# Authorisation must not encourage substitution to unsuitable alternatives

March 20th, 2023, Elke Van Asbroeck, Peter Simpson

## *Executive Summary*

*RAC and SEAC's current approach to evaluating applications for authorisation for uses of hexavalent chromium Cr(VI) for electroplating in the sanitary and decorative sectors will encourage substitution to unsuitable, SHVC-containing, alternatives that will not result in a reduction in risk. Unless addressed, this will encourage applicants and their suppliers to deprioritise research and development into SVHC-free chromium plating technology; this is contrary to the objectives of REACH.*

REACH is intended to ensure a high level of protection of human health and the environment whilst enhancing competitiveness and innovation. We are concerned that the current approach to the evaluation of applications for authorisation for the use of Cr(VI) in electroplating for sanitary and decorative applications prevents this from being achieved.

The Judgement of the General Court in Case T-837/16 (2019) provided clarity on how the suitability of alternatives should be assessed by applicants and evaluated by RAC and SEAC. Based on these clarifications, chromium (III) plating cannot be considered as a suitable alternative in general (SAGA) when it also requires the use of the reprotoxic substance of very high concern (SVHC) boric acid. This is because the substitution does not achieve an overall reduction in risk. Whilst Cr(III)/boric acid may appear to be a good substitute for an applicant there is sufficient information to conclude that it is unsustainable from a societal perspective.

Nevertheless, many sanitary and decorative electroplating companies are committing to substitute Cr(VI) with Cr(III)/boric acid. This is happening because the overall risks arising from substitution are not appropriately considered during opinion-making or decision-making process. RAC has yet to conclude on the overall risks of substituting to Cr(III)/boric acid, but this has not prevented SEAC from assuming, inappropriately, that Cr(III)/boric acid is SAGA. In the absence of a clear RAC conclusion that Cr(III)/boric acid is safer, the Commission may need to conclude whether Cr(III)/boric acid is safer taking into account the precautionary principle.

RAC and SEAC's approach to evaluation in this case discriminates against applicants that aspire to a genuinely safer, SVHC-free, alternative to Cr(VI) for electroplating; typically recommending review periods that are far shorter than requested and, consequently, far shorter than would be required to research, develop and implement **any** suitable alternative. On the contrary, SEAC typically recommends the requested review period (in many instances 12 years) for sanitary and decorative plating with Cr(VI) when applicants commit to substitute to Cr(III)/boric acid.

Such recommendations inevitably result in the unfortunate incentive for European industry to pursue regrettable substitution. This is because it will result in a more predictable and favourable regulatory outcome than sustainable substitution. This has long-term consequences for European competitiveness and strategic autonomy as well as a risk that unsustainable substitution results in overall harm to society. We note that RAC and SEAC have previously evaluated applications in such a way that safe and sustainable substitution was supported, recommending review periods of sufficient length for applicants to develop safe and sustainable alternatives and avoid regrettable substitution (e.g., Akzo Nobel, AfA ID 0109-01, for 1,2-EDC). The Court Case T-837/16 did not prevent optimal risk reduction and sustainability. On the contrary, it emphasizes the need to implement safer alternatives.

As the Commission has yet to decide on the majority of applications for the use of Cr(VI) for sanitary and decorative plating, there remains an opportunity to remedy the situation. A critical

first step will be to ensure RAC appropriately considers the overall risk reduction achieved by substitution of Cr(III)/boric acid, which will enable a clear conclusion on SAGA.

