# ANALYSIS OF ALTERNATIVES

and

# SOCIO-ECONOMIC ANALYSIS

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|---|---|
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| **Submitted by:** | The Surface Engineering Association on behalf of the members of the Surface Engineering Association Chromium Trioxide Authorisation Consortium |
| **Date:** | 21st March 2023 |
| **Substance:** | Chromium Trioxide<br><br>EC: 215-607-8<br>CAS: 1333-82-0 |
| **Use title:** | Use of chromium trioxide for the surface treatment of engineering components, mainly for the aerospace and defence sector, with the purpose of creating a coating to meet specific and critical performance characteristics. |
| **Use number:** | 1 |

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| **ALARP** | As Low As Reasonably Practicable |
| **AoA** | Analysis of Alternatives |
| **CAS** | Chemical Abstracts Service |
| **CETS** | European Committee for Surface Treatments |
| **CORAP** | Community Rolling Action Plan |
| **CTAC** | Chromium Trioxide Authorisation Consortium |
| **ECHA** | European Chemicals Agency |
| **GDP** | Gross Domestic Product |
| **PVD** | Physical Vapour Deposition |
| **RAC** | Risk Assessment Committee |
| **SEA** | Socio-Economic Analysis (or Surface Engineering Association) |
| **SEAC** | Socio-Economic Analysis Committee |
| **SME** | Small & Medium sized Enterprises |
| **SVHC** | Substance of Very High Concern |

# DECLARATION

We, the Applicants, are aware of the fact that further evidence might be requested by HSE / DEFRA to support the information provided in this document.

Also, we request that the information blanked out in the "public version" of the Analysis of Alternatives and Socio-economic Analysis is not disclosed. We hereby declare that, to the best of our knowledge as of today 21st March 2023 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.

Signed on behalf of the Applicants by the Surface Engineering Association representing the members of the Surface Engineering Association Chromium Trioxide Authorisation Consortium

D Elliott

Signature.

Name. David Elliott
Position. Chief Executive
Date. 21st March 2023
Place. Birmingham, UK

# 1.SUMMARY

This Analysis of Alternatives and Socio-Economic Analysis relate to the application for authorisation for the continued use of chromium trioxide in the surface treatment of engineering components, mainly for the aerospace and defence sector, with the purpose of creating a coating to meet specific and critical performance characteristics.
These coatings can be broken down into four categories – chromate conversion coatings, passivation of stainless steel, chromic acid anodising and sealing after anodising. All the companies involved in this application carry out sub-contract surface treatment processes.

The document has been produced by a consortium of chromium electroplating companies with the assistance of the Surface Engineering Association and their sector consultants. Full details of the companies are provided in a separate spreadsheet.

This Use includes processes that convert the surface of an active metal or coat metal surfaces by forming/incorporating a barrier film of complex chromium compounds that protects the metal from corrosion and provides a base for subsequent treatments such as painting or bonding. This includes integrated process systems where chromium trioxide is used in a series of pre/main/post-treatments. Pre-treatment includes processes such as chemical polishing, stripping, deoxidising, pickling and etching of metals. Main-treatment includes processes such as conversion coatings, passivation and anodizing, deposition and other surface treatments where a chromium trioxide-based solution is used. Post-treatment includes processes such as rinsing, staining and sealing for final surface protection. Much research and development has been undertaken to find alternatives to these surface treatment process using chromium trioxide and there are currently four particular technologies that could be considered as potential alternatives for this particular use 1, Acidic surface treatments 2, Trivalent-based surface treatments and 3, sol-gel type coatings.

However, when examining the specific performance requirements of the required coating, none of the potential alternatives were considered to be viable alternatives at the present time nor in foreseeable future. A review period of 12 years is therefore requested. Any further research and development of these 4 potential alternatives and any newly developed coatings will be regularly monitored to ensure that the reasons for rejecting these potential alternatives is still valid. This monitoring will be undertaken by members of the consortium, the Surface Engineering Association and other actors along the supply chain.

The application for authorisation by the Chromium Trioxide Authorisation Consortium (CTAC)[2] submitted to the European Chemicals Agency (ECHA), stated: The aerospace and defence sectors specify surface treatments with chromium trioxide in order to meet strict performance criteria necessary for regulatory compliance and for public safety. This consortium included two of the largest suppliers in Europe of electroplating and surface engineering wet chemistry, clearly confirming the statements in the paragraph above.

## 1.1 Continued Use Scenario

The applicants will continue to use chromium trioxide under the ALARP[3] principles and, in conjunction with the Surface Engineering Association, will continue to monitor any R&D activity and development of potential alternatives. The applicants will continue to support UK manufacturing and contribute to the UK Government's Growth Agenda and net-zero targets.

### 1.2 Most Likely Non-Use Scenario

The most likely scenario if the application for authorisation is not granted is widespread business closures, supply chain disruption and relocation of manufacturing facilities outside of the UK.

### 1.3 Societal Costs on Non-Use

The societal costs resulting from non-use is £135.67M over a 6-year period, £7.27M of that resulting from unemployment and lost wages.

### 1.4 Residual Risks

When considering the worst-case scenario, the excess lung cancer risk is 0.0902 (due to the number of workers involved and the use of very conservative exposure data) and by the continued use of biological monitoring, all routes of exposure can be assessed and the principles of ALARP – as low as reasonably practicable – will be continued at all sites.

### 1.5 Conclusion

The societal costs of not granting this authorisation far outweigh the residual risks from the continued use of chromium trioxide by these applicants.

## 2. AIMS AND SCOPE

This application for authorisation covers the use of chromium trioxide for the surface treatment of engineering components, mainly for the aerospace and defence sector, with the purpose of creating a coating to meet specific and critical performance characteristics. This SEA / AoA is part of the application for authorisation dossier produced by the consortium members.

