, even in the short term.

It is assumed that the NUS would be reviewed around mid-2023, as needed, following a draft opinion from HSE on authorisation. The process of planning and implementing a project to outsource manufacture and chrome plating of parts is expected to take between 2 and 4 years. In that case the project would not be completed before the end of 2025, and it is unlikely that the project would complete in this timeframe.

Perrin & Rowe has no experience of outsourcing manufacturing operations. FBHS has some recent experience of assessing options to outsource plating operations (covering several separate finishes) of a non-UK business that manufactured taps and mixers for the premium mass market to a lower cost platform. In this scenario, brassware would be shipped from the USA to Asia for plating then returned to the USA. The situation for this premium mass market brand meant that outsourcing plating was feasible. Higher throughput and lower quality requirements offered potential for economy of scale without compromising performance or brand equity. The situation for Perrin & Rowe (taking into account the different nature of its products) is such that the arguments for outsourcing are far less favourable.

While the conclusion of the previous detailed analysis by FBHS cannot be directly applied to Perrin & Rowe, it provides some insights that are relevant when considering options to outsource production. For example, even in the case where outsourcing appeared to present long term cost benefits and manageable issues regarding quality, the outsourcing is estimated to involve non-recoverable costs of £2.5million (US$3million) and over 2.5 years to complete. The impact of supplier minimum order quantities means additional warehousing is needed to smooth supply.

	Other Brand (outsourcing plating)	Perrin & Rowe
Quality requirements	Favourable – premium mass market. Quality requirements less exacting.	Not favourable – luxury bespoke market with exacting quality standards.
Potential for economy of scale	Favourable – high scale of throughput allows better unit costs on production and transportation.	Not favourable – low scale of throughput does not align with outsourcing model.
Additional storage requirement	Not favourable – 12-18 months storage	Not favourable – 6-12 months storage.

***Table 33**: Factors under consideration when evaluating whether to outsource plating*

6.4. Societal costs associated with non-use

This section compares the economic impacts of the applied for use scenario with those for the selected NUS.

Economic impacts are considered from the point at which a refused decision takes effect, as opposed to health effects which are considered from the UK transitional latest application date/sunset date and are discounted to the base year 2022 (date of application for authorisation) at a 4% discount rate a year.

6.4.1. Economic impacts on Perrin & Rowe

The economic impacts to Perrin & Rowe have been evaluated with reference to ECHA's guidance on assessing changes in producer surplus[43]. It aims to assess the net effect of a refused versus granted authorisation considering that losses or gains at Perrin & Rowe may be partially or wholly offset by corresponding losses or gains by, for example, competitors. The aim is thus to disregard impacts that may be offset elsewhere in society from the assessment. However, it is important to recognise that, due to firm-specific conditions and the market environment, in many cases the NUS will result in a direct transfer of economic and health impacts from Perrin & Rowe to competitors. In other words, the activity and associated impacts will simply move to a competitor within or, more likely, beyond the UK.

The Net Present Value (NPV) of the avoided planning efforts and outsourcing costs as well as avoided foregone profits provides a measure of economic impacts if the authorisation is granted and Perrin & Rowe can continue to carry out the applied for use.

In the NUS (i.e. if the authorisation is not granted), operations are outsourced to a low-cost base outside the UK (and EU). Associated profits are shifted from the UK to the new manufacturing operation, resulting in losses for UK economy. Since it will take at least until the end of 2025 to establish outsourcing operations, such losses are taken into consideration for a period of two years.

ECHA's guidance on calculating producer surplus recommends 2 years of profit losses be used for assessing producer surplus losses when suitable alternatives are generally available (SAGA). Under EU REACH, there has been extensive discussion regarding the situation regarding availability of alternatives to chromium trioxide in relation to functional plating with decorative character. Recent opinions by ECHA's RAC and SEAC have concluded suitable alternatives are generally available. This is not an opinion shared by Perrin & Rowe, as demonstrated in the Analysis of Alternatives but, notwithstanding the findings of the Analysis of Alternatives, for this reason lost profits are thus only considered for 2 years in the assessment. However, Perrin & Rowe expects that it will experience significant profit losses for the entire review period. Sales will not return to current levels once outsourcing is complete; Perrin & Rowe will need to recover market share gradually after being absent from the market for 2 years. Further, there will be a significant loss in sales due to loss of Perrin & Rowe's established 'Made in the UK' brand identity.

Costs to Perrin & Rowe considered in the assessment therefore include:

- Profit losses resulting from a period of 2 years (2024 and 2025) without manufacture or sale of chrome plated parts in the event of a refused authorisation. These profit losses would be avoided in the event of a granted authorisation.

[43] ECHA paper *SEAC's approach to assessing changes in producer surplus* (September 2021, agreed at SEAC-52), available from https://echa.europa.eu/documents/10162/0/afa_seac_surplus-loss_seac-52_en.pdf

- Costs associated with planning and implementing a project to outsource production of chrome plated parts over a 2.5-year period (mid-2023 to 2025) in the event of a refused authorisation. These profit losses would be avoided in the event of a granted authorisation.

Gross margin is used as a proxy for EBITDA in this analysis because Perrin & Rowe's EBITDA includes costs associated with the supply of product to its US parent, the full sales value of which appears in its parent company's accounts. Any change in gross margin will flow straight through to EBITDA so that change in gross margin is a reliable proxy for change in EBITDA.

The annual gross margin is forecasted using 2021 values, which is considered a representative year for Perrin & Rowe. 2021 values have been amended according to the 12-month RPI as of January 2022 (5.5%). The assessment considers inflation and growth beyond 2022 of 2% per annum, which is lower than current predictions and which Perrin & Rowe expects to exceed, given the inflationary environment and market growth expectations. The assessment estimates foregone profits lost occurring in the 2-year period from the point of a refused decision (assumed to be the end of 2023) until outsourcing is complete, in line with ECHA guidance. It also accounts for planned growth due to new product development in this period. The forecast costs are adjusted to 2022 based on a 10% discount rate, which is considered conservative and considerably higher than ECHA guidance.