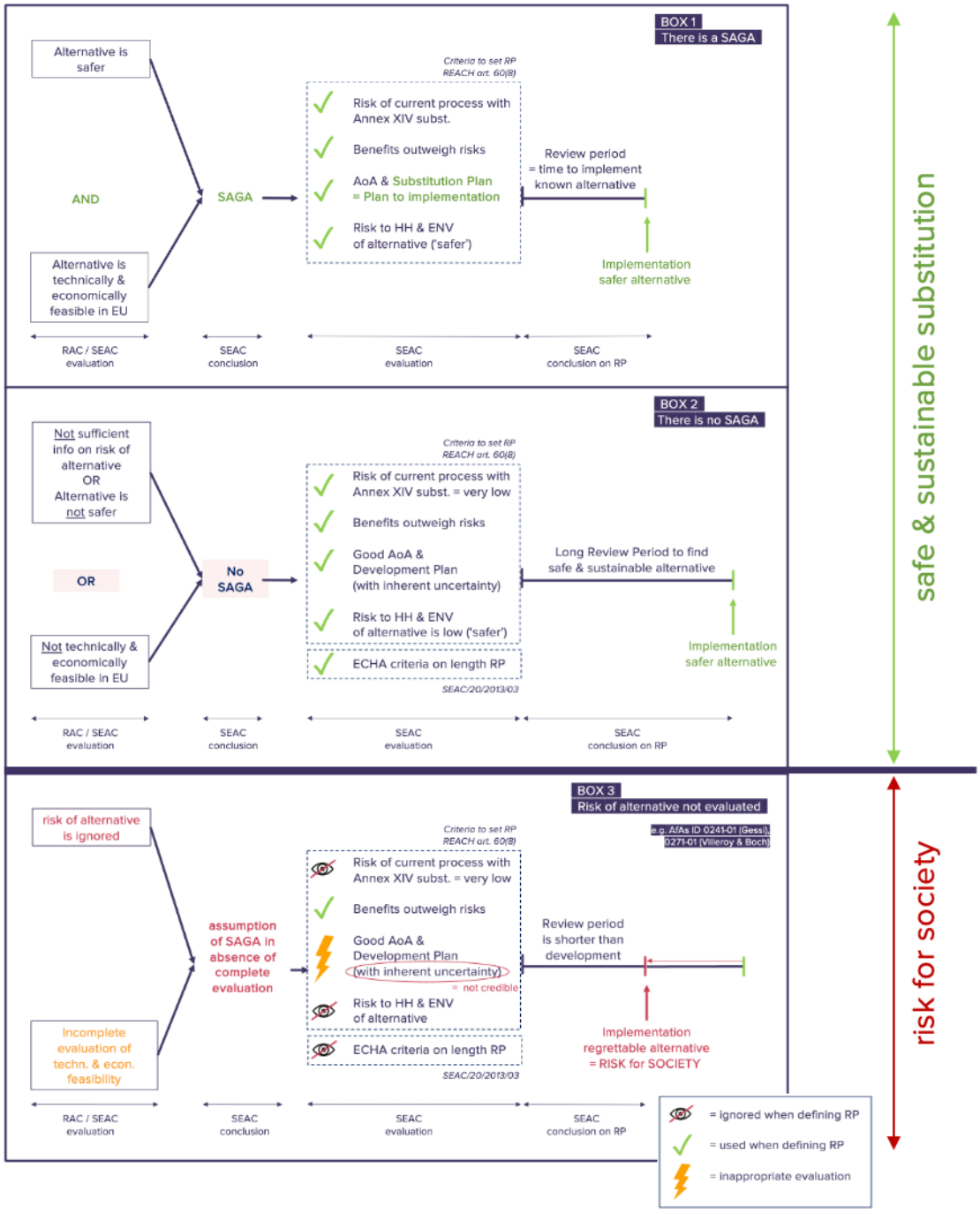


***Figure 1. Authorisation can achieve safe and sustainable substitution where RAC & SEAC's evaluation results in a clear conclusion that there is either SAGA (Box 1) or where there is no SAGA (Box 2). In both scenarios, the duration of the review period can be set using the criteria in REACH Art. 60(8) and would ensure implementation of a suitable & safer alternative.***

***On the contrary, where RAC & SEAC do not properly evaluate SAGA (Box 3) this can lead to a scenario where SEAC incorrectly assumes SAGA even when substitution would not result in an overall reduction in risk. This encourages regrettable substitution as under these circumstances it results in greater regulatory certainty (i.e., long review periods) than sustainable substitution to a safer alternative (typically recommended to have a shorter review period than needed).***

## Introduction

This short report elaborates why the evaluation of applications for authorisation for the use of Cr(VI) for sanitary and decorative plating can encourage regrettable substitution. The report concludes with a series of recommendations. Two Annexes provide additional information on (i) the risk of boric acid in surface water and (ii) a realistic minimum timeline to identify and transition to a sustainable alternative to Cr(VI) for decorative and sanitary electroplating.