The aim of the AoA is to demonstrate that no suitable alternatives to the use of chromium trioxide is currently available for this specific use.

The aim of the SEA is to demonstrate that the benefits of the continued use of chromium trioxide, for this specific use, far outweigh any potential risks to human health and / or the environment.

The scope covers the companies carrying out the chromium trioxide using process and their customers and details the societal implications of a refusal to grant an authorisation for the continued use of chromium trioxide for this specific use.

The companies using chromium trioxide are all based in the UK, so provide direct employment, generate tax revenues and preserve specialist engineering skills.

# 3. ANALYSIS OF ALTERNATIVES

## 3.1. SVHC use applied for

The use of chromium trioxide in the surface treatment of engineering components, mainly for the aerospace and defence sector, with the purpose of creating a coating to meet specific and critical performance characteristics.
These coatings can be broken down into four categories – chromate conversion coatings, passivation of stainless steel, chromic acid anodising and sealing after anodising. All the companies involved in this application carry out sub-contract surface treatment processes.

### 3.1.1. Description of the function(s) of the Annex XIV substance and performance requirements of associated products

Chromium trioxide-based surface treatments are specified in the aerospace sector because they provide

a) superior corrosion resistance and inhibition,

b) improved adhesion of subsequent coatings such as paint,

c) low electrical contact resistance and/or

d) enhanced wear-resistance.

The application for authorisation by the Chromium Trioxide Authorisation Consortium (CTAC)[2] submitted to the European Chemicals Agency (ECHA), stated:

These characteristics are essential to the safe operation and reliability of aerospace and defence equipment which operates in extreme and changing environmental conditions. These pieces of equipment are often extremely complex in design, containing numerous highly specified parts, many of which cannot be easily inspected, repaired or removed. Structural components (e.g. landing gear, fasteners) and engine parts (e.g. internal components for gas turbines) on aircraft are particularly vulnerable to corrosion. Chromium trioxide surface treatment processes and performance have been successively refined and improved as a result of many decades of research and experience in the sector, and reliable data is available to support their performance. While corrosion cannot be totally prevented, despite the highly advanced nature of chromium trioxide-based coating systems in place today, there is also extensive experience, amassed over decades, on the appearance and impact of corrosion to support its effective management in these systems. On the other hand, while several potential alternatives to chromium trioxide, predominantly trivalent chromium and mineral acid-based systems, are being investigated for different processes, substrates and treatment steps, results so far do not support reliable conclusions regarding their performance as part of such complex systems, in demanding environments and test conditions representative of in-service situations. These potential alternatives do not support all the properties of chromium trioxide-based surface treatment systems, and their long-term performance can currently only be estimated. Decreased corrosion protection performance would necessitate shorter inspection intervals, with a substantial impact on associated maintenance costs.

### 3.1.2. Market analysis of products manufactured with the Annex XIV substance

Typical components that require surface treatments for this use are components that are part of:

Landing gear, flap tracks, access doors, cargo areas, seat tracks, engine intake area, defence vehicles etc.

These examples, and many more, with *Technical Performance* as their prime requirement, drive the Market demand and 'failure' of coatings can endanger the safety of the end-user.

### 3.1.3. Annual volume of the SVHC used

The annual volume of chromium, trioxide used in the surface treatment for this specific use is 500 to 750 kgs per annum in total.

## 3.2. Efforts made to identify alternatives

The application for authorisation by the Chromium Trioxide Authorisation Consortium (CTAC) submitted to the European Chemicals Agency (ECHA), stated "as of today, no complete chromium trioxide free process, providing all the required properties to the surfaces of all articles in the scope of this application, is industrially available". This consortium included two of the largest suppliers in Europe of electroplating and surface engineering wet chemistry, clearly confirming the absence of a drop-in replacement for chromium trioxide.

Many of the aerospace primes and National Defence Departments have carried out extensive research to find suitable alternatives over more than 20 years and have still not found suitable alternatives for all uses.

Despite this, some the companies that have made this application have made significant efforts to find alternatives. Each of the applicants has provided information on the efforts they have made. Here are a few extracts:

Company 1
*Not sure if our answer here helps as we are a build to print organisation and therefore can only run prescribed processes (surface treatment process has to be approved by customer).*
*Alternatives under consideration are; Surtec 650v – Aluminium Chromate conversion replacement, and Tartaric Acid Anodise – Chromic Acid replacement (suffering issues on fuel tubes)*

Company 2
*Alternatives to chromic acid anodising such as Tartaric Sulphuric acid anodising and phosphoric acid anodising have been specified by some primes but in many cases legacy specifications restrict the use to the hexavalent chromium process.*

Company 3

*We have conducted trials using black trivalent Chrome passivate on Zinc-Nickel plated parts. The results failed to meet our customer demands, particularly the appearance, this was a grey patchy finish.*

### 3.2.1. Research and development

The applicants rely on the chemistry suppliers and Universities to conduct research and developments as the costs are prohibitive to small and medium-sized businesses. The sector association, the Surface Engineering Association, keeps abreast of research and development activities on a global scale and has been involved in a number of UK Government and EU funded project to develop alternative coatings. Any information gathered by the SEA will be circulated to the consortium members.

The SEA keeps in close contact with the aerospace primes regarding the latest research and development of alternative processes and has close links with the UK Ministry of Defence and was responsible for the development of the majority of the 03 series of standards covering various types of surface treatments.

### 3.2.2. Consultations with customers and suppliers of alternatives

Members of the consortium have been in regular discussions with their customers and the suppliers of surface engineering chemistry and examples of discussions can be seen in section 3.2

### 3.2.3. Data searches

On behalf of the consortium members, the Surface Engineering Association carries our regular data searches via academic journals and Research Gate. They also maintain regular contact with other key associations around the world such as National Association for Surface Finishing (USA), European Committee for Surface Treatments (CETS), Metal Finishers' Association of India (MFAI).