The assessment of profit losses over the 2-year period covering 2024 and 2025 considers two conservative and realistic scenarios:

1. That gross profits are not expected to grow beyond 2022.
2. That gross profits are conservatively expected to grow in real terms (2% per annum).

Units, £million	2021	2024	2025
Profits (gross margin)	[redacted]	[redacted]	[redacted]
Profits (gross margin) NPV [1]	N/A	[redacted]	[redacted]
Total profits (gross margin) NPV [1]	N/A	[redacted]	
Public range	2.5 - 5.0	2.5 - 5.0	2.5 - 5.0
[1] Discounted to 2022 based on 10% discount rate			

***Table 34**: Foregone profits in the event of a refused authorisation for 2 years following the date of a negative decision assuming no growth*

Units, £million	2021	2024	2025
Profits (gross margin)	[redacted]	[redacted]	[redacted]
Profits (gross margin) NPV [1]	N/A	[redacted]	[redacted]
Total profits (gross margin) NPV [1]	N/A	[redacted]	
Public range	2.5 - 5.0	2.5 - 5.0	2.5 - 5.0
[1] Discounted to 2022 based on 10% discount rate			

***Table 35**: Foregone profits in the event of a refused authorisation for 2 years following the date of a negative decision assuming conservative growth*

The expected avoided profits losses in the 2-year period immediately following a refused decision for this scenario amount to [redacted] (public range £5 million to £10 million) in 2022 terms.

A separate assessment considering foregone profits lost occurring in the longer timeframe covered by the review period is provided for reference. In addition to the impacts above, this scenario considers profit losses resulting from the longer period of 8 years (2024 to 2032) in the event of a refused authorisation at the end of 2023. The additional lost profits relate to sales (overall [redacted] (public range 20-40%) of current sales based on loss of the market in Australia and [redacted] (public range 10-25%) across all other geographies) conservatively estimated not to recover following reinstatement of chrome products to the Perrin & Rowe portfolio assuming completion of the outsourcing project by the end of 2025. These profit losses would be avoided in the event of a granted authorisation. Again, the assessment of profit losses over the period from 2024 to 2032 considers two scenarios; one in which no growth occurs in the business beyond 2022 and one in which modest growth (below planned levels) occurs:

1. That gross profits are not expected to grow beyond 2022.
2. That gross profits are conservatively expected to grow in real terms (2% per annum) and will benefit from growth due to planned new product development beyond 2022.

Planned growth due to new product development is not accounted for in the period between 2026 and 2032.

Units, £million	2021	2024	2025	2026	2027	2028	2029	2030	2031	2032
Profits (gross margin)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Profits (gross margin) discounted [1]	N/A	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Public range	2.5-5	2.5-5	2.5-5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5
Total profits (gross margin) [1]	-	[redacted]								
[1] Discounted to 2022 based on 10% discount rate (FBHS)										

***Table 36**: Foregone profits in the event of a refused authorisation until 2032 assuming no growth*

Units, £million	2021	2024	2025	2026	2027	2028	2029	2030	2031	2032
Profits (gross margin)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Profits (gross margin) discounted [1]	N/A	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Public range	2.5-5	2.5-5	2.5-5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.25-1.5
Total profits (gross margin) [1]	-	[redacted]								
[1] Discounted to 2022 based on 10% discount rate (FBHS)										

***Table 37**: Foregone profits in the event of a refused authorisation until 2032 assuming conservative growth*

On top of the foregone profits due to lost sales, the planning and outsourcing efforts involve additional one-off and annual costs. These one-time costs include:

- **Costs associated with project management and delivery** – based on experience within FBHS, it is expected 5 site visits to visit potential / selected third party suppliers, each involving 10 senior team members, will be required. A cost of £0.75M for these visits is estimated. It will also be necessary to retain professional services including local consultancy services (assumed day rate of £600 over an 18-month period) and legal support (assumed day rate of £2000 for 50 days) at a total estimated cost of £0.32M. These project management costs will be recognised between mid-2023 and end-2025.
- **Costs associated with developing and training the outsourced supplier** – Perrin & Rowe will need to provide samples to the selected suppliers to support product development and quality management. The cost of providing samples to the outsourced supplier is estimated to be £0.025M.
- **Costs associated with product certification** – 8,000 to 9,000 (8,500 as average) components (SKUs) will need to be recertified at the outsourced manufacturer. Recertification requires testing and listing of the component as well as in-person audit. The process is expected to required 3-months per component and per market. Markets requiring certification include UK, Germany, US and Australia. Based on recent experience, the cost of recertification is £1.8K per unit, although it is assumed that for a project of this scale, a negotiated price would be achieved with a globally recognised company. The overall cost is estimated to be £1.5M based on recent experience within the group. This cost would be recognised in 2024 and 2025.
- **Costs associated with procuring and installing new equipment** – an impact of outsourcing manufacturing inputs is the requirement for additional storage capacity. Perrin & Rowe will need substantial additional storage space (discussed below) to accommodate the increased inventory of outsourced products, and this will need new equipment to operate. A cost of £0.5M for new equipment in the warehouse has been allocated, to be recognised in 2025.

Additional annual costs that will recur for the duration of the outsourcing arrangement include:

- **Annual cost of additional warehousing** – further warehouse facilities will be needed to store and process the outsourced inventory considering the significantly extended lead times in the outsourced model (12 months versus 3 months in the current model). Costs of £1.9M per annum relate to an additional 50,000ft^2 of rented warehouse space and associated utilities based on 2022 rates.
- **Annual cost of additional transportation** – on the assumption that the outsourced product will be manufactured in Asia and transported to the UK, there will be additional shipping costs. It is assumed there will be 50 shipments per annum. Based on 2022 unit costs per shipment an estimated cost of £1.15M per annum for additional shipments will be required.