### *The Judgement of the General Court in Case T-837/16 (2019) provided clarity on how the suitability of alternatives should be assessed by applicants and evaluated by RAC & SEAC*

The Judgement clarified (§72) that a suitable alternative is a '*substance or technology whose use entails a lower risk as compared to the risk of using the relevant substance of very high concern (i.e. it is safer). Moreover, [suitable] means that such an alternative must be 'economically and technically viable' within the meaning of Article 55 of [REACH]*'. The judgement also introduced the concept of a '*suitable alternative available in general*' and concluded (§75) that a suitable alternative may be available in general (SAGA) but not feasible for an applicant or their downstream users. The European Commission (2020)[1] noted that under these circumstances '*an authorisation may still be granted if the applicant submits a substitution plan*' and, equally, that *'[a] substitution plan is not required where there are no suitable alternatives in general*'. Therefore, as a substitution plan is a requirement for an authorisation to be granted where there is SAGA, the Commission clarified that a substitution plan is '*a commitment to take the actions needed to substitute the Annex XIV substance with a suitable alternative substance or technology within a specified timetable*'; and by doing so assumed that the alternative could eventually become technically and economically feasible for the applicant. Where there is concluded to be a SAGA, the credibility of the substitution plan understandably becomes a critical element of the application for authorisation and should be carefully evaluated by ECHA's scientific committees.

The aim of the Authorisation title of REACH has always been the progressive substitution of substances of very high concern. Nevertheless, the judgment of the court put a renewed emphasis on substitution. However, it was not the intention of the court (or REACH) to require an applicant to substitute to an alternative that is not suitable, including where it would not be safer.

### *Chromium (III) plating cannot be considered as a suitable alternative in general (SAGA) when it also requires the use of the reprotoxic substance of very high concern (SVHC) boric acid – it does not reduce risk and, therefore, is inconsistent with the objectives of the Authorisation title of REACH*

Numerous companies have developed alternatives to Cr(VI) plating for decorative and sanitary applications based around the use of Cr(III) substances as the source of chromium metal. Cr(III) substances are not currently SVHC and appear to be a suitable alternative to Cr(VI). However, all Cr(III) electroplating solutions for decorative and sanitary plating currently on the market require the use of boric acid, which was identified as an SVHC in 2010 on the basis of its reprotoxic properties (Repro 1B) and recommended for inclusion on Annex XIV in 2015.

ECHA guidance states that where an alternative requires the use of an SVHC, it would not be considered a suitable alternative from a risk perspective[2]. An exception to this principle is discussed in a scenario when an alternative SVHC would be '*used in far lower quantities or in*

[1] Assessment of Alternative: Suitable Alternative Available in General & Requirement for a Substitution Plan (May 27, 2020): https://echa.europa.eu/documents/10162/13637/ec_note_suitable_alternative_in_general.pdf/5d0f551b-92b5-3157-8fdf-f2507cf071c1

[2] ECHA (2021) 'How to apply for authorisation'. Section 3.3.1.6, p. 51

*ways such that the exposure and risks could be substantially reduced or eliminated compared to the Annex XIV substance*'.

Cr(III) electroplating with boric acid is the same industrial process as Cr(VI) electroplating using the same basic technology and risk management measures; it also has the same potential for automation. Therefore, boric acid is not used in such a way that exposures and risks are substantially reduced or eliminated compared to Cr(VI). On this basis, Cr(III) electroplating with boric acid is not consistent with the scenario foreseen in the ECHA Guidance and, therefore, should not be considered as a suitable alternative to Cr(VI) from a risk perspective.

In addition, the inclusion in 2022 of reprotoxic substances, such as boric acid, alongside carcinogens and mutagens in Directive 2004/37/EC (CMR Directive)[3],[4] now requires employers to implement an **identical** hierarchy of control for reprotoxic substances in the workplace as for carcinogens and mutagens, comprising an obligation to use alternatives where technically possible (Article 4(1)[5]), followed by a requirement for use in closed systems (Article 5(2)), followed by the requirement to design work processes and engineering controls so as to avoid or minimise releases into the place of work (Article 5(5)(c)) and, finally, reliance on personal protective equipment only where other measures to reduce exposure are not technically feasible (Article 5(5)(g). The threshold/non-threshold nature of a reprotoxic hazard is not a relevant consideration when implementing the hierarchy under 2004/37/EC and underlines the equivalence in concern between carcinogenic, mutagenic and all reprotoxic substances formalised by this revision to the workplace legislation.