### 3.2.4. Identification of alternatives

Following extensive research over a number of years, there are 3 potential alternatives for this use of chromium trioxide for critical surface treatments. These 3 alternatives are all "advertised" as suitable alternatives but they are not suitable for this certain, specific application. The 3 potential alternatives are:

A) Using acidic-based surface treatments
B) Using trivalent-based surface treatments
C) Using sol-gel type coatings

All of these alternatives have been examining by numerous previous applications for authorisation which have been granted a 12-year review period by the European Chemicals Agency / European Commission

Table 1 – Shortlisted alternatives

| | |
|---|---|
| Acidic-based surface treatments | Boric, sulphuric, tartaric, nitric etc |
| Trivalent-based treatments | Sulphate or chloride |
| Sol-gel type coatings | Hydrolysis and condensation polymerisation |

## 3.3 Assessment of shortlisted alternatives

### 3.3.1 Alternative 1: Acidic Surface treatments

#### 3.3.1.1 General description of Alternative 1

There are a whole range of acidic surface treatments that have been researched and tested as potential alternatives. The current focus is on boric acid, sulphuric acid, phosphoric acid, tartaric acid, nitric acid and citric acid. These processes are currently used for certain applications in anodising, conversion coatings and the passivation of stainless steel in order to create stable oxides or passive films on the treated surface. All of the processes are aqueous immersion type processes and often carried out at room temperature.

#### 3.3.1.2 Availability of Alternative 1

All of the acidic surface treatments listed in 3.2.1.1 are commercially available but are not yet approved for use in the aerospace and defence sector for application to certain products and components. There will be a continued requirement for the coating of legacy components for the aerospace and defence sector and these have to been coated in accordance with the original approved specifications. The new build of aerospace and defence equipment will see a gradual change in the approved specifications and an eventual phase out of chromium trioxide but aerospace and defence equipment often has a 30-40 year life cycle.

#### 3.3.1.3 Safety considerations related to using Alternative 1

All of the acidic surface treatments have the potential to cause harm to humans and the environment:

| Acid | CAS Number | Issue |
|---|---|---|
| Boric | 11113-50-1 | Toxic to reproduction, SVHC, on candidate list |
| Sulphuric | 7664-93-9 | Causes severe burns & eye damage, toxic if inhaled |
| Phosphoric | 7664-38-2 | Causes severe burns & eye damage, toxic if inhaled |
| Nitric | 7697-37-2 | Fatal if inhaled, causes sever burns & eye damage |
| Tartaric | 87-69-4 | Causes serious eye damage |
| Citric | 77-92-9 | Causes serious eye irritation, potential respiratory irritant |

So, any potential alternative needs to be fully evaluated and assessed before use, not only from the technical aspect but also from the safety and health aspects as outlined above.

On a positive note, the alternatives would remove the use of chromium trioxide from the workplace. However, it has been clearly demonstrated that by working in accordance with best practice, chromium trioxide can be used with potential exposures similar to background levels.

#### 3.3.1.4. Technical feasibility of Alternative 1

All of the potential alternatives can and have been considered as alternatives for new build but cannot be considered as alternatives for existing build and legacy components that have to comply with the original specifications against which approvals were granted. The key technical advantage that none of the alternatives have yet to meet is the ability of chromium trioxide containing coatings to self-heal when the surface coating is damaged. Chromium trioxide coatings remain the benchmark for corrosion inhibition, providing protection over a wide pH range and electrolyte concentration. Chromates are both anodic and cathodic inhibitors, restricting the rate of metal dissolution whilst simultaneously reducing the rate of reduction reactions. In addition they impart a "self-healing" character to the coating during oxidative (corrosive) attack. Self-healing occurs by the reduction of the hexavalent chromium in the coating to an insoluble trivalent chromium compound.

#### 3.3.1.5 Economic feasibility of Alternative 1

Generally, the acid-based alternatives are considered to be economically similar to using chromium trioxide. There are, however, some extra process control requirements that are needed. A number of the acidic-based alternatives are more susceptible to contaminants and heating and subsequent treatment of the solutions may be required. This could lead to potential employee exposure due to the elevated process solution and extraction systems will be necessary.

#### 3.3.1.6 Suitability of Alternative 1 for the applicant and in general

Whilst considerable research and development has been completed and is still on-going, the use of acidic treatment processes is not considered as a suitable alternative for this particular use in existing and legacy equipment.

### 3.3.2 Alternative 2 – Trivalent-based surface treatments

#### 3.3.2.1 General Description of Alternative 2

Trivalent chromium processes are generally based on the same principle as chromium trioxide processes, but there are some considerable differences in the chemical composition of the solution, addition of additives, operating parameters and additional process equipment.

#### 3.3.2.2 Availability of Alternative 2

Several products based on trivalent surface treatments are already available on the market for specific uses and base materials. However, there is still extensive research being undertaken within the aerospace and defence sector as these treatments do not yet meet the required performance criteria. It is expected that this research could be completed within the next 5 to 7 years and then a further 5 to 7 years to enable full implementation across the aerospace and defence supply chain.

#### 3.3.2.3 Safety considerations related to using Alternative 2

Trivalent- based surface treatments are either sulphate or chloride based, and both have the potential to cause harm to humans and the environment:

| Substance | CAS Number | Issue |
|---|---|---|
| Chromium | 15244-38-9 | Causes severe burns & eye damage, harmful if swallowed or inhaled |

| | | |
|---|---|---|
| Sulphate | | |
| Chromium chloride | 50925-66-1 | Causes severe burns & eye damage, very toxic to aquatic life, may cause allergic skin reaction |

So, any potential alternative needs to be fully evaluated and assessed before use, not only from the technical aspect but also from the safety and health aspects as outlined above.