Several additional annual costs have not been included in the model but are indicative of the additional economic burden at Perrin & Rowe. They include:

- **Increased inventory of stock** – third party suppliers are likely to impose MOQs that will result in an increased inventory of components. Increased working capital (with an associated cash injection) is required to increase inventory due to the expectation of significantly increased lead times. It has not been possible to reliably quantify this cost to the business.
- **Annual cost of marketing** – significant additional efforts will be needed to redress fundamental changes to the brand narrative and associated collateral. It is estimated 10% of the existing annual advertising, sales and marketing budget will be needed, an additional cost of [redacted] (public range £0.25M to £0.5M) per annum.
- **Annual costs associated with managing currency risk** – outsourcing manufacture overseas will require an additional cost of £0.06M per annum relating to increased financing costs associated with foreign exchange hedging of these foreign currency denominated transactions and possibly

also increased bank charges associated with the administration of letters of credit, or other financial risk management processes Perrin & Rowe may need to implement.

- **Annual cost of additional compliance and quality management** – a local facility to ensure quality management will be required at the outsourced supplier. It has been assumed it will be possible to use locally established personnel in the FBHS group for this purpose. There will also be a doubling of costs associated with ongoing control and monitoring of compliance, considering product testing and approvals, at the outsourced supplier. An annual cost of £0.09M is estimated based on experience elsewhere in the FBHS group.

As noted in section 6.3.2, Perrin & Rowe estimates that reallocation of fixed costs in this scenario would result in unit cost increases of approximately [redacted] (public range <25%) on remaining products.

The cost of employment changes (i.e. 57 job losses at Wolverhampton and Rainham and 21 new hires in the warehouse) due to a refused authorisation are discussed as a societal impact in section 6.4.4 below. Costs associated with site closures or equipment redundancy are not considered in the NUS. Costs associated with implementing an alternative are discussed in the Analysis of Alternatives.

6.4.2. Economic impacts on the supply / value chain

In 2021, the expenses for suppliers of chemicals, raw material, energy, logistics and further services in the UK accounted for approximately [redacted] (public range £4 million - £8 million). [redacted] (public range 25%-50%) of overall suppliers are in the UK. In case the authorisation for the application of chromium trioxide is refused, it can be expected that there would be some short-term impacts relating to a loss of custom from Perrin & Rowe. A reduction in purchases from the supply chain in proportion to the percentage share of chrome products which will be outsourced ([redacted]) (public range 25%-50%) is assumed ([redacted]) (public range £1.5M to £2.5M).

These impacts are not considered in the quantitative impact calculations as the scale and term of the effect are difficult to reliably characterise.

6.4.3. Economic impacts on competitors

In case of a refused authorisation, Perrin & Rowe will stop manufacturing chromium plated brassware and implement a plan to outsource this process to a low cost third party. However, this plan will take at least an additional 2 to 3 years to implement. It is expected that in this period existing competitors with an established manufacturing base outside the UK would take over the position left by Perrin & Rowe in the luxury taps and mixers market. The economic impact on competitors is therefore likely to be positive, approximately equal to the value of the lost sales suffered by Perrin & Rowe.

In summary, chrome plating activities would transfer from one party to another. Considering the current location of competitors, the status of individual competitors with regard to the absence of regulatory requirements or existing approvals to carry on using chromium trioxide for chrome plating, and the absence of regulatory restrictions relating to the import of chrome plated parts to the UK market, it is expected that the majority, if not all, the activities would transfer from the UK to suppliers outside the UK. There would be an associated transfer of economic activity, including profit, and, importantly, risk to human health associated with these activities from the UK to the new supplier.

These impacts are not considered in the quantitative impact calculations as they can be considered a transfer of costs. However, it is important to recognise that, given that globally chrome plated products will continue to be available to the UK market, a refused authorisation will simply result in a transfer of existing economic (and health) costs from the UK.

6.4.4. Wider socio-economic impacts

The outsourcing model foreseen in the event that authorisation is refused would force changes in employment at Perrin & Rowe:

- 57 employees across the Wolverhampton and Rainham facilities would lose jobs when chromium plating is no longer carried out at the Wolverhampton site (end of 2023).
- 21 new UK warehouse staff would be recruited and trained (end of 2025/beginning of 2026).
- Additional redundancies cannot be discounted but are not considered in the impact assessment.

Due to requirements for different skills and competencies and the period between making redundancies and hiring warehouse staff, retraining existing production staff to work within the new warehouse is not considered feasible. Therefore, there would be 57 redundancies associated with plating operations and it would be necessary to separately hire warehouse staff, and this employment pattern would remain until an alternative to chromium trioxide could be introduced in the UK.

ECHA[44] and Dubourg[45] set out an approach to valuing the social costs from job losses considering:

- the value of lost output/wages during the period of unemployment;
- the cost of acquiring a new job;
- recruitment and training costs;
- scarring costs relating to compulsory redundancy; and
- the value of leisure time during the period of unemployment.

The ECHA approach and associated UK data from the Dubourg report values the social costs at 1.88 times the annual gross wage including employer taxes and 2.09 times the gross annual salary excluding employer taxes of each worker in the UK. This is lower than the value of 2.7 recommended by ECHA and can therefore be considered conservative.

The net unemployment figure associated with a refused authorisation is 36. This value has been used in the assessment of social costs. This approach underestimates the overall social cost because not all the costs associated with unemployment are offset with the costs associated with employment (not least because there will be a 2-year period between job losses in 2023 and new hires in 2025/2026). It might be reasonable to assume that the net value of lost output/wages and the value of leisure time during a period unemployment is practically offset by a similar period of new employment and even that the cost of acquiring a new job is lower when a new job is created. However, recruitment, training and scarring costs will not be offset. These costs are significant and applicable to all employees suffering job losses. Costs associated with recruitment and training costs equally apply to recruiting into new positions. The knock-on impact on morale within the business is not considered. Therefore, the social cost associated with unemployment will be higher than the value below, following ECHA's method.

Perrin & Rowe salary data (estimated) from 2021 was used to calculate social impacts of unemployment in the NUS. The data was not corrected for inflation to the 2022 base year.

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[44] ECHA paper SEAC/32/2016/04 *The social cost of unemployment* (20 September 2016, agreed at SEAC-32), available at https://echa.europa.eu/documents/10162/17086/seac_unemployment_evaluation_en.pdf

[45] Dubourg, 2016.