Therefore, consistent with the legal requirements for the use of reprotoxic substances in the workplace, it is clear that substitution of a carcinogenic SVHC with a reprotoxic SVHC in electroplating cannot be considered as a de facto 'safer' alternative to Cr(VI); considerations around the level of worker exposure should not be relevant to this conclusion.

Furthermore, whilst treatment to remove Cr(VI) from wastewater is acknowledged by RAC to be appropriate and effective[6], the physico-chemical properties of boric acid prevent its removal from wastewater meaning that releases to the environment are not controlled, let alone minimised. Generic exposure and risk assessment using information that is representative of reasonably foreseeable conditions of use suggest that the safe threshold for the environment (PNEC) can be exceeded in the environment (Annex I). On this basis boric acid is also not a safer alternative.

***RAC and SEAC typically recommend the requested review periods (up to 12 years) for sanitary and decorative plating with hexavalent chromium when applicants commit to substitute to chromium (III)/boric acid***

Long review periods (i.e. up to 12 years) are recommended for applicants (e.g. applications 0215-01, 0216-01, 0256-01, 0259-01) that commit to substitute Cr(VI) with Cr(III)/boric acid. Whereas applicants that raise the concern about the presence of an SVHC in the alternative, and describe the time needed to replace the SVHC in their applications are penalised with a recommendation for seven-year review period (cfr. Application ID 0241-01 and 0271-01 (draft opinion)).

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02004L0037-20220405&from=EN
[4] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022L0431&from=EN
[5] Substitution is termed 'replacement' in Directive 2004/37/EC
[6] Removal of Cr(VI) from wastewater is readily achieved by 'reducing' Cr(VI) species to chromium (III) hydroxide. The insoluble hydroxide is separated from the aqueous phase and disposed as solid waste. This treatment was already acknowledged to be >99% effective at removing chromium from wastewater in the EU RAR (2005). In addition, as any residual chromium remaining in the aqueous phase is present as Cr(III) species the treatment can be considered to be 100% effective at removing Cr(VI) from wastewater.

***RAC and SEAC's approach to evaluating applications for authorisation does not adequately evaluate SAGA and, because of this, discriminates negatively and unfairly, against applicants that aspire to a genuinely safer alternative to hexavalent chromium***

RAC does not evaluate an applicant's assessment of the relative risk of alternatives when SEAC concludes that alternatives are not technically or economically feasible for the applicant. This practice was established in RAC prior to the judgement of the court in case T-837/16. However, as SAGA is a prerequisite to require (or not) a substitution plan, this practice is no longer appropriate as it has the implication that SEAC (and ultimately the Commission and Member States) does not have the information it requires to conclude whether a substitution plan is necessary (or not). Equally, this practice is not consistent with SEAC's paper on setting the review period on applications for authorisation[7] that states that '*Procedurally, RAC would provide SEAC with its opinion of the remaining risk and - as appropriate – on the risks from possible alternatives…*'.

As outlined above, Cr(III) with boric acid cannot be concluded to be a suitable alternative from a risk perspective. Therefore, RAC should clearly conclude on the risks of substitution to boric acid. The explanation provided by RAC that exposure data is required prior to a robust conclusion, as claimed in recent opinions, is not consistent with the available guidance, the CMRD and previous RAC opinions where conclusions that the use of an alternative would not result in risk reduction are based on a comparative evaluation of hazard properties only[8]. In the absence of such a conclusion SEAC should conclude that an alternative has not been demonstrated to be safer and hence that it cannot be considered SAGA.

In the event that RAC does not definitively conclude on risk, their opinions should still contain the necessary information for the Commission to make a decision based on the precautionary principle[9]. This is because there is significant potential for harm to human health or the environment from transition to Cr(III)/boric acid. In this respect, it may be useful to recall that ECHA guidance[10] already envisages a scenario when assessing the risk of alternatives where *'an alternative has not been demonstrated to represent an overall reduction in the risk to human health and the environment as compared to the Annex XIV substance'* because '*the possible risks to human health and the environment have not yet been fully understood*'.