On a positive note, the alternatives would remove the use of chromium trioxide from the workplace. However, it has been clearly demonstrated that by working in accordance with best practice, chromium trioxide can be used with potential exposures similar to background levels.

### 3.3.2.4 Technical feasibility of Alternative 2

There has been some successful research and development of trivalent chromium coatings on various substrates and some have been introduced into the aerospace and defence supply chain for specific substrates such as zinc-nickel electroplated coatings and ion vapour deposited aluminium. However, outdoor testing has shown that trivalent chromium coatings do not provide the required level of corrosion protection. Process control and coating variability are still an issue and need further research and development. The adhesion of subsequent coatings, such as paint, is also below the standard obtain with chromium trioxide based coatings.

When considering the technical feasibility of alternative 2, it is not considered to meet the technical requirements for this use.

### 3.3.2.5 Economic feasibility of Alternative 2

As trivalent chromium-based coatings do not meet the technical and performance requirements of the aerospace and defence sector in general, economic feasibility has not been considered.

### 3.3.2.6 Suitability of Alternative 2 for the applicant and in general

Whilst considerable research and development has been completed and is still on-going, the use of trivalent chromium processes are not considered as suitable alternatives for this particular use.

### 3.3.3 Alternative 3 – Sol-gel type coatings

### 3.3.3.1 General Description of Alternative 3

Sol-gel is a process where solid materials are produced from small molecules. The process handles the transformation of monomers into a colloidal solution (the Sol) that acts as the forerunner for an integrated network (the Gel) of either discrete particles or network polymers. So, the procedure has essentially 2 parts: the Sol (solution) and the Gel.

- **Sol (solution):** A colloidal suspension of monomers (tiny particles that can be linked with identical molecules to create a network or polymer) on a liquid medium (usually water or alcohol).
- **Gel:** A semisolid colloidal suspension of a solid, evenly mixed in a liquid which exhibits no flow when in the steady state. Its properties cover a wide range from soft and weak to hard and tough.

In a nutshell, the Sol undergoes a hydrolysis and condensation polymerization in the activation phase to form the gel. Subsequently, the gel is applied as a coating to the substrate and is dried to create a hard, glossy film.

Depending on the geometry (size and shape) of the part to be coated, different technologies such as spraying, immersion, electrodeposition or dip-spin coating can be used for applying a sol-gel coating. The most common and commercially used application technique for sol-gel coatings is dip-spin technology, while spraying technology is the most commonly used technique within the aerospace sector.

### 3.3.3.2 Availability of Alternative 3

Products based on aqueous solutions of zirconium salts, which are activated by an organo-silicon compound, are already approved by several companies within the aerospace and defence sector for special parts (e.g. fuselage, wing). These are primarily for parts and assemblies where the corrosion performance is provided by the subsequent primer and topcoat. They provide good adhesion properties but are insufficient in terms of standalone corrosion protection. However, there is a concerted research and development effort underway to develop a whole suite of sol-gel type coatings that will meet aerospace and defence requirements, but it will take at least 10 years for them to begin to be commercially available.

### 3.3.3.3 Safety considerations related to using Alternative 3

There are many substances being considered but one of the most promising is Vinyltrimethoxysilane (VTMS). Other substances are h=being considered but all have similar types of properties.

| Substance | CAS Number | Issue |
|---|---|---|
| VTMS | 2768-02-7 | Can cause allergic skin reaction, flammable and harmful if inhaled. Has been included in ECHA CORAP process |

So, any potential alternative needs to be fully evaluated and assessed before use, not only from the technical aspect but also from the safety and health aspects as outlined above.

On a positive note, the alternatives would remove the use of chromium trioxide from the workplace. However, it has been clearly demonstrated that by working in accordance with best practice, chromium trioxide can be used with potential exposures similar to background levels.

#### 3.3.3.4 Technical feasibility of Alternative 3

The performance of the sol-gel coating is strongly dependent on the pre-treatment of the substrate and therefore many of the required performance characteristics depend not only on the sol-gel type coating but also the pre-treatment process. This has led to issue with reproducibility of the final coating. Coating of complex geometries is also an issue that can currently only be overcome by an immersion type process whereas a process that can be sprayed is required.

The corrosion resistance of sol-gel coatings is generally poor but can be improved by the addition of a chromium trioxide based primer.

Electrical resistance can also be an issue for sol-gel coatings  as the coating tends to be too thick and leads to electrical insulation.

Sol-gel coating preparations have a relatively short shelf life (a few hours) compared to chromium trioxide preparations which lasts months.

#### 3.3.3.5 Economic feasibility of Alternative 3

As sol-gel type coatings do not meet the technical and performance requirements of the aerospace and defence sector in general, economic feasibility has not been considered

#### 3.3.3.6 Suitability of Alternative 3 for the applicant and in general

Whilst considerable research and development has been completed and is still on-going, the use of sol-gel type coatings is not considered as a suitable alternative for this particular use at present.

## 3.4 Conclusion on shortlisted alternatives

Whilst all the three potential alternative coatings can, and have, replaced chromium trioxide based coatings for specific products with specific technical and performance requirements, none of them are currently considered to be viable alternatives providing the complete technical and performance characteristics for this particular use.

# 4 SOCIO-ECONOMIC ANALYSIS

## 4.1 - Continued use scenario

### 4.1.1 Summary of substitution activities

The applicant and several other members of this group of users, have researched the potential alternatives to chromium trioxide and have received sample components from suppliers of the potential alternative process equipment or material.

On assessment, none of the alternatives satisfy all the performance and aesthetic criteria required by the end users of the articles being coated. The most important performance criteria being corrosion resistance and chemical resistance with no alternative able to satisfy these criteria.

To the end user, the immediately obvious criteria are visual appearance and colour consistency where the component parts should have the same appearance i.e., "match" all other chromium plated parts in the installation – regardless of where or when they are sourced. None of the potential alternatives can satisfy these requirements.