	Cost per worker £	Net number of workers unemployed in NUS	Total cost £
Social cost of unemployment	[redacted] * 2.09 = [redacted]	57 – 21 = 36	[redacted]
Public range	40,000-75,000	-	1,440,000-2,700,000

***Table 38**: Social impacts of unemployment in the NUS*

The social cost of unemployment is valued at approximately [redacted] (public range £1.44 million to £2.7 million) in the base year.

6.4.5. Compilation of socio-economic impacts

The socio-economic impacts that are expected from ceasing the use of chromium trioxide at the end of 2023 (compared to the situation of continuing the substance use) are provided in the tables below in monetised terms. Table 39 presents the findings considering a 2-year horizon for lost profits and other related economic impacts for Perrin & Rowe over 2024 and 2025. Table 40 presents the findings considering a 10-year horizon for lost profits and other related economic impacts for Perrin & Rowe to mid-2032.

Description of major impacts	Monetised / quantitatively assessed / qualitatively assessed impacts	
Monetised impacts	**£Million per year [1]**	**£Million over 2 years**
Producer surplus loss due to ceasing the use applied for	[redacted] Public range 2.5 to 5.0	[redacted] Public range 5.0 to 10.0
Relocation or closure costs	Not considered on assumption facility can continue to operate.	
Loss of residual value of capital	Not considered on assumption facility can continue to operate.	
Social cost of unemployment	[redacted] Public range 0.72 to 1.35	[redacted] Public range 1.44 to 2.7
Spill-over impact on surplus of alternative producers	Not considered in this assessment	
Additional one-off costs (project management, certification, new equipment) and additional annual costs (warehousing, transportation)	[redacted] Public range 2.5 to 5.0	[redacted] Public range 5.0 to 10.0
Sum of monetised impacts	[redacted] **Public range 5.7 to 11.4**	[redacted] **Public range 11.4 to 22.7**
Additional quantitatively assessed impacts	Not considered in this assessment	
Additional qualitatively assessed impacts	Not considered in this assessment	
Notes: 1. Per average year during the time horizon used in the analysis		

***Table 39**: Societal costs associated with non-use considering 2-years foregone profits*

Description of major impacts	Monetised / quantitatively assessed / qualitatively assessed impacts	
Monetised impacts	**£Million per year [1]**	**£Million over 10 yrs**
Producer surplus loss due to ceasing the use applied for	[redacted] Public range 0.75 to 1.5	[redacted] Public range 7.5 to 15.0
Relocation or closure costs	Not considered on assumption facility can continue to operate.	
Loss of residual value of capital	Not considered on assumption facility can continue to operate.	
Social cost of unemployment	[redacted] Public range 0.14 to 0.27	[redacted] Public range 1.44 to 2.7
Spill-over impact on surplus of alternative producers	Not considered in this assessment	
Additional one-off costs (project management, certification, new equipment) and additional annual costs (warehousing, transportation)	[redacted] Public range 2.5 to 5	[redacted] Public range 25 to 50
Sum of monetised impacts	[redacted] **Public range 3.4 to 6.7**	[redacted] **Public range 34 to 67**
Additional quantitatively assessed impacts	Not considered in this assessment	
Additional qualitatively assessed impacts	Not considered in this assessment	
Notes: 1. Per average year during the time horizon used in the analysis		

***Table 40**: Societal costs associated with non-use considering 10 years foregone profits*

6.5. Combined impact assessment

The different impacts that are expected from non-authorisation of the use applied for can be compared to the remaining risks associated with the continued use of chromium trioxide. The findings are summarised in the table below, as relevant.

Societal costs of non-use		Risks of continued use	
Monetised impacts (£million)	[redacted] Public range 5.7 to 11.4 [redacted] Public range 11.4 to 22.7	Monetised excess risks to directly and indirectly exposed workers (£million)	0.0005 - 0.0009 per year 0.005 - 0.009 over 10 years
Additional quantitatively assessed impacts	-	Monetised excess risks to the general population (£million)	0.00002 - 0.00003 per year 0.0002 - 0.0003 over 10 years
Qualitatively assessed impacts	See section 6.4	Qualitatively assessed risks	-
Summary of societal costs of non-use	[redacted] Public range 5.7 to 11.4 [redacted] Public range 11.4 to 22.7	**Summary of risks of continued use**	0.0005 - 0.0009 per year 0.005 - 0.009 over 10 years

***Table 41**: Societal costs of non-use and risks of continued use*

6.6. Sensitivity analysis

ECHA Guidance confirms the level of detail and dedicated resources to the assessment of uncertainties should be in proportion to the scope and overall outcome of the SEA. In this case the socio-economic impacts substantially outweigh the expected worst-case health impacts. Furthermore, a conservative approach to the assessment has been taken, whereby health effects were assessed using a conservative approach and calculated over 10 years (covering the entire requested review period), while socio-economic effects were calculated over a 2-year period.

A significant assumption in the SEA is that gross margin was the best available internal indictor of profit available to Perrin & Rowe. EBITDA as calculated in not a good indicator of profit due to the way costs are allocated internally. Change in gross margin is a reliable proxy for change in EBITDA. Gross margin includes some costs that would be excluded from EBITDA. However, overall, the gross margin values presented are considered a reliable proxy for profit and therefore an appropriate parameter for this assessment.

Furthermore, there are such significant other uncertainties in the approach to the SEA, that this assumption is rather insignificant. They include:

- The reference dose response relationship for carcinogenicity of hexavalent chromium, including the assumption of linearity at low dose. This assumption is likely to over-estimate human health risk.
- Assumption of exposure of 10,000 members of the population to estimated concentrations of chromium trioxide in air 100m from the stack at the facility. Most of the population will be much further from the facility. As concentrations of chromium trioxide in air will diminish with distance from the site, this assumption is likely to over-estimate human health risk.

- Uncertainty in and relevance of the values of a statistical life (VSL) and morbidity due to cancer (VCM) published by ECHA.

- Uncertainty in the NUS including substantial and unproven assumptions regarding the implications of difference courses of action following a refused decision.