RAC's recent practice has indirectly led to SEAC evaluating several applicant's 'research and development plans' (submitted legitimately based on their conclusion that there is no SAGA) as though they were de facto 'substitution plans'. This is inappropriate, and results in an unfair evaluation, as the certainty and detail that can be included in an assessment of the steps and time necessary to substitute to an **identified** alternative (in the context of a substitution plan where there is SAGA) is fundamentally different to a description of the steps and timeline that could be envisaged to develop and transition to an, as yet, **unidentified** alternative (research and development plan) where there is no SAGA. By necessity, a research and development plan will be less concrete than a substitution plan as there is no identified alternative to substitute to (as recognised by ECHA in the AoA/SEAC format document[11]).

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[7] https://echa.europa.eu/documents/10162/13580/seac_rac_review_period_authorisation_en.pdf/c9010a99-0baf-4975-ba41-48c85ae64861

[8] For example: the application for the use of trichloroethylene by Vlisco Netherlands BV (applications 0014-01/0014-02); the application for the use of trichloroethylene by SafeChem Europe GmbH;

[9] Consistent with REACH review Action 10 "frame the application of the precautionary principle", where scientific data do not permit a complete evaluation of risks, opinions should include what information would be needed to address the uncertainties identified, the timeline for generating such information (if possible at all) and an overview of the potential consequences of inaction.

[10] Guidance on the preparation of an application for authorisation (2021). Table 8, p.85

[11] ECHA in the guidance AoA/SEAC format guidance document, Section 4.1.4. R&D plan, Version 3.01, October 2021: https://echa.europa.eu/documents/10162/17229/aoa_sea_format_with_instructions_v3-1_en.docx/c32a68c1-200b-6b6d-ca01-55bf36787ea7?t=1634199423860

In applications in which there is no SAGA, a reduced level of detail (i.e. the 'credibility' of the plan) should not result in an unfavourable evaluation by SEAC that, ultimately, is then used by SEAC to recommend a review period that is of insufficient duration to possibly achieve substitution (see Annex 2). The legitimate absence of a substitution plan should not penalise applicants. This was not the intention of the court in Case T-837/16.

Where SEAC are concerned about the level of detail in research and development plans, or the commitment of applicants to undertake them, rather than recommending a shorter review period then required to implement an alternative, SEAC could rather recommend monitoring arrangements (in line with Article 60(9)(f)) intended to ensure that companies are carrying out the actions they pledged to undertake (e.g. regular progress reports). Upon evaluation of the information provided, the Commission could decide to review the authorisation (as they currently retain the initiative to do).

***Discrimination against applicants seeking genuinely safer alternatives will result in an unfortunate and undesirable incentive for European Industry to pursue regrettable substitution as this currently results in a more predictable and favourable regulatory outcome than sustainable substitution.***

REACH is intended to ensure a high level of protection of human health and the environment whilst enhancing European competitiveness and innovation. The current approach to the evaluation of applications for authorisation for the use of Cr(VI) in electroplating for sanitary applications achieves neither of these objectives. As detailed above, a commitment to substitute Cr(VI) with Cr(III)/boric acid will not result in a meaningful reduction in risks to workers and, conversely, is likely to increase risks to both the environment and humans via the environment.

Despite this, substitution to Cr(III)/boric acid is highly likely to be favoured by European companies as, based on current RAC and SEAC opinions, it will guarantee a longer Authorisation review period than can be achieved by companies aspiring to a sustainable substitution strategy; despite sustainable substitution demonstrably requiring longer to implement than Cr(III)/boric acid (Annex 2).

In a highly competitive domestic and international market, companies with an Authorisation with a long review period will have a significant competitive advantage over companies with less favourable review periods and may be more able to compete with imported articles. Companies are unlikely to be willing to surrender the opportunity for such an advantage, despite the long-term spectre of the uncertainty associated with the potential prioritisation of boric acid to Annex XIV of REACH that would trigger a further Authorisation requirement.

Rather, in line with the objectives of REACH, a preferential market position should ideally be occupied by innovative businesses that have a long-term strategy to develop and implement safer alternatives that will ensure long-term competitiveness, sustainability and European strategy autonomy.