Where parts are supplied to a customer specification e.g. Legacy Parts, none of the alternatives are acceptable.

### 4.1.2 Conclusion on suitability of available alternatives in general

As a result of the unacceptability of alternatives, to the end users, the conclusion is that the applicants have no available or potential alternative processes likely to be introduced for the foreseeable future.

Therefore, it is not possible to produce a substitution plan.

### 4.1.3 R&D plan

Group members are SMEs, as defined in the EU recommendation 2003/361, and as such do not have access to funds to enable individual R&D activity and, in most cases, do not have the floorspace or manpower to accommodate the necessary process facilities.

The applicants must, therefore, rely on R&D carried out by the major process chemistry suppliers and Universities as the costs are prohibitive to micro, small and medium-sized businesses. The sector association, the Surface Engineering Association, keeps abreast of research and development activities on a global scale and has been involved in a number of UK Government and EU funded projects to develop alternative coatings. Any information gathered by the SEA will be circulated to the consortium members.

## 4.2 Risks associated with continued use

Given that all of the results from the Workers biological monitoring reports are within (or below) the range expected for the unexposed population i.e., <10µmol/mol creatinine and that there are no discharges of chromium trioxide to the environment, there is no excess lifetime risk to individuals (worker or general population) or to the environment.

However, as chromium trioxide is classified as a non-threshold carcinogen and using the dose response relationship for exposure to chromium trioxide developed by the Risk Assessment Committee of the European Chemicals Agency, there is an excess lung cancer risk of 2 X $10^{-3}$ by considering the worst-case scenario.

The worst-case assessment of worker health risks within this socio-economic analysis utilises the results of a study endorsed by ECHA identifying the reference dose response relationship for carcinogenicity of hexavalent chromium. These results are acknowledged to be the preferred approach of the RAC and SEAC and therefore have been used as a methodology for the calculation of work cancer risks in this socio-economic analysis.

The following steps are therefore necessary to complete the health impact assessment:

1 – Assessment of worker exposure (actual measurements)

2 – Estimation of additional cancer deaths relative to the baseline lifetime risk

3 – Estimation of additional non-fatal cancer based on survival rate statistics

4 – Monetary valuation of fatal and non-fatal cancer risks

Following the worst-case approach, the combined worker exposure values from the corresponding chemical safety report, section 10, are used to make the assessment of health impacts. Following the ECHA methodology where the applicant only provides data for

the exposure to the inhalable particulate fraction, it will be assumed that all particles were in the respirable size range and only lung cancer need be considered.

For the lung cancer calculation, excess lifetime risk (ELR) is defined as the additional risk of dying from cancer due to exposure of toxic substances incurred over the lifetime of an individual. From the ECHA RAC the unit of occupational excess lifetime mortality risk is 4 X $10^{-3}$ per $\mu$g Cr(VI)/$m^3$

Table 2: Excess lung cancer mortality risk to workers covered by this application

| | | |
|---|---|---|
| A | Inhalation exposure weighted average $\mu$g/$m^3$ | 3.22 |
| B | Excess risk unit coefficient | 4 x $10^{-3}$ per $\mu$g/$m^3$ |
| C | Excess risk for 40 years (A x B) | 12.88 x $10^{-3}$ |

| | | |
|---|---|---|
| D | Excess risk per year (C/40) | 0.322 x $10^{-3}$ |
| E | Number of workers exposed | 28 |
| F | Total annual excess risk (number of cases) | 0.0902 |

The individual development of cancer may be fatal or non-fatal whereas the dose response function considers only fatal cancer. It therefore follows that the excess risk of cancer is higher than the excess risk of fatal cancer.

According to Cancer Research UK the following table can be developed:

Table 3: Age-standardised, five-year survival rates for lung cancer in the UK, 2013-2017

| Relative cumulative survival | Non-fatal/ fatal ratio |
|---|---|
| 16.2 | 0.193 |

This means that for every fatal case of lung cancer, there is an additional 0.193 non-fatal cases in the UK. This equates to 0.0003 non-fatal cancer cases associated with this application.

Table 4: Values for fatal and non-fatal cancer taken from ECHA Guidance using December 2003 exchange rate of €1.42 / £1

| | 2003 | GDP factor | 2020 |
|---|---|---|---|
| Value of statistical life | £740,845 | 133.95 | £992,362 |
| Value of statistical life (sensitivity) | £1,590,141 | | £2,129,994 |
| Value of cancer morbidity | £370,423 | | £496,181 |
| Value of cancer morbidity (sensitivity) | £795,070 | | £1,064,997 |
| Value of cancer fatality | £1,111,268 | | £1,488,543 |
| Value of cancer fatality (sensitivity) | £2,385,211 | | £3,194,990 |

The GDP factor is the change in UK GDP between 2003 and 2020 as per the UK Office for National Statistics and allows for inflationary impacts to be included in the assessment.

Table 5: Estimated monetary value of annual risk of lung cancer from chromium trioxide exposure for this application.

| | All sites combined |
|---|---|
| Fatal cancer risk per year | 0.0902 |
| Annual cost of fatal cancer risk | |
| Per case £1,488,543 | £134266.58 |
| Sensitivity £3,194,990 | £288,188.10 |
| Non-fatal proportion | 0.193 |
| Non-fatal cancer risk per year | 0.0119 |
| Annual cost of non-fatal cancer risk | |
| Per case £496,181 | £5904.55 |
| Sensitivity £1,064,997 | £12673.46 |
| Total annual cost of cancer | £140171.13 |
| Sensitivity | £300861.56 |

These figures used the same methodology of those submitted by Grohe AG who were granted a 12-year review period for their authorisation.