- Assumptions relating to economic growth are lower than realistic estimates. In particular, the value used to assess foregone profits assumes no growth, or growth of 2% which is substantially less than planned growth. Furthermore, profits in future years are discounted at 10%, which is conservative (e.g. compared with ECHA recommendation of 4%).

- The baseline for the assessment considers foregone profits over a 2-years period, compared with health costs over the requested review period. The estimated foregone profits over 10 years are provided for context and comparison. In both cases, economic costs are far greater than health costs, where both are estimated conservatively, meaning health costs are over-estimated and economic costs are under-estimated.

6.7. Information to support the review period

A review period of 10 years is required. The evidence presented in this combined AoA-SEA supports such a review period as it demonstrates that:

- There is currently no suitable alternative generally available (SAGA) to the use of chromium trioxide in electroplating of sanitary ware to create a long-lasting and durable surface which meets aesthetic requirements.

- Like many others, Perrin & Rowe has been seeking viable alternatives to Cr(VI)-based electroplating for some time but, so far, no alternative provides the same performance levels and there is no clear prospect of their deficiencies being addressed in the foreseeable future. In addition, current candidate alternatives to Cr(VI)-based plating would add significantly to investment and production costs, a situation which is unlikely to change in the next decade because Cr(III)-based alternative technologies (as demonstrated in the AoA) are unlikely to bring any change in these respects.

- Products made with alternatives to chromium trioxide would require specific approval under other legislative areas (the Water Fittings Regulations and the Water Quality Regulations) in order to ensure they can be used safely.

- All of Perrin & Rowe's competitors supply Cr(VI)-plated products as the majority of their business. As shown in Table 6, the majority of these competitors either have authorisation or have applied for authorisation under EU REACH for the continued use of chromium trioxide or, for UK-based competitors, can be expected to apply by the end of the UK REACH transitional latest application date / sunset date. The applications under EU REACH have so far been granted or received positive opinions from RAC and SEAC. This means that the use of chromium trioxide for electroplating of sanitary ware will continue in the EU well beyond 2030. In addition, Cr(VI)-based sanitary ware remains widely available for import from the rest of the world where the use of chromium trioxide is not subject to comparable regulatory controls. This means that any switch to Cr(III)-based electroplating which is not currently comparable to Cr(VI)-based electroplating in terms of its performance would simply mean that any business switching prematurely would lose customers and market share to those firms still supplying higher-quality Cr(VI)-based products.

- If Perrin & Rowe was required to cease its use of chromium trioxide, it would do so by outsourcing production to a non-GB (and non-EU) contractor. This would entail a significant increase in costs associated with managing an external contract, transportation and warehousing to deal with longer supply lead-times. Costs would also be incurred in terms of loss of certification, real and perceived reductions in quality, impacts on the supply chain, marketing and branding issues, and so on. In addition, there would be a significant period of non-operation associated with the NUS.

- Forcing the adoption of a Cr(VI) alternative prematurely will lead to poorer quality products, more waste as products are replaced more quickly, and increased consumption of resources and energy as those extra products are manufactured. From a lifecycle and supply chain perspective, Cr(III) does not reduce risks or improve the environment.

- Perrin & Rowe is known for its emphasis on high-quality, durable bathroom and kitchen products for the luxury sector. Perrin & Rowe's focus is on quality of production, precision engineering and attention to detail, combining modern production methods with time-tested techniques. British craftsmanship is a key aspect of the brand, as is longevity and a unique aesthetic. It is reasonable to conclude that its customers would more readily notice a drop in product quality by virtue of any move to an inferior alternative to Cr(VI)-based plating. In addition, the NUS is not consistent with the 'Made in Britain' brand identity and positioning of Perrin & Rowe.

- The costs of risks to human health from continued use of chromium trioxide are estimated at less than £1,000 per year. This means the remaining risks of continued use are 'low' and, by comparison, the socio-economic benefits are 'high', a situation which is unlikely to change in the next decade. The application therefore meets the criteria for a 'long' review period, as per RAC/SEAC guidance. Perrin & Rowe requests a review period of 10 years. This is comparable with (and indeed shorter than many other) review periods requested by competitor firms in recent applications for authorisation under EU REACH.

If an authorisation is granted, Perrin & Rowe will continue in its efforts to identify and develop an alternative which has comparable performance to Cr(VI)-based plating. R&D efforts have already commenced although are not expected to lead to the development of a suitable alternative that could become available in a shorter review period. A range of substitution activities are set out in the Substitution Plan which accompanies this application for authorisation, together with a suggested timeline and details of the steps involved and their associated complexity and uncertainties.

7. Conclusions

Chromium trioxide is listed in Annex XIV of REACH. Transitional provisions under Article 127GA of UK REACH extend the latest application date and sunset date to 30 June 2022 for Perrin & Rowe, as a GB-based downstream user covered by an AfA further up their supply chain made under EU REACH.

Perrin & Rowe uses chromium trioxide for the electroplating of sanitary ware products, to apply a metallic chrome coating on top of a brass substrate. This is an essential process to ensure that finished products perform optimally under reasonably foreseeable conditions of use and achieve a specific aesthetic appearance to satisfy customer demands and expectations.

This combined AoA-SEA relates to Perrin & Rowe's use of chromium trioxide for electroplating and forms part of the demonstration made in support of the AfA to allow for continued use following the end of the transition period and extended sunset date of 30 June 2022.

Using chromium trioxide in functional chrome plating with decorative character provides many advantages due to the resulting properties of coatings deposited from chromium trioxide during electroplating. Key functionalities include:

- enhanced corrosion protection and chemical resistance of finished products;
- highly desirable aesthetic qualities (a brilliant, mirror-like surface);
- good adhesion performance when used with brass substrates; and
- excellent wear and abrasion resistance.

The AoA has sought to determine whether there are any suitable alternative substances and technologies to the use of chromium trioxide in functional chrome plating with decorative character for sanitary applications, such as taps, showerheads and bathroom and kitchen accessories. In particular, the AoA has considered:

(a) the technical feasibility of alternatives to chromium trioxide;
(b) the economic feasibility of alternatives to chromium trioxide;
(c) whether transferring to alternatives would result in reduced overall risks to human health and the environment; and
(d) whether the alternatives are available to Perrin & Rowe, i.e. whether they would be of sufficient quality and accessible in sufficient quantities.