Importantly, RAC and SEAC made conclusions that supported sustainable substitution in previous similar cases, for example in AfA ID 0109-01 (Akzo Nobel on 1,2-EDC)[12]. The applicant short-listed two alternatives: a solvent-based (cyclohexanone) and a water-based alternative. Implementation of cyclohexanone was expected to be feasible in five to six years. However, the risk reduction potential was uncertain due to a pending substance evaluation (for CMR properties). In this case RAC recognised the greater risk reduction potential for the water-based technology, and the further added value of greater energy efficiency. Even though the timeline

[12] https://echa.europa.eu/documents/10162/36e0a9b3-9430-e109-683d-e511a48e023c

to adoption was significantly longer and more uncertain for the water-based alternative than for cyclohexanone (nine years), SEAC recommended the requested nine-year review period as it had greater potential to realise '*a reduction in overall risk*' and because it is a '*more environmentally sustainable process than a solvent-based alternative*'[13]. The applicant stated '*If we would have received limited time, then we would have been forced to bet on the quickest horse*.' The certainty of the nine-year review period (until Nov 2026) allowed for investment in an innovative and sustainable alternative.

The Court Case T-837/16 did not prevent optimal risk reduction and sustainability. On the contrary, it emphasizes the need to implement safer alternatives.

***Recommendations***

As the Commission has yet to decide on the majority of applications for authorisation for the use of Cr(VI) for sanitary plating there remains a window of opportunity to remedy the current situation. The following actions are recommended.

1. ***RAC should, without delay, conclude that Cr(III) plating with boric acid is not a safer alternative to Cr(VI) for decorative or sanitary plating. In the absence of such a conclusion SEAC should conclude that an alternative has not been demonstrated to be safer and hence that it cannot be considered SAGA.*** Such an assessment could be requested under the Article 77(3)(c) process under REACH and should consider all the elements required by the Commission for precautionary decision making.

2. ***SEAC should review any previous opinions where a research and development plan was erroneously evaluated as though it was a substitution plan.*** This would ensure equal treatment of applicants and facilitate sustainable substitution.

3. ***Consistent with the established practice for 'reference dose-response and DNEL values' RAC and SEAC should establish SAGA assessments for Annex XIV substances to assist both applicants, rapporteurs and stakeholders to engage with the Authorisation process.*** Assessments of the presence of SAGA in key uses could be developed by RAC and SEAC when substances are added to Annex XIV. Whilst these assessments would not be binding on applicants, they would be likely be highly useful for applicants as they prepare applications as well as during the subsequent evaluation of applications by RAC and SEAC.

4. ***The Commission should consider using monitoring arrangements to address the uncertainty inherent to a research and development plan or minimisation of releases rather than a review report.*** This would be a more proportionate mechanism to address uncertainties in an R&D plan or in the minimisation of releases or exposures and would also ensure that applicants carry out the actions they pledged to undertake. Upon evaluation of the information provided, the Commission could decide to review the authorisation.

[13] RAC/SEAC opinion: https://echa.europa.eu/documents/10162/36e0a9b3-9430-e109-683d-e511a48e023c

## Annex 1 – The absence of appropriate and effective risk management measures for boric acid result in safe thresholds being exceeded in the environment under reasonably foreseeable conditions of use as well as potential for indirect exposure to humans via the environment

Boric acid was identified as a substance of very high concern (SVHC) under REACH in 2010 on the basis it reprotoxic properties (harmonised classification of Repro 1B). It was prioritised for inclusion on Annex XIV of REACH in 2015. The concentration limit for classification of mixtures containing boric acid as Repro 1B was recently reduced from 5.5% to 0.3%. Boric acid is not classified as hazardous to the aquatic environment. Nevertheless, a PNEC of 2.9 mg/L is reported in registration dossiers (assessment factor of 2 applied to an HC5-50 value of 5.7 mg B/L.

Boric acid (borates) are required at relatively high concentrations (60 to 100 g/L) in Cr(III) electroplating baths where it provides various functions, including as a pH regulator[14]. The boric acid concentration in Cr(III) electrolytes on the market exceed the 0.3% cut-off concentration for classification.

Boric acid cannot be removed from wastewater using conventional wastewater treatment[15]. This leads to inevitable and uncontrolled emissions of boric acid to surface water even when wastewater treatment is in place[16].

The risk to the environment posed from this use can be assessed based on standard risk assessment methodology and default assumptions. Based on an estimate of 6-7 kg boric acid consumption per 10,000 Ah of applied current to the electrolyte solution, and a boric acid concentration of 60-100 g/L, it was determined that 2 kg boric acid is required per kg of Cr(III) consumed[17].