Given that the results show no increased risk over that of the General Population and that there are no emissions to atmosphere, the implications of a non-use scenario will only affect the applicants and their customers.

Similarly, the continued-use scenario does not give rise to any additional economic burden toward health or environment.

## 4.3 Non-use scenario

If authorisation is refused, there would be an immediate loss of business and the applicants will be unable to continue trading. This will place the workers at immediate risk of unemployment and the applicants with significant costs associated with chemical disposals, redundancy, asset disposal and premises sale.

### 4.3.1 Summary of the consequences of non-use

In the non-use scenario, the applicants will cease trading and customers will resort to purchasing the same services (chromium trioxide plating) from overseas i.e., outside of The UK and The EU resulting in increasing the UK's trade deficit without removing the substance from Global use.

Larger customers with a regular requirement for the process may also take the decision to re-locate to the geographical supply base i.e., Off-shoring.

The job losses would total 329 from the applicants with an added risk within their customers employee base of ~4000 staff.

The short-term effect to the economy would be the loss of approximately £21.4M GDP (per annum) and the contribution to UK Treasury from taxes, etc.

In the medium-term, should customers decide to relocate, the loss to UK GDP would be more than £447.2M (based on "top 5" turnover).

The economic effect on the suppliers, of chromium trioxide, to the applicants cannot be quantified in this report.

The Group members in this consortium able to research, and/or trial, potential alternatives have submitted samples and consulted with their customers.

The customer responses to these are (ref. Section 3.2):

*"….we are a build to print organisation and therefore can only run prescribed processes…. process has to be approved"*

*"..legacy specifications restrict the use to the hexavalent chromium process."*

*"…results failed to meet our customer demands, particularly the appearance".*

### 4.3.2 Identification of plausible non-use scenarios

#### Non-use Scenario 1

Shut down of chrome process, resulting in company closure.

Sections 3.3.1.4, 3.3.2.4 and 3.3.3.4 detail the technical performance of each of the potential alternatives and, while some of the requirements are met, there are none that meet the 'basic' criteria of visual appearance (colour) and wear resistance.

These are critical requirements for this market sector hence, section 3.4 concludes that "none of them are currently considered to be viable alternatives for this particular use."

The customer "demand" is for technical performance, colour consistency, in addition to colour matching to existing parts and other parts available from overseas suppliers.

As there is no alternative process, the existing chromium trioxide facilities will close, and staff will be redundant.

The company must dispose of all materials, using specialist contractors to handle the hazardous waste thereby, incurring unrecoverable costs. The process facility is then dismantled and disposed to waste/scrap recovery incurring further specialist contractor cost because of the contaminated equipment.

Removal and clean-up costs reduce company balance sheet value affecting the ability to pay both statutory and commercial creditors and, possibly, staff redundancy payments.

Any Service Level Agreements (SLA) that cannot be satisfied will be subject to contingent cost claims from the customers so reducing the value of the remaining income from invoices issued prior to closure.

## Non-use Scenario 2

Change to worse performing alternative.

Section 3.3.1 details the trivalent chrome process, its operation, and its technical characteristics.

Trivalent chrome processes are unstable and energy intensive. Using this process incurs additional analytic and control staff, consumes additional energy, and gives inconsistent finishes.

These result in increased payroll cost, increased energy cost and re-processing cost (if possible). Disposal of existing chromium trioxide is done by specialist contractors. Installation of additional equipment relative to trivalent chrome processing is done – involving closure of the production facility and addition of bunding area, tanks, controls, services, and utilities.

Loss of business due to stoppage of process will occur in the **short-term**.

On restart, the final product fails performance standards or fails prematurely in service resulting in customer rejects and rework cost and/or scrappage of components – incurring replacement cost.

**Medium-term**, loss of business due to quality and throughput failures. Reduction in staffing levels due to loss of business.

Customers source products with technically acceptable coating (chromium trioxide) from available sources (overseas).

**Long-term**, cost burden and inability to supply consistent product that performs both technically and aesthetically result in loss of customers and significant reputational damage.

Customers source “original” finish (chromium trioxide) from available sources (overseas).

This results in closure of uneconomic process following financial losses due to failures in quality and delivery.

Staff are redundant when process stops.

Disposal and removal cost incurred. Business closes.

### 4.3.3 Conclusion on the most likely non-use scenario

NuS 2 is very unlikely to occur as the applicants do not have the financial capacity, floorspace or number of staff required to install a process which is known to be unacceptable.

The most likely NuS is scenario 1 i.e., Off-shoring of process and closure of applicants' business.

Immediate effect on local economy with added potential of larger customers re-locating to supply base geographic area and affecting UK GDP.

This market sector is very demanding and are concentrated on achieving a long-lasting, technically acceptable product. This fact alone, determines that the customer will demand the chromium trioxide process and this will incur transport costs and delays resulting from extended supply routes – these additional costs and delays will result in significantly inflated costs.

This fact alone, determines that the customer will demand the chromium trioxide process and this will incur transport costs and delays resulting from extended supply routes – these additional costs and delays will result in significantly inflated costs.

Sourcing this process overseas will have a negative impact environmentally resulting from the emissions from transport and will "export" the chromium trioxide work to less well-regulated areas.

## 4.4 Societal costs associated with non-use

In the continued use scenario, it is expected that there will be some additional costs associated with testing, reporting and control systems resulting from conditions applied to the authorisation approval. Although this will be contingent cost to the applicants it is very likely to be passed through the supply chain in the form of price increases therefore would not be additional cost to the applicants.

In the Business as Usual (BaU) case there would be no effect on the economics of the process or product. Employment would continue at the current levels and contributions to the local economy and national GDP would be stable.

As there are no increased health effects to either the workers or the general population, there would be no economic effect to the health or social services.

In the medium to longer term, it is expected that business levels will increase. This will result in additional turnover and employment in the supply chain thereby increasing the economic contribution of the sector.