A range of potential alternatives to chromium trioxide have been considered. The most promising and realistic for future development is electroplating based on trivalent chromium-based solutions (chromium sulphate and chromium chloride). Other potential alternatives considered include processes based on trivalent chromium + lacquer and PVD-chromium. However, all of these alternatives currently fail because they are not technically and economically feasible. In addition, there may be some reduction in risks to human health in GB but these risks would not be reduced in overall terms, as they would simply be transferred to a country other than the UK.

If products had to be manufactured using such alternatives, this would result in a very significant loss of sales and market share, with customers switching to more durable and reliable product that had been manufactured using chromium trioxide, most likely manufactured outside, and imported into, GB.

The majority of the European sanitary ware manufacturing sector has already applied for, and in some cases received, authorisation under EU REACH to continue using Cr(VI) for another 10+ years, due largely to quality problems with the principal alternatives and the time needed to remedy them. Manufacturers outside of the EU are free to use Cr(VI) without similar regulatory controls and already supply a significant proportion of the GB and EU markets. This means that any switch to inferior alternatives to Cr(VI)-based electroplating would result in a loss of customers and market share to those firms still supplying higher-quality Cr(VI)-based products.

In this way, the AoA has provided input to the SEA to help identify the most likely NUS in the event that chromium trioxide can no longer be used by Perrin & Rowe. If Perrin & Rowe's use of chromium trioxide were to cease then its only options are 'managerial' in nature. From those options considered, it is likely that Perrin & Rowe would outsource the manufacture of chrome-plated products to a non-GB (and likely non-EU) third party.

Any outsourcing project would involve significant challenge and substantial additional financial and environmental costs, not least of which would be associated with transporting and importation. Perrin & Rowe would also need to hold significantly greater inventories to protect themselves against longer lead-times and shipping delays. A number of existing jobs would be lost and there would be wider effects on the supply chain.

The costs of risks to human health from continued use of chromium trioxide are estimated at less than £1,000 per year. On the other hand, the societal costs of the NUS are estimated as being [redacted] per year (public range £5.7 million to £11.4 million) or [redacted] over 2 years (public range £11.4 million to £22.7 million), demonstrating that the benefits outweigh the costs by several orders of magnitude. The sensitivity analysis shows that this conclusion is robust to reasonable changes in assumptions. This means the remaining risks of continued use are 'low' and, by comparison, the socio-economic benefits are 'high', a situation which is unlikely to change in the next decade.

Despite the current failings of potential alternatives, Perrin & Rowe commits to continuing to devote time and resources to research and development (R&D) into alternatives. These efforts currently centre on trivalent chromium processes initially, in an attempt to address their current performance weaknesses. It is hoped that the issues with trivalent chromium-based alternatives can be resolved in the future although at this point in time this is far from clear and not guaranteed.

The Substitution Plan considers the steps proposed to switch to a hexavalent chromium-free alternative in more detail. This involves substantial R&D effort for the investigation and qualification of shortlisted alternatives, further detailed investigation of process variables, scale-up of the chosen alternative process to production trials, conducting those trials and gathering feedback, then ultimately transitioning from hexavalent chromium processes to the chosen alternative process. As a result, a review period of 10 years is requested.

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Appendices

Appendix 1: Plating line details

Station	Operation	Process sequence	Process time	Vol (ltrs)	Concentration	Supplier	Product	Make Up	Control Limits Range	Optimum
1	Load / Unload	[redacted]	-	-	-	-	-	-	-	-
2	Hot Air Dryer	[redacted]	-	-	-	-	-	-	-	-
3	Hot D/I Rinse	[redacted]	[redacted]	700	-	-	-	-	-	-
4	C/W Rinse	[redacted]	[redacted]	700	-	-	-	-	-	-
5	C/W Rinse	[redacted]	[redacted]	700	-	-	-	-	-	-
6	Neutraliser	[redacted]	[redacted]	700	[redacted]	[redacted]	[redacted]	[redacted]	-	-
7	Chrome Drag Out	[redacted]	[redacted]	700	-	-	-	-	-	-
8	Chrome Plate	[redacted]	[redacted]	1300	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
9	Soak Cleaner	[redacted]	[redacted]	700	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
10	C/W Rinse	[redacted]	-	700	-	-	-	-	-	-
11	C/W Rinse	[redacted]	-	700	-	-	-	-	-	-
12	Electro Clean	[redacted]	[redacted]	1050	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
13	Acid Dip	[redacted]	[redacted]	700	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
14	C/W Rinse	[redacted]	-	700	-	-	-	-	-	-

15	C/W Rinse	[redacted]	-	700	-	-	-	-	-	-
16	Nickel Strike	[redacted]	[redacted]	1150	[redacted] [redacted]	[redacted] [redacted]	[redacted] [redacted]	[redacted]	[redacted]	[redacted]
17	Not in Use	-	-	700	-	-	-	-	-	-
18	Not in Use	-	-	700	-	-	-	-	-	-
19	Not in Use	-	-	700	-	-	-	-	-	-
20	Not in Use	-	-	700	-	-	-	-	-	-
21	Not in Use	-	-	1070	-	-	-	-	-	-
22	Mild Acid Rinse	[redacted]	-	1070	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	-
23	Sulphuric Etch	-	[redacted]	700	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	-
24	C/W Rinse	-	-	700	-	-	-	-	-	-
25	C/W Rinse	[redacted]	-	700	-	-	-	-	-	-
26	Nickel Drag Out	[redacted]	-	700	-	-	-	[redacted]	[redacted]	[redacted]
27	Nickel Plate 1	[redacted]	[redacted]	1150	[redacted]	[redacted]	-	[redacted]		
28	Nickel Plate 2	[redacted]	[redacted]	1150	[redacted]	[redacted]	-	[redacted]		
29	Nickel Plate 3	[redacted]	[redacted]	1150	[redacted]	[redacted]	-	[redacted]		
30	Nickel Plate 4	[redacted]	[redacted]	1150	[redacted]	[redacted]	-	[redacted]		