Based on an annual consumption of 40tpa Cr(III), representing a large production site or the sum of several sites within an area, the calculated boric acid concentration in surface water was estimated to be 3.6 mg Boron/L, which exceeds the PNEC for fresh water (2.9 mg/L) and typical background concentrations (< 0.017 – 0.6 mg B/L). Thus, a risk has been demonstrated (PEC/PNEC >1).

Similar to concerns associated with wastewater treatment, boric acid cannot be removed from water intended for human consumption. This leads to concerns regarding exposure to humans via the environment via drinking water.

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[14] As confirmed during the ECHA workshop on Cr(III) plating (Oct 2022) https://echa.europa.eu/documents/10162/2156132/summary_conclusions_cr_workhop_en.pdf/74168d39-5007-1d81-c056-4f46b5acea92?t=1667220573924

[15] NICNAS, Boric acid and precursors to boric acid: Environment tier II assessment, 8 March 2019:

"[…] The boron compounds in this group have a variety of uses in household and commercial applications. Boric acid has applications in personal care products and high-volume consumer and commercial cleaning products which can lead to its release into sewers. As boron is not efficiently removed from wastewater during sewage treatment, the use of boron compounds in these products has significant potential to result in environmental exposure through a common pathway involving their release in the treated effluents and biosolids produced by sewage treatment plants (STPs). Boron is one of the most common phytotoxic ions that may be present in treated wastewater effluent (FAO, 1992). Boron is largely unaffected by wastewater treatment (ATSDR, 2010) and therefore influent concentrations are not expected to be significantly higher than measured effluent concentrations."

(This assessment was carried out by staff of the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) using the Inventory Multi-tiered Assessment and Prioritisation (IMAP) framework.)

[16] ECHA Workshop conclusion 7: "*Regeneration of borates is not possible and Waste Water Treatment Plants do not eliminate borates from the waste water. Hence, at present, discharge of borates to surface waters is unavoidable*."; and Conclusion 10: "*The review of the BREF document for the surface treatment of metals and plastics' sector is underway. Boron and its compounds have been identified here as a key environmental issue."*

[17] This estimate was presented at the ECHA Cr(III) workshop and confirmed by another participant (Qualipac Aurillac) https://echa.europa.eu/documents/10162/2156132/07_cr_workshop_lemoine_en.pdf/212cb3d2-aa58-2f59-73aa-8fb656827fbd?t=1666690521027

## Annex 2 – A realistic research and development timeline for SVHC-free chromium plating technology

Boric acid is a multi-functional component of current Cr(III) plating solutions for sanitary/decorative applications (functioning as more than just a pH buffer) determining key properties of the chrome surface layer, such as corrosion resistance. There is no drop-in alternative available. Therefore, substitution of boric acid requires fundamental research and development to ensure that all aspects of its functionality can be replaced. An appropriate research and development timeline can be derived using the concept of 'technology readiness levels'.

Technology readiness levels (TRLs), developed by NASA but subsequently adopted by the EU[18], describe the readiness of a technology through the entire research and development process. TRLs range from *TRL 1 – basic principles observed,* to *TRL 9 – actual system proven in operational environment*[19]. TRL 9 is, therefore, indicative that the technology is a proven alternative available to Cr(VI) users pending their own assessment (e.g. their own technical and economic feasibility assessment).

In the absence of existing research projects into boric-acid free Cr(III) plating, the duration of the entire research and development timeline can be estimated using the duration of previous Cr(VI) electroplating research and development projects (as surrogates for Cr(III) research) and then benchmarking these against applicable 'technology readiness levels' (Figure 1).

The following projects were considered[20]:

- CHROMFREE (Chromium free surface pre-treatments and sealing of Tartaric Sulphuric Anodizing)[21]. Project of 28 months developed a technology to TRL 5 from TRL 1/2.
- Kova-Kromi: Development of a workplace-friendly and environmentally acceptable hard chromium plating process[22]. Project of 24 months intended to develop a pilot scale Cr(III) hard chrome process based on the developed laboratory scale process, i.e. starting at TRL 4 and reaching TRL 6/7.
- LIFE CROMOZERO: Environmentally friendly and safer chromium-free process for hard coatings[23] aims to achieve a final industrial pilot plant (TRL = 8) over 3-years. The process will industrialise the patented PECVD process which is currently at TRL = 5[24].
- FreeCr6plat (Chrome plating without toxic Cr(VI). An ecofriendly electroplating for automotive plastic parts) [25]. FreeCr6plat* aimed to progress from TRL 8 to final testing and certification in 32 months. Overall time-span of FreeCr6plat** from TRL 1 (in 2008) to industrialization has taken 12 years[26].