Confidentiality concerns from customers makes it extremely difficult to obtain quantitative information about their detailed spend or the value contribution to turnover from the plating service. However, the approximation used for this report is 2% of customers' product selling cost (turnover). As the share of the customers sales value resulting from chromium plated parts cannot be quantified, the combined turnover value of the applicants (£20.54M) is used to calculate the contribution to GDP value.

Thereby: **£21.4M/2% = £1,070M GDP value.**

In the non-use scenario the sales value (£21.4 M GDP) would be lost because of closure of the applicant businesses. Any export value (not quantified) would be lost and the remainder of the estimated £1,070M GDP value would be replaced by import cost.

This would effectively more than double the effect to the UK trade balance as there would be transportation and additional inventory costs to be factored into the cost of supply.

As this is a demand driven product, it is not possible to quantify the financial impact on the customer supply chain.

In this case the cost calculations take account of the unemployment costs associated with the closure of the applicants' businesses. Because of the numerous companies involved and the wide age demographic that is likely, it is assumed the average age of the workers to be 40 i.e. 20 years old = newly skilled, 60(+) years old highly skilled therefore assume the mid-value as the average for the purpose of this assessment.

It is assumed that all those workers made redundant as a result of the non-use scenario and closure of the applicants businesses would experience a period of temporary unemployment. This assumption is based on the understanding that the workers are generally highly skilled and therefore likely to regain employment within a relatively short period.

Using a conservative approach, the estimated unemployment periods and resultant costs will be calculated using data published by the Office for National Statistics (ONS) 14 June 2022. These data show a 'total' unemployment rate of 3.9% but, a rate of 27.4% for those aged 16-64.

The 'total' figure is used so that there is no bias to the resultant costs even though workers in this industry are predominantly male. Further, it is assumed that re-employment within the first year will be within 3 months and that the rate of re-employment is constant year-on-year and that re-employment is achieved at the mid-point of the second and subsequent years i.e. 6 months unemployed in that year.

It can be seen from table 6 that it is expected that all workers will be re-employed by 4 years after redundancy.

**Table 6: Annual unemployed by year following closure**

Average salary cost = £31772 (ref. ONS April 2021)

| Permanent Workers | | Social cost (£77/week – 2022) | Lost Earnings (net avg salary) |
|---|---|---|---|
| 329 | 2023 | £600,037 | £4,161,299 |
| 90 | 2024 | £164,410 | £1,660,033 |
| 25 | 2025 | £45,048 | £454,849 |
| 7 | 2026 | £12,343 | £124,629 |
| 2 | 2027 | £3,382 | £34,148 |
| 1 | 2028 | £927 | £9,357 |
| **TOTALS** | | **£826,148** | **£6,444,315** |

In all cases, conservative estimations and assumptions have been used to ensure that the socio-economic impacts of the non-use scenario have not been overestimated. Further, there are likely to be a number of additional negative effects which have not been quantified or monetised due to a lack of suitable data and/or information. These include temporary reductions in output and employment in the applicants' supply chains and in the local economies surrounding the affected manufacturing sites.

### 4.4.1 Economic impacts on applicants

In the non-use scenario, the applicants' businesses will close resulting in total loss of profit but will remove cost of manufacturing i.e., raw material, utilities, payroll, etc.

However, there will be costs incurred because of redundancy payments (unquantifiable. Values subject to workers age, service, etc.), disposal of residual stock and process chemicals (unquantifiable. Subject to analysis and volumes).

Also, disposal of fixed assets (process equipment, etc.) is likely to be for 'scrap' value only as there will be no market in the UK for this equipment. Financial value of this scrap will result in a reduction of balance sheet values for fixed assets.

Once chemical disposal, clean-up and asset disposal are complete, the property (buildings & land) can be sold. Current industrial property values are relatively high (2022) but, in this scenario, there will be numerous properties available which may serve to depress the market value.

Again, for the purposes of this assessment, the costs are assumed to equal the reduction in manufacturing cost, the balance sheet value and potential return on asset sale.

As the applicant will need to finance the disposals and clean-up costs, the probability is that they will enter Administration or Liquidation putting the immediate burden of redundancy cost on to the Public Purse.

### 4.4.2 Economic impacts on the supply chain

In the non-use scenario there will be an immediate effect on the customer base in that the only option will be to purchase the same goods and services from outside the UK/EU.

This will increase lead-time, costs and reduced service levels.

Cost increases will be passed on to their customers who will already be suffering delayed supply and possibly result in cancellation of supply contracts and, what are currently exports of goods and services will probably be lost to the overseas suppliers who will deal directly with the export customers.

### 4.4.3 Economic impacts on competitors

While there is some use of alternative processes within the UK these have been dismissed by this market sector as being unacceptable.

This means there would be no economic advantage achieved by any UK based competitor who are using an alternative. The entire value of the customer base will be lost to foreign suppliers.

### 4.4.4 Wider socio-economic impacts

In addition to the socio-economic impacts described in the previous sections, the non-use scenarios might be associated with wider economic impacts. These include possible impacts on government tax receipts. These are transfers from workers, consumers, and capital owners to taxpayers, and are effectively included in the figures presented above, which are defined in terms of total economic value. Taxes are a transfer of a portion of that value between parties — the distributional aspects (the extent to which part of these values are transferred to taxpayers) are not considered in detail.

There might also be impacts on local economic activity and development because of the non-use scenarios, but these impacts are expected to be limited.

There will clearly be an impact on international trade, with UK-based production being replaced partly or wholly by output produced outside the UK/EU. This is detailed in the previous sections and would be a combination of the lost output value from the applicants plus additional freight costs and the lost export values of goods and services from the customers trading values.