Appendix 2: Information on substances used in Cr(III) electroplating alternatives

***Table 42**: Assessed alternative – [redacted] (chloride based)*

Substance	Parameter	Details
Chromium (III) hydroxide sulphate	EC number	914-129-3
	CAS number	12336-95-7
	IUPAC name	Chromium hydroxide sulphate
	Molecular formula	$CrOHSO_4$
	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	>900°C
	Density	1.25 g/cm^3
	Vapour pressure	N/A
	Water solubility	1 000 g/L
	Flash point	N/A
	Hazard classification	Acute Tox 4; H332 (Harmful if inhaled)
	Workplace exposure limits	0.5 mg/m^3 long term exposure limit (8-hr TWA) for Chromium (III) compounds (as Cr)
	Registration details	Registered at 100-1,000 tonnes (full, joint submission) Registration number 01-2120761005-64-XXXX
Chromium (III) chloride	EC number	233-038-3
	CAS number	10025-73-7
	IUPAC name	Chromium trichloride
	Molecular formula	$CrCl_3$
	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	1,150°C
	Density	2.8 g/cm^3
	Vapour pressure	N/A
	Water solubility	585 g/L
	Flash point	N/A
	Hazard classification	Metal Corr. 1; H290 (May be corrosive to metals) Acute Tox. 4; H302 (Harmful if swallowed) Skin Sens. 1; H317 (May cause an allergic skin reaction) Aquatic Chronic 2; H411 (Toxic to aquatic life with long lasting effects)
	Workplace exposure limits	0.5 mg/m^3 long term exposure limit (8-hr TWA) for Chromium (III) compounds (as Cr)

	Registration details	Registered at 100-1,000 tonnes (full, joint submission) Registration number 01-2120065910-58-XXXX
Iron (II) sulphate	EC number	231-753-5
	CAS number	7720-78-7
	IUPAC name	Iron (2+) sulfate
	Molecular formula	$FeSO_4$
	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	>300°C
	Density	Anhydrous 3.7 g/cm^3; Monohydrate 3.0 g/cm^3
	Vapour pressure	N/A
	Water solubility	Anhydrous 228g/L; Monohydrate 295 g/L
	Flash point	N/A
	Hazard classification	Metal Corr. 1; H290 (May be corrosive to metals) Acute Tox. 4; H302 (Harmful if swallowed) Skin Irrit. 2; H315 (Causes skin irritation) Eye Irrit. 2: H319 (Causes serious eye irritation)
	Workplace exposure limits	1 mg/m^3 long term exposure limit (8-hr TWA) for Iron salts (as Fe) 2 mg/m^3 short-term exposure limit (15 min reference period) for Iron salts (as Fe)
	Registration details	Registered at 1,000+ tonnes (full, joint submission) Registration number 01-2119513203-57-XXXX
Sulphuric acid	EC number	231-639-5
	CAS number	7664-93-9
	IUPAC name	Sulfuric acid
	Molecular formula	H_2O_4S
	Physical state at 20°C and 101.3 kPa	Liquid
	Melting point	10.67°C
	Density	1.83 kg/L
	Vapour pressure	6 Pa
	Water solubility	1,000 g/L
	Flash point	N/A
	Hazard classification	Metal Corr. 1; H290 (May be corrosive to metals) Skin Corr. 1A; H314 (Causes severe skin burns and eye damage) Eye Dam. 1; H318 (Causes serious eye damage)
	Workplace exposure limits	0.05 mg/m^3 long term exposure limit (8-hr TWA) for Sulphuric acid (mist)
	Registration details	Registered at 1,000+ tonnes (full, joint submission) Registration number 01-2119458838-20-XXXX

Ammonium hydrogensulphate	EC number	232-265-5
	CAS number	7803-63-6
	IUPAC name	Ammonium hydrogensulphate
	Molecular formula	$H_3N.H_2O_4S$
	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	147°C
	Density	1.78 g/cm^3
	Vapour pressure	N/A
	Water solubility	No data available
	Flash point	N/A
	Hazard classification	Skin Corr. 1B; H314 (Causes severe skin burns and eye damage) Eye Dam. 1; H318 (Causes serious eye damage)
	Workplace exposure limits	N/A
	Registration details	Registered as an intermediate only (joint submission) Registration number 01-2120909710-61-XXXX
Ethanol	EC number	200-578-6
	CAS number	64-17-5
	IUPAC name	Ethanol
	Molecular formula	C_2H_6O
	Physical state at 20°C and 101.3 kPa	Liquid
	Melting point	-114°C
	Density	0.79 g/cm^3
	Vapour pressure	5,726 Pa
	Water solubility	789,000 mg/L
	Flash point	12.85°C
	Hazard classification	Flam. Liq. 2; H225 (Highly flammable liquid and vapour) Eye Irrit. 2; H319 (Causes serious eye irritation) STOT SE 2; H317 (May cause damage to organs)
	Workplace exposure limits	1,920 mg/m^3 (1,000 ppm) long term exposure limit (8-hr TWA)
	Registration details	Registered at 1,000+ tonnes (full, joint submission) Registration number 01-2119457610-43-XXXX
Butanedioic acid, sulfo-, 1,4-dipentyl ester, sodium salt	EC number	213-085-6
	CAS number	922-80-5
	IUPAC name	Sodium;1,4-dioxo-1,4-dipentoxybutane-2-sulfonate
	Molecular formula	$C_{14}H_{26}O_7S.Na$

	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	No data available
	Density	No data available
	Vapour pressure	No data available
	Water solubility	No data available
	Flash point	No data available
	Hazard classification	Skin Irrit. 2; H315 (Causes skin irritation) Eye Irrit. 2: H319 (Causes serious eye irritation)
	Workplace exposure limits	N/A
	Registration details	Not registered
Ammonium chloride	EC number	235-186-4
	CAS number	12125-02-9
	IUPAC name	Ammonium chloride
	Molecular formula	ClH_4N
	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	338°C
	Density	1.527 g/cm^3
	Vapour pressure	1.3 hPa (at 30°C)
	Water solubility	372 g/L
	Flash point	N/A
	Hazard classification	Acute Tox. 4; H302 (Harmful if swallowed) Eye Irrit. 2; H319 (Causes serious eye irritation)
	Workplace exposure limits	10 mg/m^3 long term exposure limit (8-hr TWA) as fume 20 mg/m^3 short-term exposure limit (15 min reference period) as fume
	Registration details	Registered at 1,000+ tonnes (full, joint submission) Registration number 01-2119487950-27-XXXX
Boric acid	EC number	233-139-2
	CAS number	10043-35-3
	IUPAC name	Boric acid
	Molecular formula	H_3BO_3
	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	N/A
	Density	1.489 g/cm^3
	Vapour pressure	N/A