[18] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

[19] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

[20] Only one of the available Cr(VI) projects covered the complete timeline from TRL 1 to TRL 9. Nevertheless, when the different projects are considered together, the duration of each project and the progress in TRL achieved within it, can be used to provide an estimate of the reasonable minimum length of time required for an SVHC-free Cr(III) alternative for decorative plating to progress through the complete development process from TRL 1 (current status) to TRL 9

[21] https://cordis.europa.eu/project/id/BRST975195

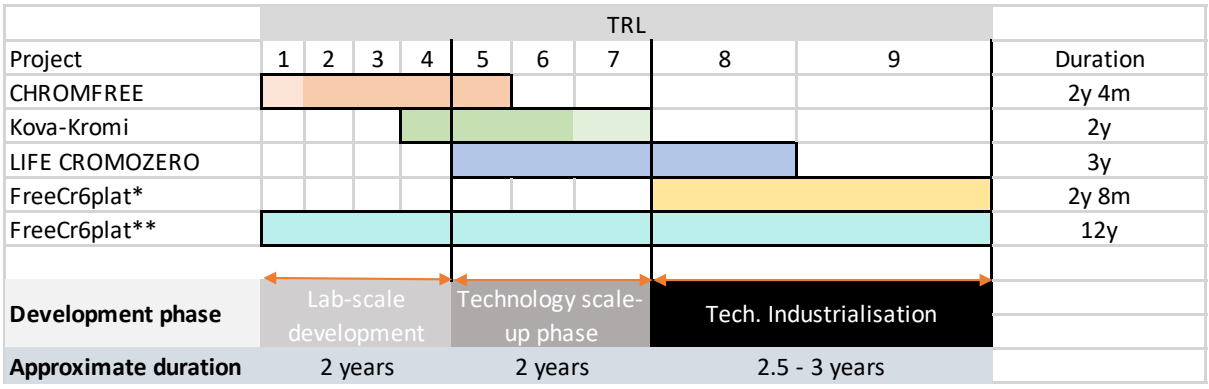
[22] https://cordis.europa.eu/project/id/BRST975195

[23] https://webgate.ec.europa.eu/life/publicWebsite/project/details/5605

[24] https://life.beretta.com/en/project/

[25] https://cordis.europa.eu/project/id/829535/reporting

[26] https://www.avanzarematerials.com/projects/freecr6plat/about-the-project/




**Overview of EU-funded research projects for Cr(VI) alternatives including starting and final TRL level, and duration.**

The analysis suggests that development of an alternative from conception (TRL 1) to proven technology at laboratory scale (TRL 4) is around 24 months. Development from TRL 4 to TRL 7 (technology scale-up phase), is a further two years. Finally, technology industrialisation, going from a working prototype to successful use of the technology on the market is between 2.5 – 3 years. Importantly, the length of time needed to progress through the TRL levels is not linear, and that at higher TRLs, the length of time required to progress between stages is greater (e.g., comparing CHROMFREE to FreeCr6plat).

This analysis suggests a minimum development time for an SVHC-free Cr(III) plating solution for decorative applications to be on the market could be seven years after research and development projects are initiated. A further 1 to 1.5 years would then be required for a downstream user of Cr(VI) to undertake its own substitution (technological conversion) e.g., equipment order and delivery, installation and optimisation. However, based on the observation that progress though TRLs takes longer at higher levels, it is important to note that the *FreeCr6plat* project took a total of 12 years from project initiation (TRL 1) to become a full-scale, implementable process and is the only available benchmark for the full development timeline. It should also be noted that research and development of current Cr(III) plating solutions with boric acid for decorative applications has been underway for many years and the technical properties of the resulting surface layer for functional applications with decorative character remain unacceptable for the majority of markets.

**Therefore, a total of 13 to 13.5 years would be a realistic minimum timeline for research, development and implementation of an SVHC-free Cr(III) electroplating alternative for sanitary and decorative plating.**