### 4.4.5 Compilation of socio-economic impacts

**Table 7: Societal costs associated with non-use.**

| **Description of major impacts** | **Monetised/quantitatively assessed/qualitatively assessed impacts** |
|---|---|
| **1. Monetised impacts** | **£ [per year[1]] [Over x years]** |
| Direct business loss due to closure | £21.4M |
| Potential supply chain impact | £1,070M |
| Social cost of unemployment | £826,148 over 6 year period |
| Cost of lost wages | £6,444,315 over 6 year period |
| | |
| **Sum of monetised impacts** | £1,098,670,463 |
| **2. Additional quantitatively assessed impacts** | **[Per year] [Over x years]** |
| | Not applicable |
| **3. Additional qualitatively assessed impacts** | |
| | Not applicable |

## 4.5 Combined impact assessment

**Table 8: Societal costs of non-use and risks of continued use.**

| **Societal costs of non-use** | | **Risks of continued use** | |
|---|---|---|---|
| Economic impacts (annual)<br>Social impacts (over 6 years – declining value per year) ref table 4 | £21,400,000<br>+<br>£7,270,463 | Monetised excess risks to directly and indirectly exposed workers<br>(Annual values) | £140,171.13<br>£300,861.56 (higher bound sensitivity) |
| Off-shoring by supply chain (annual) | £1.070Bn | Monetised excess risks to the general population | No risk to general population |
| Qualitatively assessed impacts | Not applicable | Qualitatively assessed risks | No direct emissions to the environment |

Therefore, the total costs of the non-use scenario are estimated at £135.67M over the 6-year period from the implementation date. The added value lost, to UK GDP, by the supply chain offshoring manufacture would be £6.42Bn over the same 6-year period.

The total benefit of the non-use scenario i.e., avoiding the direct cost to human health as a result of exposure to Cr(VI) is estimated at £0.841M over the same period, with a value of £1.805M as an upper bound sensitivity.

It can be seen, then, that the costs of non-use clearly outweigh the benefits by several orders of magnitude.

### Costs of non-use per unit of release.

Not applicable

## 4.6 Sensitivity analysis

The societal cost of continued use is severely increased in the calculations because of the WEL value used where results are reported as <0.025mg/m$^3$ and where reports have not been made available.

Assuming analysis levels to be similar to those reported as 'actual' values, the societal costs are expected to reduce by a factor of 10 as a minimum.

In this circumstance, the cost benefits of continued use increase by a significant factor.

## 4.7 Information to support for the review period

This group of applicants consider a review period of 12 years to be appropriate for the use of Cr(VI) in the coating of "Technical Components" to create a coating which provides specific performance characteristics, matches existing parts and those supplied from other sources.

- The market for these products is dominated by Cr(VI) processed products because of their superior performance, long lifetime in use and aesthetic quality in comparison to the available alternatives.
- The available alternatives to Cr(VI)-processed products have critical performance weaknesses which explain why they meet only niche requirements in this sector. While these critical performance weaknesses exist, any future lack of availability of UK-manufactured Cr(VI)-processed products in the UK will be met through imports of Cr(VI)-processed products (particularly from China), not through any substitution for non-chrome alternatives;

- As a result, until these critical performance weaknesses have been overcome, it will never be economically viable for the applicants to stop producing Cr(VI)-processed products in favour of these alternatives, and the non-use scenario will continue to be the closure of the applicants chrome businesses and with the additional risk of the supply chain (customers) relocating to a country outside of the UK/EU to an available geographic supply-base;

- The costs of these closures and relocation of the supply-base are extremely high and will continue to be so;

- In comparison, the risks of the applicants continued use of Cr(VI) are very low and will continue to be so. These risks will not be avoided in the non-use scenario, but simply shifted from the UK to another country outside of the UK/EU;

- Within the wider industry, and material suppliers, research into alternatives to Cr(VI)-based electroplating has been carried out for decades to address the existing performance weaknesses of alternatives, and it continues to do so. However, the performance advantages of Cr(VI) are very strong, and major innovations and developments would be necessary to overcome them. Industry has initiated joint research with academic groups in an attempt to address these weaknesses, but no significant success is expected within the foreseeable future;

- Even if a viable alternative of equivalent performance to Cr(VI) was to become available, it would still take several years to develop into a marketable product, to industrialise the production process, and to implement the necessary process changes for large-scale manufacture. These changes are expected to be highly costly. In addition, there will still be a need to provide continued support to customers of existing Cr(VI) products, in terms of spares, etc., in line with the market demands.

- The conclusion of this assessment is that research and development efforts made in the past and ongoing efforts made by Industry have not led and will not lead to the development of a suitable alternative that could be available within the normal review period. The remaining risks are low and the socio-economic benefits are high (around 20 times), both estimated on a highly conservative basis, and there is clear evidence that this balance is not likely to change in the next 12 years. Taking this into consideration, the applicants argue that a `long' review period of twelve (12) years is appropriate.

# 5 CONCLUSION

Section 4.7 (above) details the reasons why the applicants recommend authorisation for continued use of Cr(VI) [chromium trioxide] and this authorisation to be granted with a review period of 12 years.

# 6 REFERENCES

1. BS EN ISO 6158:2018 Metallic and other inorganic coatings. Electrodeposited coatings of chromium for engineering purposes.
2. Application for authorisation for the continued use of chromium trioxide produced by the Chromium Trioxide Authorisation Consortium (CTAC) made up of the key producers and importers of chromium trioxide and wet process chemistry for electroplating.
3. ALARP – Health & Safety Executive principle – As Low As Reasonably Practicable. This involves weighing a risk against the trouble, time and money needed to control it. It describes the level to which the Health & Safety Executive expect to see workplace risks controlled.
4. Survey on technical and economic feasibility of the available alternatives for chromium trioxide on the market in hard/functional and decorative chrome plating. A report produced by the German Federal Institute for Occupational Safety & Health (BAuA)