	Water solubility	48.8 g/L
	Flash point	N/A
	Hazard classification	Repr. 1B; H360FD (May damage fertility. May damage the unborn child)
	REACH regulatory status	Appears on the Candidate List of SVHC Recommended for inclusion in Annex XIV (EU REACH only)
	Workplace exposure limits	N/A
	Registration details	Registered at 1,000+ tonnes (full, joint submission) Registration number 01-2119486683-25-XXXX
Formic acid	EC number	200-579-1
	CAS number	64-18-6
	IUPAC name	Formic acid
	Molecular formula	CH_2O_2
	Physical state at 20°C and 101.3 kPa	Liquid
	Melting point	8°C
	Density	1.22 g/cm³
	Vapour pressure	42.71 hPa
	Water solubility	Miscible
	Flash point	49.5°C
	Hazard classification	Flamm. Liq. 3; H226 (Flammable liquid and vapour) Acute Tox. 4; H302 (Harmful if swallowed) Acute Tox. 3; H331 (Toxic if inhaled) Skin Corr. 1A; H314 (Causes severe skin burns and eye damage) Eye Dam. 1; H318 (Causes serious eye damage)
	Workplace exposure limits	9.6 mg/m³ (5 ppm) long term exposure limit (8-hr TWA)
	Registration details	Registered at 1,000+ tonnes (full, joint submission) Registration number 01-2119491174-37-XXXX
Ammonium formate	EC number	208-753-9
	CAS number	540-69-2
	IUPAC name	Ammonium formate
	Molecular formula	$CH_2O_2.H_3N$
	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	116°C
	Density	1.28 g/cm³
	Vapour pressure	N/A
	Water solubility	1,020 g/L

	Flash point	N/A
	Hazard classification	Eye Irrit. 2; H319 (Causes serious eye irritation)
	Workplace exposure limits	N/A
	Registration details	Registered at 1-10 tonnes (full, joint submission) Registration number 01-2120831661-59-XXXX

***Table 43**: Assessed alternative – [redacted] (sulphate based)*

Substance	Parameter	Details
Chromium (III) hydroxide sulphate	EC number	914-129-3
	CAS number	12336-95-7
	IUPAC name	Chromium hydroxide sulphate
	Molecular formula	$CrOHSO_4$
	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	>900°C
	Density	1.25 g/cm^3
	Vapour pressure	N/A
	Water solubility	1 000 g/L
	Flash point	N/A
	Hazard classification	Acute Tox 4; H332 (Harmful if inhaled)
	Workplace exposure limits	0.5 mg/m^3 long term exposure limit (8-hr TWA) for Chromium (III) compounds (as Cr)
	Registration details	Registered at 100-1,000 tonnes (full, joint submission) Registration number 01-2120761005-64-XXXX
Malic acid	EC number	230-022-8
	CAS number	6915-15-7
	IUPAC name	Malic acid
	Molecular formula	$C_4H_6O_5$
	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	131°C
	Density	1.615 g/cm^3
	Vapour pressure	N/A
	Water solubility	647 g/L
	Flash point	N/A

	Hazard classification	Skin Irrit. 2; H315 (Causes skin irritation) Eye Irrit. 2; H319 (Causes serious eye irritation)
	Workplace exposure limits	N/A
	Registration details	Registered at 1,000+ tonnes (full, joint submission) Registration number 01-2119906954-31-XXXX
Boric acid	EC number	233-139-2
	CAS number	10043-35-3
	IUPAC name	Boric acid
	Molecular formula	H_3BO_3
	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	N/A
	Density	1.489 g/cm³
	Vapour pressure	N/A
	Water solubility	48.8 g/L
	Flash point	N/A
	Hazard classification	Repr. 1B; H360FD (May damage fertility. May damage the unborn child)
	REACH regulatory status	Appears on the Candidate List of SVHC Recommended for inclusion in Annex XIV (EU REACH only)
	Workplace exposure limits	N/A
	Registration details	Registered at 1,000+ tonnes (full, joint submission) Registration number 01-2119486683-25-XXXX

***Table 44**: Assessed alternative – Post-plate passivation*

Substance	Parameter	Details
Potassium permanganate	EC number	231-760-3
	CAS number	7722-64-7
	IUPAC name	Potassium permanganate
	Molecular formula	$HMnO_4.K$
	Physical state at 20°C and 101.3 kPa	Solid
	Melting point	240°C
	Density	2.7 g/cm³
	Vapour pressure	N/A
	Water solubility	64 g/L

	Flash point	N/A
	Hazard classification	Oxid. Solid 2; H272 (May intensify fire; oxidiser) Acute Tox. 4; H302 (Harmful if swallowed) Skin Corr. 1C; H318 (Causes serious eye damage) Repr. 2; H361 (Suspected of damaging fertility or the unborn child) STOT RE 2; H373 (May cause damage to organs) Aquatic Acute 1; H400 (Very toxic to aquatic life) Aquatic Chronic 1; H410 (Very toxic to aquatic life with long lasting effects)
	Workplace exposure limits	N/A
	Registration details	Registered at 1,000+ tonnes (full, joint submission) Registration number 01-2119480139-34-XXXX

Appendix 3: Trivalent chromium electroplating process and constituents

***Table 45**: Trivalent chromium electroplating process and constituents*

Process	Product	Constituents	% w/w	CAS No.
[redacted] (chloride based)	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]
[redacted] (suphate based)	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]
Post plate passivation	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]	[redacted]